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Copy to Allan Ota

gdc

COASTAL ENVIRONMENTAL ANALYSTS

2 July 1997

Pat Young
American Samoa Program Manager
Office of Pacific Island and native American Programs
Environmental Protection Agency
75 Hawthorne Street (E-4)
San Francisco, CA 94105

Dear Pat;

Re: Revised Ocean Dumping Report

Enclosed are two copies of the revised report on ocean dumping studies in American Samoa. I have reissued the entire report rather than just the modeling section to keep everything under one cover. The major changes include an extensive new section (Section 4) and appendix (Appendix 11) on the evaluation of monitoring data (and comparison to model results) and an greatly expanded section (Section 3) on modeling. I believe all of Dr. Abdelrhman's comments have been substantially and adequately addressed. I have forwarded by Federal Express a copy of the report directly to him and have distributed the report as described in the list below.

Sincerely,

Steve

Steve Costa

cc: Dr. Mohamed Abdelrhman/EPA/EAS/AED
Sheila Wiegman/ASEPA
Norman Wei/StarKist Foods
Jim Cox/Van Camp Seafood
Barry Mills/StarKist Samoa
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Rcd 7/3/97

JOINT CANNERY OCEAN DUMPING STUDIES

IN

AMERICAN SAMOA

Revised Report

Submitted to

U.S. Environmental Protection Agency, Region 9
American Samoa Environmental Protection Agency

Prepared for

StarKist Samoa
(Permit OD 93-01 Special)
and
VCS Samoa Packing
(Permit OD 93-02 Special)

Prepared by

CH2M HILL

and

gdc

Revised
June 1997

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Executive Summary

The ocean dumping permits issued to StarKist Samoa and VCS Samoa Packing require a variety of monitoring and reporting activities. One such activity is a re-evaluation of previous bioassay testing and dispersion modeling reported in previous studies. This activity is described in special condition 3.3.5 of the permits issued to each of the canneries. Ocean monitoring data is also collected as a requirement of the permits (special condition 7). This report presents the results of the bioassay tests and modeling, including evaluation of the monitoring data, done under special condition 3.3.5.

High strength waste, to be disposed of by ocean dumping, was sampled from each cannery as it was transferred to the FV *Tasman Sea*. Samples were taken three times, during various seasons of the year, and shipped to Advanced Biological Testing (ABT) in Tiburon, California. At ABT, bioassays were conducted with a number of test organisms as required by the permits. The methods and test species used were modified in consultation with USEPA as the study progressed. The lowest LC50 recorded in the series of bioassays was 0.12 percent.

The previous modeling was done during the preparation of an Environmental Impact Statement done by U.S. Environmental Protection Agency. This modeling was reviewed and evaluated. CH2M HILL used a different approach to estimate an initial dilution (consisting of an immediate dumping dilution and a nearfield dilution). The two components of the initial dilution were based on propeller theory and the concept of a momentum jet. The farfield dilution was based on the same model (mathematical and physical description) previously used, but implemented with a spreadsheet application.

The results of the model, although considered quite conservative (underpredicting dilution of the waste with receiving water), indicated somewhat higher dilutions at the edge of the dumping zone than previously predicted by the model used in the FEIS. Direct comparisons cannot be made since the vessel in use is not the same. However, predictions for the worst case, corresponding to average ocean currents, in the summer, and at maximum discharge rate, indicate a concentration at the edge of the dumping zone that is 0.0021·(LC50) described above.

Ocean monitoring data collected as a requirement of the permits includes analysis of the high strength waste material prior to disposal and receiving water monitoring. These data were examined and evaluated for consistency with the model predictions. Although the data collection is not specifically designed for model verification, the evaluation conducted supports, and is consistent with, the model predictions. The available data indicates that the wastefield is sufficiently diluted and mixed within the designated dumping zone to eliminate any effects outside the immediate disposal area.

The original report on these studies was reviewed by Dr. Mohamed A. Abdelrhman of the Environmental Protection Agency's Research Laboratory in Narragansett, Rhode Island. Dr. Abdelrhman extensively reviewed the modeling section of the original report. The revised report was prepared in response to his suggestions and comments. Although, no revisions were incorporated into those parts of the report concerning the bioassay tests and results, the entire report was reissued for the convenience of keeping the entire set of study results under one cover.

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1. Introduction

The Regional Administrator of EPA Region IX determined that ocean disposal of fish processing wastes off American Samoa meets EPA's ocean dumping criteria (40 CFR Parts 227 and 228). Based on this determination EPA issued special ocean dumping permits to StarKist Samoa, Inc. and VCS Samoa Packing, Inc. on September 1, 1993. Special condition 3.3.5 of both permits requires bioassay testing of the waste from each cannery and a re-evaluation of the model previously used to predict concentrations of fish processing wastes disposed of at the designated disposal site. A copy of this special condition is provided in Appendix 1. This section of the report describes the purpose of the report, presents pertinent background information, and describes the organization of the materials presented in subsequent sections.

Purpose

The purpose of this report is to document the results of the bioassay and modeling studies required by the special ocean dumping permits under special condition 3.3.5. StarKist Samoa (Permit No. OD 93-1 Special) and VCS Samoa Packing (Permit No. OD 93-01 Special) were required to conduct and submit the results of toxicity tests using fish processing wastes generated at the permittees' American Samoa tuna processing and packing plants. The wastes tested were DAF (dissolved-air flotation waster water treatment processes) sludge and other high strength waste streams that are barged to sea for disposal at the permitted dump site. The report describes the methods and results of the bioassay tests.

Permit condition 3.3.5 requires that the bioassay results be used to re-evaluate the previous model predictions of dispersion of the plume created by dumping fish processing wastes at sea. The model re-evaluation was conducted by: evaluation of the previous model for application to the current disposal operations, development and application of a revised more sophisticated model(s), and evaluation of available field data for consistency with model predictions. The report describes these modeling exercises and the results of the model predictions.

Background

StarKist Samoa and VCS Samoa Packing (the canneries) began ocean disposal of DAF sludge off the south coast of Tutuila Island in December of 1980 (Permit Number: OD 79-01/02 Special). A field study of the fate and transport of the waste was described by Soule and Oguri (1983). In 1990 the disposal site was moved further offshore into deeper water based on an Environmental Impact Statement done by EPA (1989) and a supplementary mathematical model study (SOS, 1990). The existing permit was issued for the deep water site in 1993 (effective date of 1 September 1993 - expiration date 31 August 1996).

The existing permits allow disposal at the deep water site mentioned above is located approximately 5.16 nautical miles offshore in a water depth of about 9000 feet. The dump site is a circle of 1.5 nautical mile radius. The permit allows the disposal of up to a total of 200,000 gallons per

day including: DAF sludge (60,000 gallons per day) and high strength process stream wastes (100,000 gallons per day of precooker water and 40,000 gallons per day of press water). The concentrations of various physical and chemical parameters are limited in the permits. Special conditions in the permits require monitoring and analysis of the fish processing wastes to be disposed of, monitoring of vessel operations and position, notices to regulatory agencies, receiving water monitoring, and biological community observations and reporting.

This report was prepared under special condition 3.3.5 as discussed above and reproduced in Appendix 1. A draft study plan was prepared and submitted to USEPA and ASEPA in November 1993 (CH2M HILL, 1993). Comments were received from EPA on the study plan in a letter dated 10 December 1993. These comments concerned details of the bioassay sample collection, shipping, and certain protocols of the bioassay tests. The comments were easily accommodated and the draft study plan was not revised. The final study plan consists of the Draft Study Plan and the EPA comments which are included as Appendix 2. In addition, some changes were made to the bioassay test protocols and procedures, with the concurrence of EPA. These changes are documented in descriptions of the bioassay tests below, and in the following section of the report.

Scope of Report

The special permit condition addresses two distinct efforts: bioassay testing and model re-evaluation. Although the results of the bioassay testing can be used with the model results to predict the potential for toxicity, the two parts of the study are quite different and are best described independently. Therefore, this report is presented in four main parts: a description of the bioassay test results, a description of the results of the modeling, an evaluation of the available field monitoring data with comparisons to the model predictions, and a final section presenting conclusions and recommendations. References are provided and additional detailed information is provided in Appendices.

For the bioassay tests, this report basically summarizes the previous memoranda sent to EPA after each of the sampling and testing episodes. For the modeling portion of the studies, the report extends the memorandum previously sent to EPA summarizing the results and provides detailed descriptions of the modeling study to a level sufficient to allow independent review of the modeling as well as responding to EPA comments on the previously reported modeling results. The interpretation of the modeling and field data evaluation results, incorporating the bioassay information, is formalized in this report.

2. Bioassay Testing

Bioassay tests were conducted as required in the permits with modifications as approved by EPA and documented below. General guidance for these tests was provided by USEPA (1991), ASTM (1992), and the EPA/COE "Green Book" (1991). Specific guidance for performing biological-effects tests for Ocean Disposal permits are outlined in Part III, Section 11 of the Green Book; *Evaluation of Dredged Material Proposed for Ocean Disposal: Testing Manual* (EPA and COE, 1991). However, the fish processing wastes to be disposed under the permits are not similar to solid dredged materials. The high strength waste materials are mostly positively to neutrally buoyant liquid phase wastes. The physical and chemical nature of the wastes required that the tests be conducted as effluent tests, which was agreed to by EPA (see Appendix 2). The following sections briefly summarize the methodology for sampling and testing, and report the results of the tests. More detail is given in the Study Plan (Appendix 2) and the standard operating procedures (SOP) for the collection of the high strength wastes (HSW) (Appendix 2). Approved changes made to the permit conditions and study plan as the study proceeded are described and documented below.

HSW Sampling Procedures

High strength waste samples were collected at each cannery from the existing sampling ports in the storage tank transfer lines. Three samples were taken at 10 minute intervals while waste was being transferred from the storage tanks to the barge. Samples for the bioassay tests were composited from the three discrete samples. Waste from each cannery was sampled and tested separately. Detailed procedures used for sampling, sample handling, and shipping are included in the SOP referenced above. The sampling periods were modified from the original sampling plan as follows:

- Originally scheduled 30 November 1993: Sampled 16 February 1994
- Originally scheduled 28 February 1994: Sampled 20 October 1994
- Originally scheduled May 31, 1994: Sampled 23 June 1995

Changes in sampling and testing periods were approved by EPA as described in the correspondence included in Appendix 4.

Test Species

The permit condition requires toxicity testing with three species selected from three groups listed in section 3.3.5 of the permit. The study plan initially set up a proposal that the tests be conducted with the pacific mysid shrimp (*Holmesimysis costata*) juveniles, pacific sanddab (*Citharichthys stigmaeus*) juveniles, and purple sea urchin (*Strongylocentrotus purpuratus*) larvae. The rational for this selection is provided in the Study Plan (Appendix 2). It was further proposed that, if necessary, *Mytilus* sp. (mussels) would be used as a backup species to the sea ur-

chin and white shrimp (*Paneaus vannami*) would be used as a back-up test species for the mysid shrimp should the primary test species be unavailable at the time of the bioassays.

In their comments on the study plan (see Appendix 2) EPA recommended replacing *Holmesimysis costata* with *Mysidopis bahia* which was done. For the first of the three required testing episodes both *Mytilus edulis* (blue mussel) and *Strongylocentrotus purpuratus* were tested, and, as described in more detail below, *Mytilus* was selected for the following tests. Because of difficulties in spawning *Mytilus* was not tested during the third test.

Testing Methodology

The testing methodologies used for acclimation and holding of test organisms, sample preparation, and experimental conditions and procedures, QA/QC, and data analysis are described in the Study Plan (Appendix 2) and in the detailed laboratory reports (Appendix 5). However, one aspect of the testing procedures, the potential for and handling of high IDOD, deserves special note. Initial dissolved oxygen demand (IDOD) has been determined to be a problem with cannery effluent and high strength waste streams. Preliminary IDOD measurements were done at the canneries in October of 1993. The results indicate a typical IDOD demand within the first 15 minutes and a second high demand that occurs between 10 and 14 hours. The second demand can, if not anticipated, compromise and even make useless a bioassay test in progress. The results of these IDOD measurements were used for guidance in determining sample dissolved oxygen (DO) conditions and aeration procedures required for the bioassays in this study. Advanced Biological Testing of Tiburon, California, performed the bioassays and was able to anticipate and account for this aspect of the tuna cannery wastes.

Results of the Bioassay Tests

Three sets of bioassay tests were conducted on the HSW for each cannery. The results of these tests were reported to USEPA and ASEPA in separate memoranda for each testing episode. Modifications and changes to the original study plan were made for each of the tests as documented in the memoranda and in communications with EPA provided in Appendix 4. Each of these testing episodes is briefly reviewed below and the results of all of the tests are given in Table 2.1.

First Set of Bioassay Tests

Sampling for the first bioassays tests was done in February 1994 (see EPA comments on the Draft Study Plan in Appendix 2). Detailed methods and results of the tests are presented in the attached: *"Results of a Bioassay Conducted on Two High Strength Waste Samples from the Van Camp and StarKist Tuna Canneries in American Samoa"* prepared by Advanced Biological Testing Inc., Tiburon, California, and provided in Appendix 5. Acute effluent bioassays were conducted on four species including the three listed in the study plan plus one of the alternates. The species used were *Mysidopsis bahia* (mysid shrimp) juveniles, *Mytilus edulis* (blue mussel) larvae, *Strongylocentrotus purpuratus* (purple sea urchin) larvae, and *Citharichthys stigmaeus* (speckled sanddab) juveniles. The results of these bioassays are summarized in the Table 2.1 below and

were provided to EPA as a memorandum to the American Samoa Project Manager (CH2M HILL, 1994).

Based on the results of the first set bioassays, CH2M HILL recommended two changes to the HSW bioassay protocol as follows:

- Reduction of the upper end of the HSW concentration series for all bioassays to a maximum of 3.0 percent. This was done for the first set of tests after discussions with EPA as reported in the laboratory report (Appendix 5). No additional information is required at concentrations greater than 3.0 percent and reducing the maximum concentrations reduces the amount of HSW that needs to be sampled and shipped. We recommended a series of concentrations for the bioassays of 3.0%, 1.5%, 0.8%, 0.2%, 0.1%, and 0.05%.

- Continue running bioassays with *Mytilus edulis* while monitoring the effects of aeration on organism mortality and drop the use of *Strongylocentrotus purpuratus* larvae as test organisms for the HSW. This recommendation was made for the following reasons:

  - Special Condition 3.3.5 of the permits required only three organisms be tested; one organism each out of three specified groups. *Mysidopsis bahia* and *Citharichthys stigmaeus* satisfy the requirements for Groups 2 and 3. Group 1 contains larval stages of both bivalves and echinoderms and running just *Mytilus edulis* should satisfy this requirement.

  - Because of the high oxygen demand of the effluent, all test containers required aeration throughout the tests to maintain adequate oxygen concentrations for the test organisms. Aerating the chambers using *Mytilus edulis* and *Strongylocentrotus purpuratus* larvae as bioassay test organisms gives problematic results. Aeration is standard protocol for bioassays on fish and invertebrates when oxygen levels fall below 40% of saturation, but is not standard protocol for bioassays on larval bivalves and echinoderms. The effects of aerating the water on the survival of these organisms is not known. Because the *Mytilus edulis* bioassays are only run for two days (vs. four for the *Strongylocentrotus purpuratus*) the organisms are exposed for half the time and the effects of aeration may be reduced.

  - The mortality of the control group was substantial for the echinoderms and is unacceptable according to protocol. The cause of the high mortality in the control is not known.

The results and methods for the first set of tests and the recommendations described above were reviewed and accepted by EPA as documented in the attached communications dated 29 August 1994 (Appendix 4). The recommendation for reducing the maximum concentrations of the samples was accepted by U.S. EPA and, after consultation between Advanced Biological Testing and EPA, new test concentrations were established for the mysid, mussel, and sanddab tests of 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% as a volume dilution in 30 ppt sea water. The recommendation for dropping the urchin test was accepted by U.S. EPA. The mussel test was continued to investigate the effects of aeration as described below. Other recommendations

were made by EPA in the letter, which were adopted as described below and in the detailed laboratory reports.

Second Set of Bioassay Tests

The results of the second set of tests are presented in the attached: "*Results of a Bioassay Conducted on Two High Strength Waste Samples from the Van Camp and StarKist Tuna Canneries in American Samoa*" prepared by Advanced Biological Testing Inc. (ABT), Tiburon, California, (Appendix 6). The second sampling was conducted in October 1994. Acute effluent bioassays were conducted on *Mysidopsis bahia* (mysid shrimp) juveniles, *Mytilus edulis* (blue mussel) larvae, and *Citharichthys stigmaeus* (speckled sanddab) juveniles. The results of these bioassays are summarized in the Table 2.1 below and were provided to EPA as a memorandum to the American Samoa Project Manager (CH2M HILL, 1995a).

In the first test described above it was determined that due to the high oxygen demand, including a high immediate oxygen demand, of the effluent all test containers required aeration throughout the tests to maintain adequate oxygen concentrations. Aeration is standard protocol for bioassays on fish and invertebrates when oxygen levels fall below 40% of saturation, but is not standard protocol for bioassays on larval bivalves and echinoderms. Therefore, aerating the chambers containing *Mytilus edulis* may give problematic results. In the second test gentle aeration was initiated on Day 0, and continued for the duration of the tests. To assess the effects of aeration, an aeration control for the mussel test was run simultaneously. No statistical differences were observed between aerated and unaerated controls. It was recommended that this type of aeration continue to be used with the mussel test.

Third Set of Bioassay Tests

The results of the third set of tests are presented in the attached: "*Results of a Bioassay Conducted on Two High Strength Waste Samples from the Van Camp and StarKist Tuna Canneries in American Samoa*" prepared by Advanced Biological Testing Inc. (ABT), Tiburon, California, (Appendix 7). The third sampling was conducted in June 1995 this test was delayed to get better seasonal coverage with the concurrence of USEPA (see Appendix 4).

Acute effluent bioassays were conducted on *Mysidopsis bahia* (mysid shrimp) juveniles and *Citharichthys stigmaeus* (speckled sanddab) juveniles using HSW collected separately from the StarKist Samoa and VCS Samoa Packing canneries in Pago Pago Harbor, American Samoa. The results of these bioassays are summarized in Table 2.1 below and were provided to EPA as a memorandum to the American Samoa Project Manager (CH2M HILL, 1995b). For this sampling *Mytilus edulis* (blue mussel) larvae were unavailable as the mussels were spawning. The U.S. EPA reviewed the problem of the mussel spawning and waived the requirement to conduct the bioassay test on the mussel larvae for this sampling period (see Appendix 4).

Summary of Results of the Bioassay Tests

Table 2.1 summarizes the results of the bioassay tests. As noted above, each of the testing episodes is reported on in detail in Appendices 5, 6, and 7.

Table 2.1
Summary of High Strength Waste Bioassay Results.

Test Organism	Endpoint	StarKist Samoa			VCS Samoa Packing		
		2/94	10/94	6/95	2/94	10/94	6/95
Citharichthys stigmaeus (sanddab)	LC_{50}	0.27%	0.35%	0.396%	0.59%	0.37%	0.626%
	NOEC	0.20%	0.25%	0.25%	0.40%	0.25%	0.25%
	LOEC	0.40%	0.50%	0.50%	0.80%	0.50%	0.50%
Mysidopsis bahia (mysid shrimp)	LC_{50}	0.12%	1.16%	0.675%	0.59%	0.79%	0.625%
	NOEC	0.05%	0.50%	0.125%	0.05%	0.50%	0.25%
	LOEC	0.10%	1.00%	0.25%	0.10%	1.00%	0.50%
Mytilus edulis (blue mussel)	LC_{50}	>1.20%	>2.0%	[2]	>1.20%	>0.20%	[2]
	IC_{50}	<0.08%	0.10%	[2]	<0.08%	0.18%	[2]
Strongylocentrotus pupuratus (urchin)[1]	LC_{50}	1.20%	-	-	1.20%	-	-
	IC_{50}	<0.08%	-	-	0.10%	-	-

[1] Urchin test not conducted in second and third test periods (w/concurrence of U.S. EPA).
[2] Mussel larvae not available for test, requirement waived by U.S. EPA for this test.

3. Model Evaluation

This section describes the re-evaluation of certain previous model predictions of dispersion of the plume created by dumping fish processing wastes at sea. The previous predictions are presented in Appendix B of the FEIS (EPA, 1989) and in a supplementary study (SOS, 1990). This model is referred to as the "FEIS model" throughout this section of the report. Appendix B of the FEIS is reproduced in Appendix 8 of this report for convenience. The model re-evaluation was conducted in four phases as describe below. The steps were:

- The previous model, as described in the 1989 FEIS, was used. This model was reformulated and implemented as an Excel 5.0 spreadsheet and the results of this reformulation checked against the previous (FEIS) results.
- The input data and assumptions used in the FEIS model were examined and evaluated. Critical parameters, including assumed values for diffusion coefficients, initial dilution, and ambient conditions were reviewed. The appropriateness and applicability of previously assumed values are evaluated and discussed.
- A somewhat different approach for the initial dilution as the waste is pumped into the propeller slipstream was developed. The objective of the new approach for initial dilution with a different model is intended to account for changes in vessel characteristics and operational methods and to develop more representative overall model predictions. Model predictions were developed for the current disposal operations using the new initial dilution procedures and the reformulated farfield model.
- The model predictions are then used by applying the new bioassay test results presented in the previous section and this evaluation is provided in the conclusions and recommendations section (Section 5) of the report below.

A summary of the model evaluation was provided to USEPA and ASEPA in a memorandum prepared by CH2M HILL (1995c). The descriptions below expand and further document the summary previously provided, and include information responding to comments on the previous (July 1996) version of this report.

Previous Model Formulation

The previous model (FEIS model, EPA 1989), is based on an approach originally developed by Brooks (1960), and has been found by the authors of this report to be typically very conservative (overpredicts concentrations) in similar applications. Other assumptions in the model are also considered to be conservative as described in the discussions below. The term conservative, as used in this section of the report and when applied to assumptions or methodology, always indicates that the expected result is most likely to be an <u>overstatement of concentration</u> (waste) or an <u>understatement of dilution</u> within the temporal and spatial context of the statement. The results of the model are presented in terms of dilution (or concentration) of fish

processing waste versus distance from the point of introduction into the receiving water. Based on the results of the bioassay tests, the distance from the dump site where the effluent is diluted to the limiting permissible concentration (LPC) level can be determined.

The FEIS model formulation, based on the approach presented by Brooks (1960), is essentially the same basic model as CDIFF (Yearsley, 1989). The formulation developed by Brooks calculates the lateral diffusion of a discharge plume as it is advected in the longitudinal direction and does not account for longitudinal dispersion. As initially developed by Brooks, the approach does not account for vertical diffusion, does not provide for the settlement of negatively buoyant constituents in the plume, and does not account for the dispersion of a positively buoyant plume or positively buoyant components of the discharged material. In addition the model, as implemented in the FEIS, assumes a line source of constant strength. The basic model formulation is given by a dimensionless expression of the form:

$$\frac{C_{\max}}{C_o} = \frac{H/4}{\sqrt{2K_v t + \frac{H^2}{16}}} erf\left[\sqrt{\frac{1.5}{\left(1+\frac{8At}{L^{(2/3)}}\right)^3 - 1}}\right]$$

where C_{max}/C_0 is the ratio of the centerline plume concentration to the initial concentration, L is a length parameter, A is a horizontal dissipation coefficient equal to the horizontal turbulent diffusion coefficient (ε) divided by $L^{4/3}$ with units of $[L]^{2/3}/[t]$, *erf* indicates the error function, and all other variables and parameters are discussed below (and detailed descriptions can be found in Appendix 8 and associated references).

The FEIS model provides for a settling velocity by redefining the longitudinal coordinate at a downward angle defined by the relationship between the longitudinal current speed and assumed vertical settling velocity such that:

$$x' = x \cdot \cos(\theta)$$

where

$\theta = \tan^{-1}(u/w_S)$

u = ambient horizontal, longitudinal velocity

w_S = settling velocity

x = horizontal longitudinal coordinate given by t·u (t is time)

x′ = redefined longitudinal coordinate

The FEIS model also accounts for vertical diffusion by applying a non-dimensional concentration reduction factor based on a Fickian diffusion coefficient (K_v). This factor is applied to the calculated centerline concentration $(C_{max})_{CL}$ to obtain an adjusted value $(C_{max})_{ADJ\text{-}CL}$ accounting for vertical diffusion as:

$$(C_{max})_{ADJ\text{-}CL} = (C_{max})_{CL} \cdot \{(H/4) / (2 \cdot K_v \cdot t + H^2/16)^{0.5}\}$$

where H is the initial vertical plume dimension defined as the vertical extent of the plume at the beginning of initial dilution, with H/4 as the distance from the surface to the point of C_{max}, and is a vertical dimension used to account for the effect of vertical diffusion in the farfield model. The relationship of H to the plume geometry is discussed further below. Travel time along the plume trajectory is represented by t. The two changes described above are the only modifications made to the original Brooks formulation. The FEIS model input variables include ambient current speed, initial dilution, settling velocity, and initial plume dimensions (as characterized by L).

Based on the descriptions in the 1989 FEIS, the model was reproduced and tested by CH2M HILL. The model results for all cases were not able to be exactly reproduced and there may be some errors, simplifications, or inconsistencies in the original formulation. However, these errors are not "fatal" and generally not significant. In fact, the differences noted below may be simply caused by differences in the numerical formulation between the two approaches. The maximum disagreement between results from the CH2M HILL formulation and the initial FEIS formulation of the model are on the order of 10 percent, and typically much smaller. Tables 3.1 and 3.2 show the comparison of published predictions for the FEIS model and the CH2M HILL spreadsheet model predictions based on the same set of differential equations. The FEIS model predictions appear to have been reasonable, and probably conservative, for the development of the ocean dumping siting and operational procedures.

Evaluation of the Previous Model

The FEIS model is evaluated below on the basis of the assumptions and input used to develop and implement the model. These factors fall into three categories which are examined to determine the general and specific applicability of the model approach and the model formulation and implementation, respectively. The three categories considered are: [1] assumptions involved in the basic formulation of the model involving the fundamental physics and mathematics used; [2] the assumptions and methodology used to chose the magnitudes of the variables describing the important physical processes; and [3] the values used for the description of ambient conditions and characteristics of the waste material. Each of these categories of model assumptions and input was examined and re-evaluated, as discussed in more detail below. In addition to the direct re-evaluation of the model assumptions and inputs, the sensitivity of the model to important variables was assessed.

The FEIS model is based on differential equations that consider lateral and vertical diffusion. Longitudinal diffusion (in the direction of the ambient current) is neglected because of its relative magnitude which is small compared to other terms. This assumption is well founded for the current patterns observed and anticipated in the disposal area. The actual equations were developed by Brooks (1960) and can be rearranged to resemble the classical error function by adding an exponential decay term. For open ocean applications the diffusivity is expressed in terms of a 4/3 power relationship, which is a widely accepted approach (see for example Fischer et al. (1979). The affect of vertical diffusion is assumed to be Fickian. An appropriate term is multiplied with the error function to predict total diffusion from both lateral and vertical components. The approach taken in the FEIS model appears reasonable for application to the far-

field following the initial development of the waste plume. It is noted that the model as reproduced by CH2M HILL on a spreadsheet application uses a numerical approximation to the error function (with an associated error of less than $2 \cdot 10^{-7}$). Differences between the FEIS model and the CH2M HILL implementation of that model described above may be explained, at least in part, by differences in the approximations used for the error function.

The vertical diffusion in the FEIS model is dependent on a coefficient of vertical diffusion which is assumed constant during the winter and depth dependent during the summer (as reflected in the results in Tables 3.1 and 3.2). The reasoning behind this approach is based on the seasonal existence of a thermocline in the summer. The vertical diffusion coefficient is the only depth varying parameter in the governing equations used in the FEIS model.

In the FEIS model the initial plume depth is take to be H/4, where the dimension H is obtained from the equation,

$$U \cdot L \cdot H \cdot C_0 = Q$$

where,

U = ambient velocity,
L = a characteristic length parameter,
C_0 = the initial waste concentration (at the beginning of farfield dilution),

and

Q = the flow rate of the waste stream from the barge.

The width of the initial plume is taken to be twice the turning radius of the dumping vessel. A characteristic length of the vessel, set equal to the geometric mean of the half beam, and the draft of the vessel, is the length parameter used in the equation to calculate initial concentration. The FEIS modeling report does not clearly justify this assumption. One of the suggested modifications to the model, as described below, is a better description of the initial dilution of the plume. The formulation used in the FEIS model is not particularly well founded in physics, although it appears to be quite conservative in terms of the formulation of initial dilution, particularly for the vessel and disposal method currently being used (based on the discussions below) and is acceptable from a regulatory basis where any uncertainty should be on the conservative side.

The FEIS model makes several assumptions concerning the initial dumping of the waste. First, the relative velocity term that is used in the equation for calculating the initial concentration, C_0, is simply the speed of the vessel (over the bottom) where:

$$C_0 = Q/(1.814 \cdot \pi \cdot R^2 \cdot V)$$

with

Q = to the discharge rate of waste

R = a characteristic length of the body as described in Appendix 8

V = relative speed of the ship to the receiving water.

It is noted that C_0 is a dimensionless concentration, or the constant 1.814 has dimensions of inverse concentration. The FEIS is not clear on this point and the original references must be re-

viewed to clarify this point. However, the specification and use of C_0 is the major difference between the FEIS model and the revised model calculations presented below, and the FEIS specification of C_0 is not used further in this study.

In the FEIS specification of C_0, the assumption is made that as the ship circles in a constant ambient current, the net effect of the ocean current is canceled out. In addition, the flow value used is a time average which changes in response to relative velocity. Thus, it may be considered that there is no net effect on initial concentration because the calculation of C_0 involves flow in the numerator and relative velocity in the denominator. Regardless of the rationale, the ambient current speed is at least an order of magnitude smaller than the vessel speed, thus the use of vessel speed for relative velocity is a reasonable assumption.

Assumptions used, once the initial dumping has occurred, include maintaining the majority of the plume near the surface, surface waves can be disregarded, the plume does not reach the 120 fathom contour, and the pumping rate mixes the flow without altering the wake pattern of the vessel. All of these assumptions are physically reasonable or, if over-simplified, appear to result in a conservative approach (dilution will be under predicted since the effects would be generally to confine the wastefield to a region that might be smaller than would actually occur).

Three areas for improvement in the FEIS model have been identified as a result of the evaluation summarized above. One of these involves the modeling of the initial dilution processes which determines the initial concentration used as an initial condition in the farfield model. The other two areas involve the actual formulation of the farfield model and are discussed below. These problems with model formulation probably explain, at least in part, the differences in predictions of the FEIS model and CH2M HILL's application of that model as discussed above. No reason to significantly modify, or replace, the farfield model (essentially the FEIS model) has been identified other than to address the points discussed below. However, it is believed that a more realistic approach to initial dilution is available and has been incorporated into the overall model, as described below in the following section on revised model predictions.

In the FEIS modeling report, the values given for the vertical diffusion coefficient, K_V, are based on seasonal variability. As described above, winter values are held constant. Summer values are presented for depth ranges of 100 meter intervals: 0 to 100 meters, 100 to 200 meters, and below 200 meters. K_V is the only depth dependent variable in the model. The results shown in Appendix B of the FEIS (Appendix 8 of this report; see page B-18) show different values of C_{MAX}/C_0 for two fall velocities of 0.1 cm/sec and 0.01 cm/sec for, and only for, the case of 0.2 knot ambient current (values are the same for the two fall velocities for other ambient currents). Since all depths are less than 100 meters for these two cases, and K_V is constant, the differences are curious.

For the reason described above, CH2M HILL's implementation of the FEIS model could not replicate the results for the 0.2 knot current speed (see Table 3.2). In addition, the CH2M HILL implementation could not reproduce the deep (fall velocity of 1 cm/sec) case within an accuracy of up to about 10 percent (see Table 3.2). The latter discrepancy may well be related to the other problems mentioned above. The original model code was not obtained, so a definitive answer concerning these problems was not available. However, the differences are not particularly troublesome, given the nature of the model to begin with, as discussed above, and do not compromise the results of the original study in any way. Overall agreement remains very good.

Examination of the characteristics of the HSW indicates that it will generally remain near the surface as a neutrally buoyant plume and the farfield model does not need to consider a negatively buoyant fraction. Thus, in the developments below, CH2M HILL considered only a surface plume and did not vary K_V with depth (but only with season).

Another possible problem with the implementation of the FEIS model occurs when the two waste pumping rates are considered. The modeling report indicates that the discharge rate from the vessel is 140 gpm per knot of vessel speed, up to 10 knots. Initial concentration of waste is a function of flow divided by relative velocity. This implies that the initial concentration will remain about the same, particularly since the vessel speed is taken as the relative velocity as discussed above. However, the initial concentrations reported are 0.000222 and 0.000621, for a discharge of 500 gpm and 1400 gpm, respectively. It appears that the vessel speed was not varied with discharge rate. Again, this leads to conservative predictions, as the initial concentration for the higher discharge rate is over-stated. The model as implemented by CH2M HILL for the current disposal operations did vary vessel speed with discharge.

The FEIS model was developed based on a different vessel, using a different operational mode of discharge, than currently used. CH2M HILL has considered the current vessel and operational procedures. Based on the evaluation of the existing model, including the possible errors mentioned above and the changes in discharge operation, a revised model for the initial dilution process (prediction of initial concentration) is considered appropriate. The revisions should account for both the discharge of the material directly between the two counter rotating propellers of the FV *Tasman Sea* and a more sophisticated approach to dilution in the propeller slip stream. Farfield dilution can then be calculated following methods similar to those used previously, and using CH2M HILL's spreadsheet formulation of the initial FEIS farfield model (and applying the changes described above to the original FEIS formulation).

Revised Model Formulation and Predictions

An independent model was formulated and used to evaluate the dispersion of waste discharged from the barge. The purpose of this model is to provide an alternative to more realistically describe the fate and transport of the discharge. The primary differences between the FEIS and the CH2M HILL model approaches are the use of initial dilutions as determined based on the dynamics of the propeller slipstream and the use of characteristics of the current dumping vessel.

The new model developed by CH2M HILL consists of three parts:

- Dumping dilution - results from the initial discharge into the propeller wash and is numerically equivalent to the propeller discharge rate plus the waste discharge rate divided by the waste discharge rate:

- Nearfield Dilution - results from the entrainment of sea water into the momentum jet from the propellers which contains the waste discharge

- Farfield Dilution - results from the subsequent dilution of the plume and is essentially the same model used previously with the differences described above.

The major difference between the previous (FEIS) and current approach is the development of initial concentration (C_0 in the FEIS model) to be used in translating the farfield (Brooks' formulation) calculations into actual concentrations or total dilutions. The combination of dumping dilution and nearfield dilution is essentially a replacement for the specification of C_0 previously used in the FEIS. The formulation and predictions for each of the three parts of the model are described below. The transition between the nearfield and farfield is also discussed. Figure 3.1 is a schematic of the various regions modeled and discussed below.

The vessel characteristics assumed for the models are based on the known vessel characteristics as described by the vessel operator and are as follows:

Number of Propellers:	2 - counter rotating (to CL from above)
Propeller Diameter:	4 feet
Propeller Spacing:	15 feet on center
RPM/Speed:	500 rpm at slow ahead (6 knots - stabilized)
	700 rpm at 8 knots
	900 rpm at 10 to 11 knots
Draft:	12 feet (propeller CL at 10 feet)
Beam:	38 feet
Discharge Pipe:	6 in diameter to CL of propeller pair

Dumping Dilution

The dumping dilution is the immediate dilution realized as the discharge pipe releases waste at the stern of the vessel between the two counter-rotating propellers (Figure 3.2 illustrates the process schematically). It is calculated as the propeller discharge rate (water flow through the propeller) plus the waste discharge rate divided by the waste discharge rate:

$$DD = \frac{Q_p + Q_e}{Q_e}$$

Dumping dilution is equivalent to the ratio of concentration immediately after injection of the waste to the initial concentration. The discharge rate through the propeller can be calculated using propeller theory. The most direct calculation is based on the momentum theory of propellers and a practical explanation and description, with further references, can be found in Liou and Herbich (1976). CH2M HILL project staff have used this approach to calculate induced water speeds by ferries in Puget Sound (Washington), barges on the Cohansey River (New Jersey) to evaluate subsequent induced sediment transport.

The velocity V_0 (in knots) through the propeller immediately behind the vessel is given by:

$$V_0 = (1+b) \cdot V_A$$

where

V_A is the ship speed (knots),

and

$b = 2a = 2 \cdot (1/\eta_1 - 1)$, with η_1 = ideal efficiency = $2/\ (1+(C_T+1)^{1/2})$.

The term C_T is the dimensionless thrust loading coefficient,

$$C_T = T/(0.5 \cdot \rho \cdot A_0 \cdot (V_A)^2)$$

where

T = thrust developed = $K_T \cdot \rho \cdot n^2 \cdot D^4/3600$ (units of force - knots·slugs·rpm)
K_T = the thrust coefficient described below (knots/(feet·rpm))
ρ= density of water (1.99 slugs per cubic foot)
A_0 = disk area of propeller, $\pi/4 \cdot D^2$ (square feet)
n = rpm of propeller (revolutions per minute)
D = diameter of propeller (feet).

The term K_T is the thrust coefficient which is a function of the propeller-characteristic curve and is approximated as a function of the speed coefficient, J_T, as described in Liou and Herbich (1976):

$$K_T = 0.48 - 0.41 \cdot J_T$$

and

$$J_T = 101.33 \cdot V_A/(n \cdot D)$$

where variables are as defined above.

From the above velocity V_0 and the propeller area A_0, the flow through the propeller (Q_0) can be calculated as $V_0 \cdot A_0$.

Application of the above relationships, using the vessel characteristics provided, results in the following immediate dumping dilutions: 400:1 and 367:1 for discharge flows of 1400 gpm and 840 gpm, respectively, and for a single propeller stream. For the dual propellers the dumping dilutions become 800:1 and 733:1 for the same flows, since half the effluent is considered entrained behind each propeller. The vessel is assumed to be traveling at 10 knots and at 6 knots for discharge rates of 1400 gpm and 840 gpm, respectively. This is the reasonable range of speeds the vessel can make in the open sea. These flows correspond to winter time (June 1 through November 30) permitted disposal rates of 140 gpm/knot with a maximum of 10 knots. The summer permitted limit is at 120 gpm/knot with a maximum of 10 knots and the dilutions would be approximately 1.17 times those listed above. Calculations for dumping dilutions are summarized in Table 3-3 and 3-4.

Nearfield Dilution

The use of propeller theory to determine the immediate initial dilution partially replaces the initial dilution (or concentration, C_0) used in the FEIS model. As described above, CH2M HILL also applied another model between the initial dilution and the farfield predictions based on the Brooks method. This was done to account for the rapid mixing within the propeller slipstream. The model assumes that all of the waste discharged is entrained in the slipstream. This is considered a very good assumption, and, based on the disposal method, it is difficult to see how the situation could be otherwise.

The nearfield approach used (Sobey, 1994) considers conservation of momentum in a round momentum jet (the propeller slip stream). The centerline velocity, U_{CL}, and flow at any distance x from the point of discharge, Q_x, are given by:

$$U_{CL} = \frac{1}{\alpha x}\sqrt{\frac{K_o}{2\pi I_2}}$$

and

$$Q_x = \alpha x I_1 \sqrt{\frac{2\pi K_o}{I_2}}$$

where

$K_0 = Q_0 \cdot V_0$
with subscript $_0$ indicating initial conditions at the propeller,
$Q_0 = V_0 \cdot A_0$
where V_0 is the velocity of the jet through the propeller and is taken relative to the ambient fluid and A_0 is the propeller area,
$I_1 = 0.72$,
$I_2 = 0.36$,

and

$\alpha = 0.096$.

For the above two equations, consistent units must be used since all constants are unitless. For example, distance in feet, velocity in feet per second, and flow in cubic feet per second are consistent units.

Nearfield dilution (D_N) at a distance x from the point of discharge is given by Q_x/Q_0. The dilution as a function of x will remain the same for various vessel speeds, since the initial flow through the propeller changes in direct response to vessel speed. This apparently counter-intuitive result is shown as follows:

$$D_N = \frac{Q_x}{Q_0} = \frac{\alpha x I_1 \sqrt{\frac{2\pi K_0}{I_2}}}{A_0 V_0}$$

but

$$K_0 = Q_0 V_0$$

and

$$Q_0 = A_0 V_0$$

so D_N is not a function of V_0; it is only a function of distance (x) for a given A_0.

The momentum theory for propellers also provides a means to calculate velocity and is given in Liou and Herbich (1976):

$$V(r,x) = (V_0 \cdot D_0/x) \cdot 10^{\varepsilon}$$

where

$\varepsilon = 0.79 - 33 \cdot (r/x)^2$
r = distance in the radial direction

and on the centerline (r = 0):

$$V(x) = U_{CL} = (V_0 \cdot D_0/x) \cdot 6.17.$$

As a check the calculations for velocity were done using both equations for centerline velocity and agreement was excellent when calculated on the same basis. Calculations for nearfield dilutions are summarized in Table 3-3 and 3-4 which also contain the pertinent calculations and comparisons for both methods.

The nearfield dilution achieved will be affected because of the interference between the two jets when they merge. This will result in a smaller "entrainment area" (the surface area of the plume) exposed to "clean" (ambient as opposed to the water in the second plume) water. In addition the plumes will intercept the surface and this will also reduce the entrainment area. When these results are considered, and the geometry of a round jet is maintained, the surface area available for entrainment is reduced to about 50 percent of the area of an otherwise undisturbed double plume, or approximately the same as an undisturbed single plume, past a point about 300 feet from the point of discharge. Table 3.5 shows the nearfield dilution as a function of distance, taking into account the affect of the adjacent propeller slip stream. The calculation scheme and results for determining the factor by which the surface area of the jet is affected are provided in Appendix 9. It is noted that the distance along the nearfield plume is considered at a constant depth below the water and the plume is considered neutrally buoyant with insignificant settling or deepening of the plume (in terms of the farfield model geometry, $x \approx x'$).

The interference of side-by-side plumes and the surface will also act to change the shape of the plume, and result in increased surface area compared to the calculations above. Other factors such as concentration gradients across the plume and the actual flow field also act to make the use of an entrainment area approach somewhat conservative, since actual entrainment areas are expected to be larger than the development presented here. However, to maintain a good degree of conservatism, we have assumed the dilution for both slipstreams combined, once the plumes merge, will be reduced by the entrainment ratio as calculated.

Transition Region

The modeling performed for this study has not strictly attempted to provide a smooth match or connection between the nearfield and farfield plumes. The transition region is ignored. The parameter H, as used in the FEIS farfield model, is the dimension applicable at the beginning of the farfield calculations - but may not match the dimension at the end of the nearfield calculations, arbitrarily taken to be 1000 feet from the vessel. In general, the connection between farfield and nearfield models are seldom rigorous. For the present study, the farfield model is used as an estimate of the additional dilution one might expect

in the dumping zone following nearfield dilution. This approach is taken since, from a regulatory perspective, the combination of dumping and nearfield dilution is sufficient and any subsequent farfield dilution is considered a safety factor. The consequences of this approach are discussed in more detail below.

There are three regions (Figure 3.1) to consider following the initial mixing that is referred to as dumping dilution: a region where turbulent diffusion dominates, a transition region where turbulent diffusion and passive diffusion are comparable, and a region where only passive diffusion is acting. The diffusion, and thus dilution, is greater in the turbulent region than in the passive region, and would be intermediate between these two in the transition region. This study takes an approach that considers the nearfield within a region that is dominated by turbulent diffusion in the jet. This region was "arbitrarily" taken as 1000 feet based on examination of the lapse rate of dilution (with distance) compared to the lapse rate of dilution as predicted by the farfield model.

Considered more rigorously, nearfield dilution can be considered to end where passive diffusion is comparable to turbulent diffusion within the plume. This may not be at 1000 feet as assumed and a more justifiable distance, based on specific conditions for each case considered, could be developed. At this point the region where turbulent and passive diffusion would be comparable is ignored and the farfield dilution calculations are applied. Since the transition region would exhibit greater diffusion than the farfield (passive) region, this approach should understate the dilution achieved. This is consistent with the objectives of the study which are not necessarily to provide the most accurate or sophisticated prediction of dilution but rather to provide a prediction to evaluate the impacts of discharge at the edge of the permitted zone in the context of measured toxicity of the waste. If a demonstrably conservative approach shows no impact there is no rationale for refining the predictions.

A smooth transition between the end of the nearfield to the beginning of the farfield would require yet another model that handles both turbulent (turbulence originating from the propeller slip stream) and passive (ambient levels of turbulence) diffusion in the transition region where they are of comparable magnitude. This was not done and the dimensions of the plume between the nearfield and farfield are not necessarily matched. However, the dimension at the beginning of the farfield is the same as previously used in the FEIS and is based on the turning radius of the ship. The reason for this is, that based on the ambient current speed, vessel speed, and dumping track of the vessel, the vessel operations are constrained by the permit such that plume overlap is not, in general, expected except as follows: an overlap type of phenomena is anticipated at the point of plume formation by merging as the vessel turns down current at the end of alternate legs. To account for this eventuality we used a length parameter based on the turning radius of the ship as the worst case starting condition for the farfield calculations just as was done in the FEIS model.

As mentioned above, the value at 1000 feet is taken as the value for the nearfield dilution in the calculations of total dilution described below. Additional justification for this, supporting the discussion above, can be found in Tables 3.3 and 3.4, where the plume velocity at 1000 feet is shown to be comparable to the maximum ambient ocean currents. Thus, nearfield dilution ends when the plume speed approaches the speed of the ambient currents. This is a conservative (under predicts dilution) approach since there will be addi-

tional or enhanced dilution in the propeller stream further than this distance for lower than maximum ambient currents

Farfield Dilution

The evaluation of the previous (FEIS) farfield modeling can be summarized fairly succinctly: after examination of the previous work, and considering the characteristics of the new disposal vessel (counter-rotating twin screw propulsion with waste introduced between the screws), the most significant shortcoming of the previous model appears that it very likely substantially underpredicted the initial dilution. To address the implications of the evaluation in more detail an approach was developed to predict the initial and subsequent phases of dilution (dumping dilution and nearfield dilution as described above) that is considered somewhat less conservative in terms of possibly under predicting initial dilution, than the original model. It was not attempted to describe the fate of the waste in great detail or in a rigorously definitive fashion, but to provide estimates sufficient for planning and regulatory decision making and attempting to keep assumptions "conservative" as defined above.

As mentioned above, CH2M HILL used the previously applied farfield transport model implemented on an Excel spreadsheet. The FEIS model is described in Appendix 8 which reproduces Appendix B of the FEIS referenced above. Appendix 8 should be consulted for a thorough review of the physical and mathematical basis of the model, since that description is not reproduced here. As discussed above, when using the same input data as used in the FEIS modeling, the results are in excellent agreement. The geometry and dimensions of the current vessel are used. Initial concentration is set to unity to calculate relative dilutions (or concentrations).

Two key parameters used in this model are the vertical diffusion coefficient, K_V, and the horizontal dissipation parameter, A. Varying these parameters in the model, using the spreadsheet formulation, demonstrated that the results are not particularly sensitive to K_V and are, as expected, moderately sensitive to variations in A. Since the time of development of the FEIS model there is no data that would indicate that these constants should be changed from the previous values, and the same values were used. In addition, a literature survey of recommended values for A indicate that the value used is reasonable for open ocean applications. Fischer (1979) recommends using a value between 0.0002 and 0.001; Yearsley (1989) recommends the same range; Grace (1978) recommends 0.00015 to 0.005; and Baumgartner et al.(1993) recommend 0.0002 to 0.001. These suggested ranges are generally for application to nearshore coastal and inland waters. For open ocean water, with no effects of boundaries and significant wind and wave action, the high end of the suggested range is appropriate. Thus, the value previously used in the FEIS model (0.001) has been retained. Note that units of A as discussed above are $ft^{2/3}/sec$.

As in the case of the previous modeling, the farfield dilution is seasonally dependent based on the strength and structure of the thermocline. Farfield predictions were done for the same set of conditions as done previously:

- A range of ambient ocean current speeds of 0.2 to 1.0 knots

- A range of vessel speeds of 6 and 10 knots
- Winter conditions with no change in K_V with depth
- Summer conditions with K_V dependent on depth (however, only the surface layer was modeled for this case because that is a worst case condition)

The results of the farfield modeling are summarized in Table 3.6 and detailed model output is provided in Appendix 10. Table 3.6 reports the farfield dilution at distances of 2.5 and 5 nautical miles from the release area corresponding to the approximate down current edge of permitted dump zone and the closest point to possible land influence. (These distances are somewhat less than actual distances to the points referenced.) Results for ocean currents of 0.4 knots and 0.8 knots, corresponding to minimum and maximum expected ocean currents (as discussed in the FEIS) are described for vessel speeds of 6 and 10 knots in Table 3.6. Results for additional cases are provided in Appendix 10.

The permits specify in some detail where the disposal is to be done within the designated dump site (Special Condition 4.3.1 through 4.3.3) and a computerized navigational system is required (Special Condition 4.5). The permits further require the master of the vessel to submit a plot of the vessel course for each dumping operation (Special Condition 4.3.4) and maintain and submit a detailed log of operations (Special Condition 4.3.7). Of particular note are the requirements for the vessel positioning for disposal operations which are summarized as follows:

- the vessel "...shall proceed directly to the center of the disposal site"..;
- "...the master of the vessel shall observe the conditions at the dump site center, noting the vessel's position (latitude and longitude), wind direction and observed surface current direction...";
- "...the master of the disposal vessel shall proceed 1.1 nautical miles up current from the center of the disposal site and record the position of the disposal vessel (latitude and longitude). This position shall be the starting point for disposal operations..."

The vessel navigation is done using GPS (and a plot is generated on each trip to the disposal site). Potential errors in navigation are on the order of 100 feet. Therefore, the master of the vessel should have no problem finding the center of the dump zone or positioning the vessel as described above. In addition, using GPS, observing the wind direction, and with a knowledgeable crew familiar with windage and current drift near surface current direction is relatively easy to determine. It is the surface current that is important for the dispersion of the wastes. The wastes are essentially neutrally to slightly positively buoyant (only a very small fraction, if any, will be significantly negatively buoyant) as described by the monitoring data discussed in Section 4 of the report below. Therefore, any deeper currents, that might be in a different direction than the near surface layer, will not be important for dispersion within the dump zone.

The points above provide justification for assuming that the waste will be dumped at the correct location and the nearest distances to the down current edge of the dump site and

the nearest shoreline or reef will be greater than 2.5 and 5 nautical miles, respectively. Therefore dilution based on disposal at other than the permit specified locations has not been discussed. However, the information needed to assess the effects of dumping at various distances from the edge of the site is provided in the detailed descriptions of the farfield model results in Appendix 10, and the interested reader may therefore calculate total dilution at any distance from the discharge vessel desired. Figure 3.3 will also provide an estimate of predicted dilutions with distance from the vessel.

Summary of Model Predictions

The dilutions for the range of seasonal and operational parameters are as follows:

- Dumping dilution: The immediate dilution on dumping ranges from approximately 730:1 to 930:1 depending on discharge rate (seasonal constraint) and vessel speed, assuming a maximum permitted discharge per knot of vessel speed.

- Nearfield dilution: The dilution within the propeller slipstream, for first 1000 feet, is predicted to be about 42:1.

- Farfield Dilution: Using essentially the same model as applied in the FEIS the farfield dilution is predicted to range from approximately 11:1 to 30:1 prior to reaching the edge of the dumping zone, and 24:1 to 77:1 prior to reaching the shore line or closest reef area. The farfield dilution depends on a number of environmental and operational variables and can vary from season to season and from day to day.

The dilutions described above are developed in a multiplicative fashion where the dilution is applied to the concentrations at the beginning of the individual mixing processes. Thus the overall dilution at the edge of the dumping zone is the product of the numerical values of the three dilutions described above:

Total dilution = (dumping dilution) x (nearfield dilution) x (farfield dilution)

The results of the model predict minimum dilutions of approximately 400,000:1 at the edge of the dumping zone (for summer conditions with an ocean current of 0.8 knots and a dumping rate of 1200 gallons per minute corresponding to a vessel speed of 10 knots). These dilutions are predicted under what the authors of this report consider to be conservative (under predicted dilutions) and worst case conditions. In addition the farfield dilution calculations are based on centerline or maximum values and the average dilutions within the plume would be less by approximately a factor of two. The range of dilutions, and corresponding concentrations of waste are described in more detail in the concluding section of the report (Section 5). As an example of dilution through the dumping zone from the point of discharge, Figure 3.3 shows dilution as a function of distance for winter and summer conditions that would exhibit the lowest overall dilutions (highest ocean currents and highest permitted dumping rates and vessel speeds).

Deviations from the Study Plan

The original study plan for the modeling is provided in Appendix 2. There were a number of minor deviations from the initially described study plan for the modeling elements of the study. As in any study of this kind, such deviations often arise. All such deviations are, at least implicitly, covered in the report. These deviations included:

- Sensitivity to lateral diffusion and vertical diffusion coefficients: For the reasons presented above, including the difficulty of obtaining site specific field, the same coefficients for horizontal diffusion in the farfield model were applied as used in the FEIS study. Although a formal sensitivity analysis was not done, variations in the coefficient were examined and no reason was found to change the previous value. The examination of monitoring data, presented in Section 4 below, provides a level of confidence that the model predictions are appropriate and the physics of the plume dispersion appear to be somewhat conservatively estimated (dilution appears to be underestimated) by the model and the coefficients used in the model.

- Effluent characteristics of density and settling speed were not explicitly utilized in the modeling (except in reproducing the previous FEIS results). As described in the report we considered the entire plume as a surface plume which provides a worst case analysis and is consistent with the density of the wastes as described in Section 4 below. The initial dilution is so rapid and at such a level that the assumption of neutral buoyancy is very well approximated.

- The field data to rigorously calibrate and verify the model is not available and would be difficult to obtain. Based on the final conclusions concerning toxicity, such an effort is not justified. The available monitoring data, however, was compiled, collated, examined, and evaluated and additionally analyzed to provide a qualitative and potentially semi-quantitative method of evaluating the model predictions. Section 4 below describes this process and the results indicate that this process is sufficient for the purposes of the study.

In general, the study plan was followed, with the minor deviations described above not affecting the usefulness or the application of the study results.

Table 3.1
Comparison of Original FEIS and CH2M HILL Reformulated Model Predicitions

Distance (n. mi.)	Winter Conditions			Summer Conditions		
	CH2MHILL Model	FEIS Model	Percent error	CH2M HILL Model	FEIS Model	Percent error
Cmax/Co for Current Speed of 0.2 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.06745			0.10016		
1.0	0.03365	0.03364	-0.03	0.05001	0.04999	-0.04
1.5	0.02044	0.02043	-0.04	0.03039	0.03038	-0.05
2.0	0.01380	0.01379	-0.07	0.02053	0.02052	-0.05
2.5	0.00997	0.00996	-0.07	0.01483	0.01482	-0.07
3.0	0.00754	0.00754	-0.06	0.01123	0.01122	-0.07
3.5	0.00591	0.00591	-0.06	0.00880	0.00880	-0.02
4.0	0.00476	0.00476	-0.04	0.00709	0.00709	0.03
Cmax/Co for Current Speed of 0.2 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.06745			0.10016		
1.0	0.03365	0.03364	-0.03	0.05001	0.05000	-0.02
1.5	0.02044	0.02043	-0.04	0.03039	0.03039	-0.01
2.0	0.01380	0.01380	0.00	0.02053	0.02052	-0.05
2.5	0.00997	0.00996	-0.07	0.01483	0.01483	-0.01
3.0	0.00754	0.00754	-0.06	0.01123	0.01123	0.02
3.5	0.00591	0.00591	-0.06	0.00880	0.00880	-0.02
4.0	0.00476	0.00476	-0.04	0.00709	0.00709	0.03
Cmax/Co for Current Speed of 0.4 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.05648			0.08393		
1.0	0.03386	0.03385	-0.02	0.05037	0.05035	-0.04
1.5	0.02305	0.02305	-0.02	0.03431	0.03430	-0.03
2.0	0.01685	0.01684	-0.04	0.02508	0.02507	-0.03
2.5	0.01291	0.01290	-0.04	0.01921	0.01920	-0.06
3.0	0.01023	0.01022	-0.08	0.01523	0.01522	-0.04
3.5	0.00832	0.00831	-0.10	0.01238	0.01238	-0.03
4.0	0.00690	0.00690	-0.06	0.01028	0.01028	0.00
Cmax/Co for Current Speed of 0.4 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.05648			0.08393		
1.0	0.03386	0.03385	-0.02	0.05037	0.05036	-0.02
1.5	0.02305	0.02305	-0.02	0.03431	0.03430	-0.03
2.0	0.01685	0.01684	-0.04	0.02508	0.02507	-0.03
2.5	0.01291	0.01290	-0.04	0.01921	0.01921	-0.01
3.0	0.01023	0.01022	-0.08	0.01523	0.01522	-0.04
3.5	0.00832	0.00832	0.02	0.01238	0.01238	-0.03
4.0	0.00690	0.00690	-0.06	0.01028	0.01028	0.00
Cmax/Co for Current Speed of 0.8 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.04161			0.06190		
1.0	0.02828	0.02827	-0.02	0.04209	0.04207	-0.04
1.5	0.02139	0.02138	-0.04	0.03184	0.03183	-0.04
2.0	0.01694	0.01693	-0.06	0.02522	0.02521	-0.05
2.5	0.01382	0.01382	-0.02	0.02058	0.02058	-0.01
3.0	0.01153	0.01153	-0.02	0.01717	0.01717	-0.01
3.5	0.00979	0.00979	0.01	0.01458	0.01457	-0.04
4.0	0.00843	0.00842	-0.08	0.01255	0.01254	-0.06
Cmax/Co for Current Speed of 0.8 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.04161			0.06190		
1.0	0.02828	0.02827	-0.02	0.04209	0.04209	0.01
1.5	0.02139	0.02138	-0.04	0.03184	0.03184	-0.01
2.0	0.01694	0.01694	0.00	0.02522	0.02522	-0.01
2.5	0.01382	0.01382	-0.02	0.02058	0.02058	-0.01
3.0	0.01153	0.01153	-0.02	0.01717	0.01717	-0.01
3.5	0.00979	0.00979	0.01	0.01458	0.01457	-0.04
4.0	0.00843	0.00842	-0.08	0.01255	0.01254	-0.06

Table 3.2
Comparison of Original FEIS and CH2M HILL Reformulated Model Predicitions

Distance (n. mi.)	Summer Deep			Summer Mid-Depth		
	CH2MHILL Model	FEIS Model	Percent error	CH2M HILL Model	FEIS Model	Percent error
Cmax/Co for Current Speed of 0.2 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.10348			0.10016		
1.0	0.05168	0.05423	4.70	0.05001	0.04999	-0.04
1.5	0.03141	0.03242	3.11	0.03039	0.03038	-0.05
2.0	0.02122	0.02172	2.31	0.02053	0.02052	-0.05
2.5	0.01533	0.01562	1.87	0.01483	0.01482	-0.07
3.0	0.01161	0.01179	1.57	0.01123	0.01133	0.90
3.5	0.00910	0.00922	1.33	0.00880	0.00947	7.06
4.0	0.00733	0.00741	1.13	0.00709	0.00805	11.95
Cmax/Co for Current Speed of 0.2 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.10348			0.10016		
1.0	0.05168	0.05423	4.70	0.05001	0.05000	-0.02
1.5	0.03141	0.03242	3.11	0.03039	0.03039	-0.01
2.0	0.02122	0.02172	2.31	0.02053	0.02052	-0.05
2.5	0.01533	0.01562	1.87	0.01483	0.01483	-0.01
3.0	0.01161	0.01179	1.57	0.01123	0.01133	0.90
3.5	0.00910	0.00922	1.33	0.00880	0.00947	7.06
4.0	0.00733	0.00741	1.13	0.00709	0.00805	11.95
Cmax/Co for Current Speed of 0.4 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.08674			0.08393		
1.0	0.05206	0.05794	10.15	0.05037	0.05035	-0.04
1.5	0.03546	0.03798	6.63	0.03431	0.03430	-0.03
2.0	0.02592	0.02726	4.92	0.02508	0.02507	-0.03
2.5	0.01986	0.02067	3.93	0.01921	0.01920	-0.06
3.0	0.01574	0.01627	3.27	0.01523	0.01522	-0.04
3.5	0.01280	0.01317	2.80	0.01238	0.01238	-0.03
4.0	0.01063	0.01089	2.43	0.01028	0.01028	0.00
Cmax/Co for Current Speed of 0.4 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.08674			0.08393		
1.0	0.05206	0.05795	10.16	0.05037	0.05036	-0.02
1.5	0.03546	0.03799	6.66	0.03431	0.03430	-0.03
2.0	0.02592	0.02727	4.95	0.02508	0.02507	-0.03
2.5	0.01986	0.02067	3.93	0.01921	0.01921	-0.01
3.0	0.01574	0.01627	3.27	0.01523	0.01522	-0.04
3.5	0.01280	0.01317	2.80	0.01238	0.01238	-0.03
4.0	0.01063	0.01089	2.43	0.01028	0.01028	0.00
Cmax/Co for Current Speed of 0.8 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.06398			0.06190		
1.0	0.04350	0.04207	-3.40	0.04209	0.04207	-0.04
1.5	0.03291	0.03532	6.81	0.03184	0.03183	-0.04
2.0	0.02607	0.02859	8.81	0.02522	0.02521	-0.05
2.5	0.02127	0.02287	6.98	0.02058	0.02058	-0.01
3.0	0.01775	0.01883	5.74	0.01717	0.01717	-0.01
3.5	0.01507	0.01585	4.94	0.01458	0.01457	-0.04
4.0	0.01297	0.01355	4.28	0.01255	0.01254	-0.06
Cmax/Co for Current Speed of 0.8 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.06398			0.06190		
1.0	0.04350	0.04208	-3.38	0.04209	0.04208	-0.02
1.5	0.03291	0.03533	6.84	0.03184	0.03184	-0.01
2.0	0.02607	0.02859	8.81	0.02522	0.02522	-0.01
2.5	0.02127	0.02287	6.98	0.02058	0.02058	-0.01
3.0	0.01775	0.01884	5.79	0.01717	0.01717	-0.01
3.5	0.01507	0.01585	4.94	0.01458	0.01457	-0.04
4.0	0.01297	0.01355	4.28	0.01255	0.01254	-0.06

Table 3.3
Dumping Dilution and Nearfield Dilution Calculations for a Single Propeller
Vessel Speed of 6 knots

Round Momentum Jet Theory
(from Sobey, 1994)

Ko	24707	
I1	0.72	
I2	0.36	
alpha	0.096	

Effluent Discharge (waste flow)
1.872 (ft^3/sec)

Dumping Dilution
366.70

Initial Velocity with respect to current
26.27 (knots)
13.52 (m/s)
44.34 (ft/sec)

Initial flow through Propeller
557.21 (ft^3/sec)
15.78 (m^3/s)

Distance from propeller
(25 feet is start of established flow)

Centerline Plume Velocity with respect to current (ft/sec)	feet
43.55	25
10.89	100
5.44	200
3.63	300
2.72	400
2.18	500
1.81	600
1.56	700
1.36	800
1.21	900
1.09	1000
0.54	2000
0.22	5000
0.11	10000

Nearfield Dilution
Momentum jet entrains fluid

Distance (feet)	Flow (ft^3/sec)	Dilution
25	1135	2.04
100	4539	8.15
200	9078	16.29
300	13617	24.44
400	18156	32.58
500	22695	40.73
600	27234	48.88
700	31773	57.02
800	36312	65.17
900	40850	73.31
1000	45389	81.46
2000	90779	162.92
5000	226947	407.29
10000	453894	814.59

Propeller Momentum Theory
(from Liou and Herbich, 1976)

Ships Speed	6	(knots)
Diameter of Propeller	4	(feet)
RPM of propeller	500	
Speed Coefficient (Jt)	0.30	
Thrust Coeficient (Kt)	0.36	
Thrust (T)	12571.99	
Thrust Loading Coefficient (Ct)	27.93	
Ideal Efficiency (n1)	0.31	
coefficient a	2.19	
ceofficient b	4.38	
Current Speed	0	(knots)
	0.00	(ft/sec)
Initial Velocity (Vo) with respect to ship	32.27	(knots)
	16.60	(m/s)
	54.47	(ft/sec)
Initial flow through Propeller (Qo)	684.46	(ft^3/sec)
(for dumping dilution)	19.38	(m^3/s)

Centerline Plume Velocity with respect to ship (ft/sec)
53.74
13.43
6.72
4.48
3.36
2.69
2.24
1.92
1.68
1.49
1.34
0.67
0.27
0.13

Table 3.4
Dumping Dilution and Nearfield Dilution Calculations for a Single Propeller
Vessel Speed of 10 knots

Round Momentum Jet Theory
(from Sobey, 1994)

Ko	84800	
I1	0.72	
I2	0.36	
alpha	0.096	

Effluent Discharge (waste flow)
3.119 (ft^3/sec)

Dumping Dilution
399.91

Initial Velocity with respect to current
48.67 (knots)
25.04 (m/s)
82.15 (ft/sec)

Initial flow through Propeller
1032.29 (ft^3/sec)
29.23 (m^3/s)

Distance from propeller
(25 feet is start of established flow)

Centerline Plume Velocity with respect to current (ft/sec)	feet
80.68	25
20.17	100
10.08	200
6.72	300
5.04	400
4.03	500
3.36	600
2.88	700
2.52	800
2.24	900
2.02	1000
1.01	2000
0.40	5000
0.20	10000

Nearfield Dilution
Momentum jet entrains fluid

Distance (feet)	Flow (ft^3/sec)	Dilution
25	2102	2.04
100	8409	8.15
200	16818	16.29
300	25227	24.44
400	33636	32.58
500	42045	40.73
600	50453	48.88
700	58862	57.02
800	67271	65.17
900	75680	73.31
1000	84089	81.46
2000	168178	162.92
5000	420446	407.29
10000	840891	814.59

Propeller Momentum Theory
(from Liou and Herbich, 1976)

Ships Speed	10	(knots)
Diameter of Propeller	4	(feet)
RPM of propeller	900	
Speed Coefficient (Jt)	0.28	
Thrust Coeficient (Kt)	0.36	
Thrust (T)	41791.50	
Thrust Loading Coefficient (Ct)	33.42	
Ideal Efficiency (n1)	0.29	
coefficient a	2.43	
ceofficient b	4.87	
Current Speed	0	(knots)
	0.00	(ft/sec)
Initial Velocity (Vo) with respect to ship	58.67	(knots)
	30.18	(m/s)
	99.02	(ft/sec)
Initial flow through Propeller (Qo)	1244.38	(ft^3/sec)
(for dumping dilution)	35.24	(m^3/s)

Centerline Plume Velocity with respect to ship (ft/sec)
97.69
24.42
12.21
8.14
6.11
4.88
4.07
3.49
3.05
2.71
2.44
1.22
0.49
0.24

Table 3.5
Nearfield Dilution Calculations

Distance (feet)	Dilution	Entrainment Coefficient	Adjusted Dilution
25	2.04	1.00	2.04
100	8.15	0.79	6.44
200	16.29	0.58	9.45
300	24.44	0.55	13.44
400	32.58	0.53	17.27
500	40.73	0.53	21.59
600	48.88	0.52	25.42
700	57.02	0.52	29.65
800	65.17	0.52	33.89
900	73.31	0.51	37.39
1000	81.46	0.51	41.54

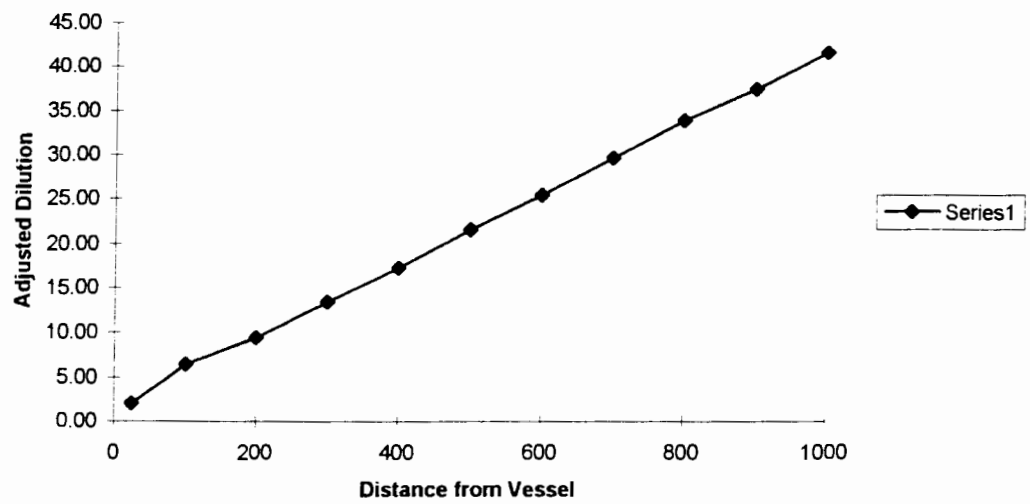


Table 3.6

Farfield Dilution Model Results

Ocean Current (knots)	Vessel Speed (knots)	Dilution	
		Winter Conditions	Summer Conditions
Dilution at 2.5 Nautical Miles Down Current			
0.4	6	29.6	20.0
	10	17.9	12.1
0.8	6	27.6	18.6
	10	16.6	11.2
Dilution at 5 Nautical Miles Down Current			
0.4	6	76.6	51.5
	10	46.1	31.1
0.8	6	59.1	39.7
	10	35.5	23.9

Figure 3.1
Schematic Diagram of Wastefield Plume Elements

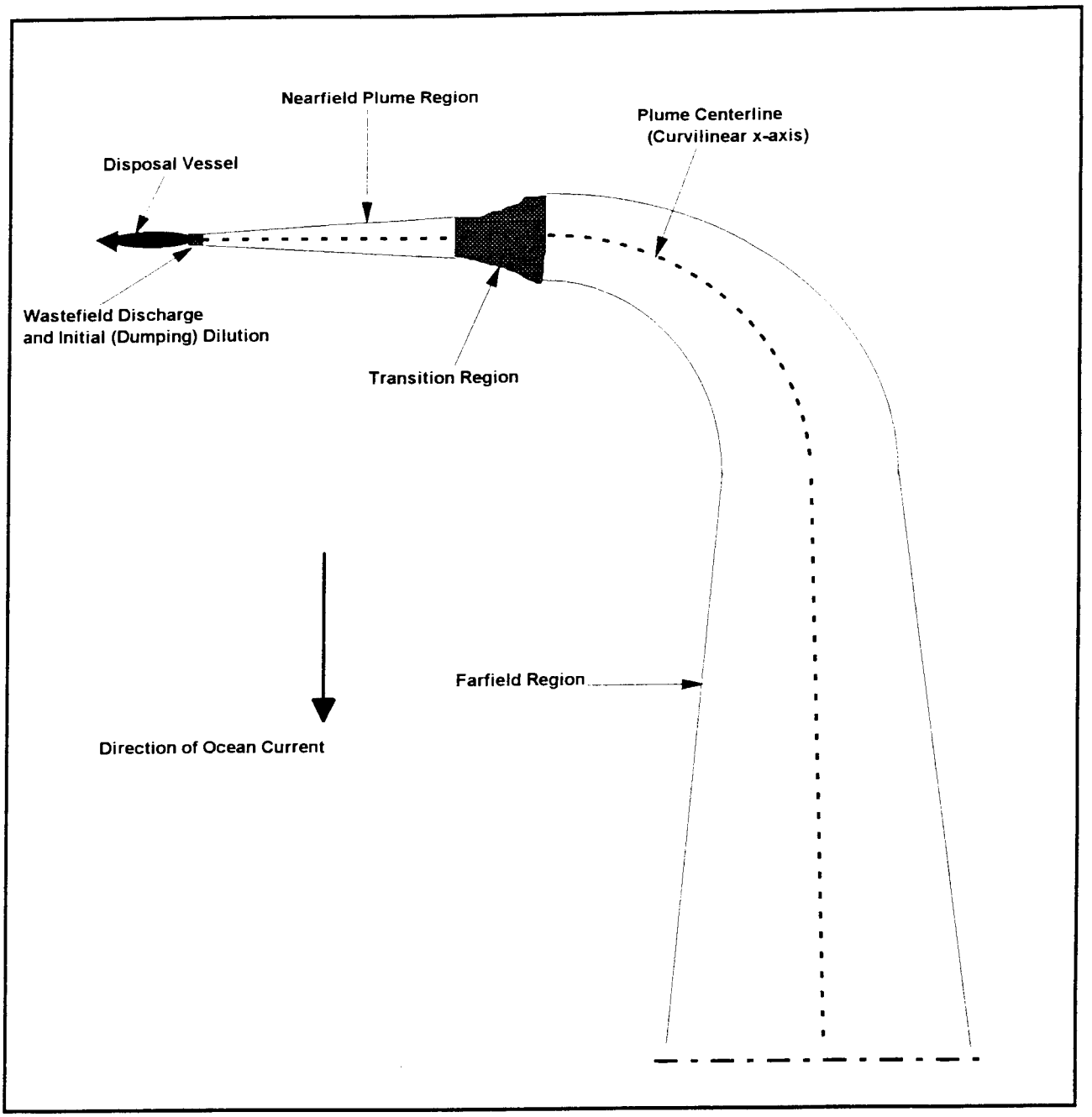
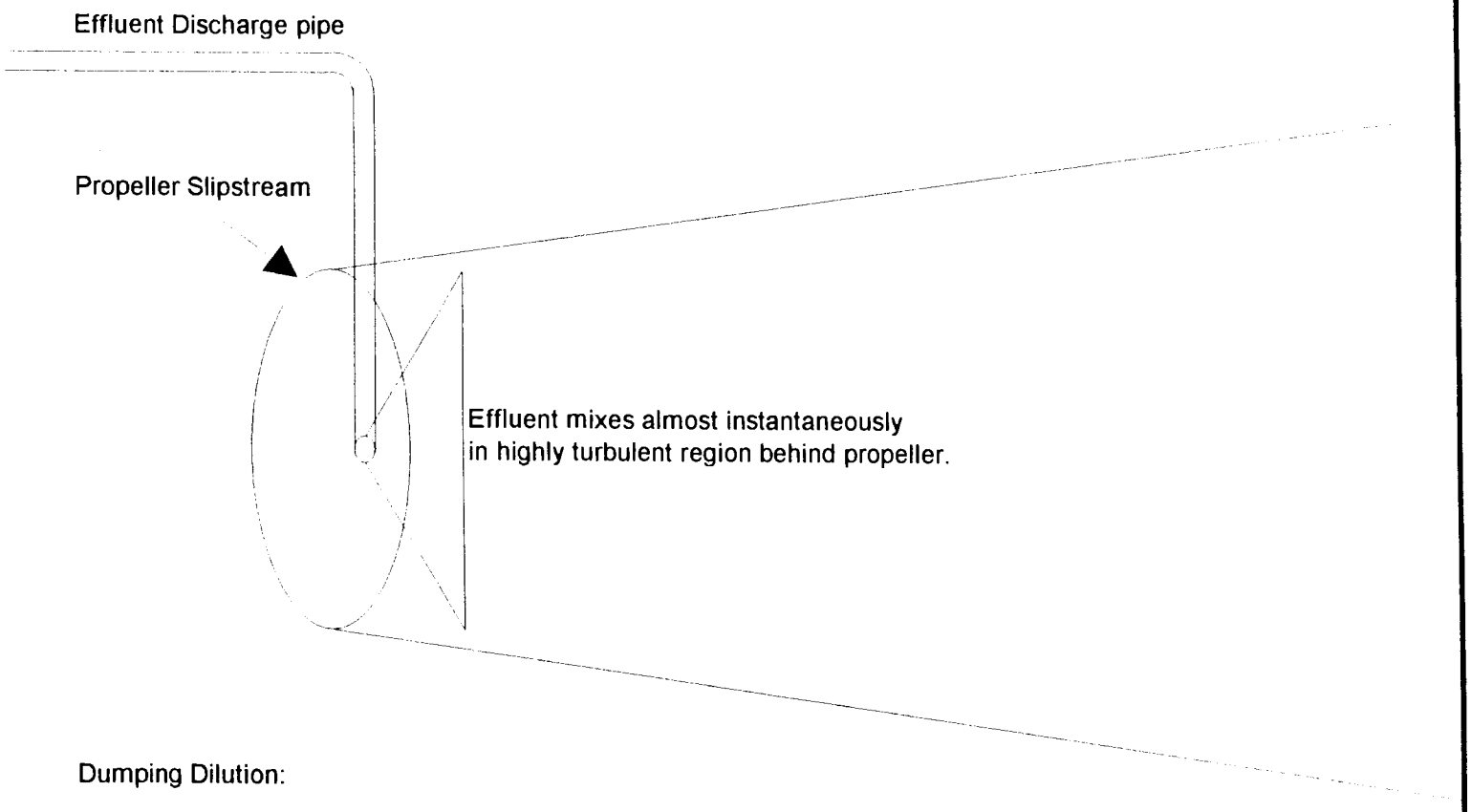


Figure 3.2
Dumping Dilution Schematic

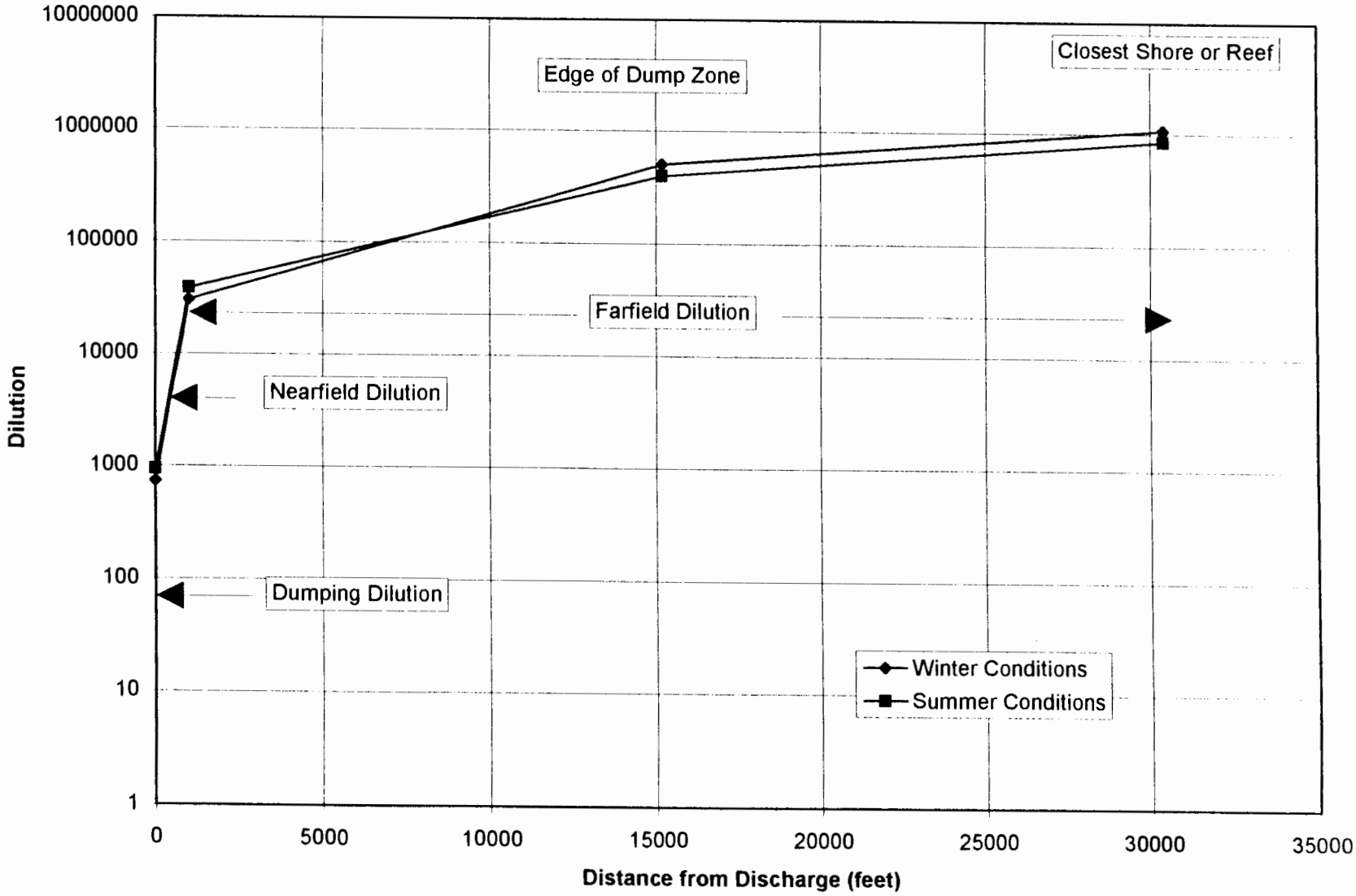


Dumping Dilution:

$$\frac{Qe+Qp}{Qe}$$

Qe = effluent flow into each propeller slipstream
Qp = propeller flow through each propeller

Figure 3.3
Dilution with Distance from Ship



4. Monitoring Data Evaluation

There has been no data collection specifically designed to calibrate or verify model predictions or assess dilution of the wastefield through the approved dumping site. However, the ocean dumping permits do require the canneries to collect waste stream and receiving water data. These data can be used to qualitatively, and to a limited extent, quantitatively, assess the behavior of the wastefield after dumping and assess the general applicability of the model predictions. The available data are first described and examined below (all data discussed in this section of the report is for the time period September 1993 through September 1996). Following the initial description, the data are applied to an evaluation of the wastefield in the receiving water, to the extent possible. The results of the evaluation are also interpreted in terms of the model predictions presented in the previous section. All of the data described in this section of the report is available from EPA Region IX.

Review of Monitoring Data

The canneries are required to collect data from the onshore high strength waste (HSW) storage tanks and monitoring data at the ocean dumping site on a monthly basis. In addition, the canneries must report the daily volumes disposed of at the dump site. Table 4.1 shows the dates of ocean site monitoring and the volumes disposed of by each cannery. The waste from both canneries is maintained separately onshore and combined when pumped into the disposal vessel. Average daily volumes disposed of by each cannery on a monthly basis are listed in Appendix 11. It is noted that on an average basis the volumes are about the same for each cannery with Samoa Packing accounting for approximately 49 percent and StarKist Samoa for about 51 percent.

The onshore data collected by each cannery includes the analysis of certain constituents from the HSW storage tanks. These data were collected twice per month over most of the time period and once per month in the more recent portion of the period. The parameters analyzed include: total suspended solids (as non-filterable reside -TSS), the volatile fraction of the total suspended solids (TVSS), five day biological oxygen demand (BOD_5), oil and grease (O&G), total phosphorus (TP as P), total nitrogen (TN as N), ammonia (as N), pH, and density. The results of the analysis for the period considered (September 1993 through September 1996) are summarized in Table 4.2 and a detailed data compilation is provided in Appendix 11 for each cannery.

The receiving water monitoring data are collected monthly before and after dumping operations. Water samples are collected at three depths (1, 3, and 10 meters below the surface) at six stations as follows:

- Station 1C, a control station at the location where dumping will commence (based on current direction) before dumping starts
- Station 1, in the center of the active dumping area immediately following the discharge of HSW

- Stations 2, 3, and 4, in the center of the "plume" or wastefield as it moves down current (determined visually) at distances of 0.25, 0.5, and 1.0 nautical miles down current of station 1
- Station 5, at the "leading edge" of the wastefield determined as the point furthest downstream from the dumping area where there is still a visual trace of the plume

The parameters measured in the field include pH, temperature, odor, and visual appearance (as well as location determined using GPS, wind, current, and sea conditions). The samples collected are analyzed for: TSS,TVSS, O&G, TP, TN, and ammonia. As mentioned above the dates of ocean monitoring are shown in Table 4.1. Summaries of the analyses carried out for each constituent at each station and depth are given in Table 4.3. Detailed data compilations are provided in Appendix 11. Figures 4.1 through 4.6 show the median values for each of the constituents listed above for each station and depth. The statistics in Table 4.3 and the graphical descriptions in Figures 4.1 through 4.6 were constructed by eliminating obvious outliers (discussed further below) and using the reporting limits for those samples that were not detected. The values are shown in parentheses (outliers eliminated) or are shaded (not detected) in the tables in Appendix 11.

The onshore monitoring samples and the receiving water monitoring samples may sometimes be of the same material but are not from the same material in general. The canneries may sample onshore on different days and neither may coincide with the day of ocean monitoring, or if on the same day may still not be the same material. However, there is a 37 month series of data considered, and long term effects should be well described. Reviewing the data, the median has been chosen as a good representative value. However, all of the data are provided in Appendix 11 if the reader wishes to select a different approach for analysis. It is noted that the median for both the onshore and receiving water data is generally lower than the mean. Significant characteristics of each constituent measured in the receiving water samples are described below:

- TSS measured at the control station, prior to the start of dumping, and at the monitoring stations are essentially indistinguishable (Figure 4.1). Variability in the natural background appears to mask any effect of the wastefield. Occasional very high values are observed and are probably artifacts of a particular sample (for example the sample serendipitously contains a larger organism or piece of natural organic or inorganic detritus). This constituent is unlikely to provide much information concerning the wastefield transport and dilution, other than to indicate that the waste is immediately highly dispersed and diluted since the median discharge values are on the order of 36000 mg/l (see discussion below and Appendix 11) and values measured in the receiving water (including at the control station) are on the order of 1 mg/l.
- TVSS is the volatile fraction of TSS and the same general comments concerning TSS apply as well to TVSS (Figure 4.2). This constituent is also unlikely to provide much information concerning the wastefield transport and dilution, other than to indicate that the waste is immediately highly dispersed and diluted. Median discharge values are on the order of 23000 mg/l (see discussion below and Appendix 11) and values measured in the receiving water (including background) are on the order of 0.5 mg/l.

- O&G is seldom detected at either the control station or at stations within the plume (Figure 4.3). Except for a few anomalous spikes (see Appendix 11), which are infrequent and likely not indicative of the behavior of the wastefield for reasons similar to those described for TSS above. O&G is nearly always not detected at the control station or in the wastefield. Therefore, this constituent is also unlikely to provide much information concerning the wastefield transport and dilution, other than to indicate that the waste is immediately highly dispersed and diluted. Median discharge values are on the order of 22000 mg/l (see discussion below and Appendix 11) and reporting limits in the receiving water samples, including background, are 1 to 0.6 mg/l.

- TP median values are shown in Figure 4.4 for the control station and the stations in the wastefield plume. This constituent illustrates what appears to be a discernible trend or difference between the control station and the wastefield stations. However, the variation is slight and this constituent is not likely to provide comprehensive information concerning the wastefield transport and dilution. TP is probably a better tracer than those constituents discussed above, particularly at the 3 and 10 meter depths. Median discharge values are on the order of 1000 mg/l (see discussion below and Appendix 11) and values measured in the receiving water (including background) are on the order of 0.03mg/l.

- TN median values, shown in Figure 4.5, for the control station and the stations in the wastefield plume illustrate a distinct trend or difference between the control station and the wastefield stations. It must be kept in mind that TN is not a conservative substance, but over the times scales considered (a few hours) TN is probably a better tracer than any of those constituents discussed above. Median discharge values are on the order of 6000 mg/l (see discussion below and Appendix 11) and values measured in the receiving water (including background) are on the order of 0.2 mg/l.

- Ammonia median values, shown in Figure 4.6, for the control station and the stations in the wastefield plume also illustrate a distinct trend or difference between the control station and the wastefield stations. Ammonia, possibly even more so than TN, is not a conservative substance, but over the times scales considered (a few hours) is probably a better tracer than any of those constituents discussed above, with the possible exception of TN. Median discharge values are on the order of 3200 mg/l (see discussion below and Appendix 11) and values measured in the receiving water (including background) are on the order of 0.03 mg/l.

Estimates of Dilution

Under the constraints described above, the monitoring data and onshore waste stream data can be used to estimate the dilution of the wastefield. The median values of the concentrations in the HSW and the receiving water were used for this purpose. The dilution was calculated using the following relationship:

$$S = (C_E - C_A)/(C_P - C_A)$$

where

S = dilution, accounting of ambient concentrations in the diluting water

C_E = concentration of a particular constituent in the HSW

C_A = concentration of the constituent in the ambient receiving water (background)

and

C_P = concentration of the constituent measured at a particular station in the plume.

Dilution is dimensionless (as a ratio) and the concentrations must all be expressed in identical units, in this case mg/l.

The dilution calculations, using the above relationship, were carried out for each constituent at each station and depth and the results of the calculations are shown in Appendix 11 and summarized in Table 4.4. The application of this relationship to the data available will not yield meaningful results if the measured ambient concentration (C_A) is equal to or greater than the measured plume concentration (C_P). In such cases the calculated dilution will be infinite or negative, respectively. For conservative substances, such results are physically meaningless, and simply indicate that the measurements are not done at a fine enough resolution to carry out the calculations. In such cases, the dilution is indicated as N/C (can not be calculated) in Appendix 11 and are not included in the summary in Table 4.4.

The values shown in Table 4.4 are averages of all dilutions calculated using all of the constituents, stations, and depths, that yielded a positive dilution. The trend between Stations 1 through 4 is relatively weak, although on average there is increasing dilution with distance from Station 1. On the other hand Station 5 dilutions are an order of magnitude higher than the other stations. Station 5 is on the leading edge (as visually determined) of the wastefield and Stations 1 through 4 are collected (as visually determined) in the center of the wastefield. The recorded latitudes and longitudes of Stations 4 and 5 were used to estimate the distance between Stations 4 and 5. The detailed calculations are given in Appendix 11 and indicate that Station 5 is approximately 0.4 nautical mile down current of Station 4.

Comparison to Model Results

Comparing the field data analyses discussed above and the model results described in Section 3 of the report is useful and provides insight concerning the validity of the model predictions. However, the field data analysis can not be used for rigorous calibration or verification for at least three reasons: [1] the field data collection was not designed to conform to the model strategy since the model tracks the plume from discharge into the farfield during and following discharge and the field data looks at the overall wastefield following discharge of all material, [2] the laboratory analyses were not, and could not be, carried out to a level of resolution adequate to accurately calibrate a model that must predict dilutions on the order of 10^6:1, [3] the natural variability of the background levels of the

constituents measured also prevents use of such data in a model predicting very high dilutions.

The comments above notwithstanding, the field data and analysis can provide a check on the reasonableness of the model predictions. The model predicted dilutions with distance from the discharge point following the initial or dumping dilution are shown in Figure 3.2 above. This figure indicates that the after discharge for a distance of up to about one nautical mile (6000 feet) the dilution in the plume will be between approximately 50,000:1 to 100,000:1. The field data, considered in summary form, as describe in Table 4.4 indicates that the dilution within the center of the final wastefield from the point of initial dumping to within 1 mile is approximately 140,000:1 to 340,000:1. When the average of all stations and depths is considered the dilution is 227,000:1. Thus, through the processes of dumping dilution, subsequent mixing in the propeller slipstream, and including the initial stages of farfield dilution, it appears that the overall prediction of the model is indeed quite conservative (by a factor of about 3:1).

Ocean monitoring Station 5 is at the "leading edge" of the overall wastefield. Where this sample is taken is very subjective and it could be actually at the leading edge of the wastefield as it moves through the dump zone or it could be within the wastefield. There is no strictly comparable model prediction for this station. Values calculated from the field data indicate dilutions that range from 360,000:1 to 6,360,000:1 (see Appendix 11) with an average of 2,800,000 (Table 4.4). As described above, this station is about 1.4 nautical miles down current of the initial starting point for disposal operations. For Station 5, the results strongly indicate, with reference to Figure 3.2, that the model is conservative by a factor of greater than 3:1 in the farfield. It is recognized that measurements from Station 5 are not conclusive because of the nature of the sampling, however, the results fully support those conclusions drawn using information from the other stations.

Table 4.1
Dates of Ocean Monitoring and Volumes Disposed
September 1993 - September 1996

DATE	VOLUME DISPOSED		
	Samoa Packing (gallons)	StarKist Samoa (gallons)	COMBINED (gallons)
10-Sep-93	120,750	190,000	310,750
27-Oct-93	85,000	100,000	185,000
17-Nov-93	151,000	150,000	301,000
10-Dec-93	78,000	80,000	158,000
21-Jan-94	109,000	150,000	259,000
9-Feb-94	67,000	80,000	147,000
9-Mar-94	152,000	140,000	292,000
26-Apr-94	159,000	129,000	288,000
23-May-94	77,000	80,000	157,000
15-Jun-94	130,000	135,000	265,000
21-Jul-94	129,000	130,000	259,000
16-Aug-94	28,300	85,000	113,300
20-Sep-94	147,000	135,000	282,000
1-Oct-94	77,000	85,000	162,000
17-Nov-94	133,000	135,000	268,000
14-Dec-94	74,000	75,000	149,000
27-Jan-95	149,000	135,000	284,000
25-Feb-95	72,000	70,000	142,000
3-Mar-95	111,000	130,000	241,000
8-Apr-95	79,000	85,000	164,000
3-May-95	70,000	125,000	195,000
28-Jun-95	79,000	75,000	154,000
7-Jul-95	139,000	105,000	244,000
1-Aug-95	69,000	130,000	199,000
14-Sep-95	68,000	156,875	224,875
19-Oct-95	101,000	106,867	207,867
15-Nov-95	65,000	110,002	175,002
19-Dec-95	142,000	187,500	329,500
15-Jan-96	87,000	67,500	154,500
7-Feb-96	139,000	166,875	305,875
13-Mar-96	141,000	169,375	310,375
23-Apr-96	142,000	119,375	261,375
2-May-96	140,000	138,750	278,750
19-Jun-96	61,600	53,125	114,725
10-Jul-96	92,700	70,625	163,325
7-Aug-96	103,850	76,250	180,100
5-Sep-96	202,200	123,125	325,325
		Maximum	329,500
		Minimum	113,300
		Average	222,990
		Median	224,875
		Standard Deviation	65,736

Table 4.2
Results of Onshore Composite (Storage Tank) Samples
September 1993 - September 1996

	TSS (mg/L)	TVSS (mg/L)	BOD5 (mg/L)	0&G (mg/L)	TP (mg/L)	TN (mg/L)	Ammonia (mg/L)	pH (SU)	Density (g/ml)
Samples from Samoa Packing Onshore Storage Tank									
No. Samples	62	62	62	61	62	62	62	60.00	62.00
Maximum	86300	72800	480000	404200	3500	19040	8400	7.39	1.03
Minimum	5390	897	11300	919	287	1960	560	5.00	0.98
Mean	22217	14125	49279	37836	1200	6539	2609	6.52	1.00
Median	16800	8770	23200	14780	1200	6160	2430	6.67	1.00
St. Dev.	16346	15464	90696	66742	616	2839	1149	0.52	0.01
Samples from StarKist Samoa Onshore Storage Tank									
No. Samples	70	70	69	70	70	70	70	70.00	70.00
Maximum	150000	131000	136750	187779	3830	14300	10800	7.13	1.04
Minimum	20400	2700	37800	3920	87	1190	282	5.40	0.94
Mean	59122	40832	78533	26103	971	5808	3977	6.57	1.00
Median	53900	36850	72289	21780	832	5560	3875	6.60	1.00
St. Dev.	24702	23284	22434	24512	654	2148	1926	0.30	0.02

Table 4.3
Ocean Monitoring Data
September 1993 - September 1996

	STATION AND DEPTH																	
	CONTROL			STATION 1			STATION 2			STATION 3			STATION 4			STATION 5		
	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)
TSS (mg/L)																		
Minmum	0.4	0.6	0.6	0.5	0.6	0.7	0.6	0.5	0.5	0.6	0.4	0.6	0.4	0.4	0.6	0.5	0.6	0.4
Maximum	6.3	18.0	8.7	7.4	14.9	8.7	9.6	9.5	8.1	7.9	8.3	8.3	14.5	7.0	9.4	6.7	9.4	6.8
Mean	1.6	1.8	2.0	1.8	2.1	1.9	1.9	1.9	2.0	1.6	1.4	1.8	2.3	1.9	1.8	1.5	1.5	1.7
Median	1.4	1.0	1.7	1.2	1.6	1.5	1.4	1.5	1.4	1.2	1.0	1.2	1.6	1.5	1.4	1.2	1.1	1.4
Std. Dev.	1.0	2.8	1.5	1.5	2.4	1.6	1.7	1.6	1.8	1.4	1.4	1.4	2.6	1.4	1.6	1.1	1.4	1.2
No. of Samples	37	37	37	37	37	36	37	37	37	36	37	35	37	36	37	37	37	37
TVSS (mg/L)																		
Minmum	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.2	0.1
Maximum	1.4	1.3	2.9	1.3	2.4	1.9	3.5	1.9	1.6	1.3	1.4	1.8	2.7	2.6	1.5	1.4	1.2	2.5
Mean	0.5	0.4	0.7	0.6	0.7	0.7	0.7	0.6	0.6	0.5	0.5	0.6	0.6	0.6	0.5	0.4	0.5	0.6
Median	0.4	0.4	0.6	0.5	0.5	0.6	0.5	0.6	0.6	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Std. Dev.	0.3	0.2	0.5	0.4	0.5	0.4	0.6	0.4	0.4	0.3	0.3	0.4	0.5	0.5	0.3	0.3	0.2	0.4
No. of Samples	36	35	36	36	36	35	36	36	37	35	36	34	35	35	36	36	36	36
O&G (mg/L)																		
Minmum	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Maximum	1.00	1.00	1.12	1.00	1.60	1.28	1.28	1.00	1.79	1.00	1.00	1.00	1.00	1.00	3.20	1.08	1.00	1.00
Mean	0.64	0.64	0.65	0.65	0.67	0.66	0.66	0.64	0.69	0.64	0.64	0.63	0.64	0.64	0.71	0.66	0.64	0.64
Median	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Std. Dev.	0.11	0.11	0.13	0.12	0.19	0.15	0.15	0.11	0.25	0.11	0.11	0.09	0.11	0.11	0.43	0.14	0.11	0.11
No. of Samples	37	37	37	37	37	36	37	37	37	37	37	36	34	36	37	37	37	37
OCEAN MONITORING DATA FOR TOTAL PHOSPHOROUS (mg-P/L)																		
Minmum	0.009	0.012	0.008	0.014	0.013	0.009	0.012	0.006	0.005	0.009	0.005	0.012	0.012	0.006	0.006	0.006	0.007	0.006
Maximum	0.520	0.114	0.093	0.239	0.571	0.096	0.125	0.240	0.571	0.078	0.057	0.213	0.390	0.243	0.115	0.239	0.059	0.079
Mean	0.054	0.029	0.032	0.039	0.047	0.037	0.038	0.044	0.050	0.031	0.027	0.034	0.052	0.040	0.034	0.044	0.028	0.028
Median	0.030	0.024	0.026	0.029	0.030	0.033	0.031	0.029	0.034	0.029	0.024	0.028	0.028	0.030	0.029	0.028	0.026	0.024
Std. Dev.	0.090	0.019	0.019	0.040	0.090	0.017	0.027	0.046	0.090	0.016	0.012	0.033	0.078	0.041	0.021	0.048	0.013	0.015
No. of Samples	37	37	37	37	37	37	37	37	37	37	37	37	37	37	36	37	37	37
TOTAL NITROGEN (mg-N/L)																		
Minmum	0.033	0.106	0.090	0.116	0.097	0.094	0.106	0.108	0.076	0.088	0.088	0.115	0.102	0.105	0.098	0.090	0.102	0.102
Maximum	0.568	0.356	0.771	0.785	0.618	0.712	0.590	0.612	0.659	0.492	0.518	0.970	0.860	0.640	0.418	0.945	0.345	0.422
Mean	0.178	0.172	0.229	0.268	0.245	0.269	0.227	0.222	0.237	0.196	0.200	0.245	0.223	0.206	0.193	0.187	0.167	0.176
Median	0.151	0.151	0.187	0.232	0.206	0.239	0.181	0.190	0.187	0.180	0.177	0.183	0.183	0.179	0.174	0.148	0.149	0.150
Std. Dev.	0.091	0.064	0.157	0.154	0.123	0.133	0.115	0.116	0.134	0.087	0.097	0.175	0.140	0.100	0.076	0.150	0.057	0.072
No. of Samples	36	37	37	37	37	37	37	37	37	37	37	37	37	37	36	37	37	37
AMMONIA (mg-N/L)																		
Minmum	0.001	0.003	0.001	0.005	0.004	0.005	0.003	0.003	0.001	0.004	0.005	0.004	0.005	0.003	0.003	0.002	0.003	0.004
Maximum	0.250	0.093	0.199	0.147	0.182	0.164	0.191	0.132	0.127	0.134	0.139	0.140	0.118	0.135	0.202	0.260	0.105	0.197
Mean	0.026	0.015	0.024	0.051	0.053	0.051	0.045	0.043	0.046	0.038	0.039	0.042	0.036	0.038	0.043	0.028	0.019	0.029
Median	0.013	0.012	0.014	0.035	0.038	0.034	0.028	0.033	0.039	0.025	0.037	0.032	0.028	0.026	0.029	0.015	0.012	0.014
Std. Dev.	0.044	0.015	0.036	0.045	0.049	0.042	0.045	0.037	0.037	0.034	0.029	0.035	0.032	0.035	0.051	0.044	0.022	0.039
No. of Samples	37	37	36	36	37	36	36	36	36	37	37	37	37	37	36	36	36	37

Table 4.4
Average Dilutions Calculated from Ocean Monitoring Data

	Depth			
Calculated Dilutions at:	**1 m**	**3 m**	**10 m**	**Average**
Station 1 @ 0.0 nmiles	227,928	138,122	137,233	167,761
Station 2 @ 0.25 nmiles	214,950	139,169	126,650	160,256
Station 3 @ 0.5 nmiles	231,674	176,086	338,072	248,611
Station 4 @ 1.0 nmiles	201,548	171,089	307,717	226,785
Average Stations 1-4	219,025	156,116	227,418	200,853
Station 5 - Leading Edge	1,590,694	432,544	6,362,773	2,795,337

Figure 4.1
Median Values of TSS from Ocean Monitoring

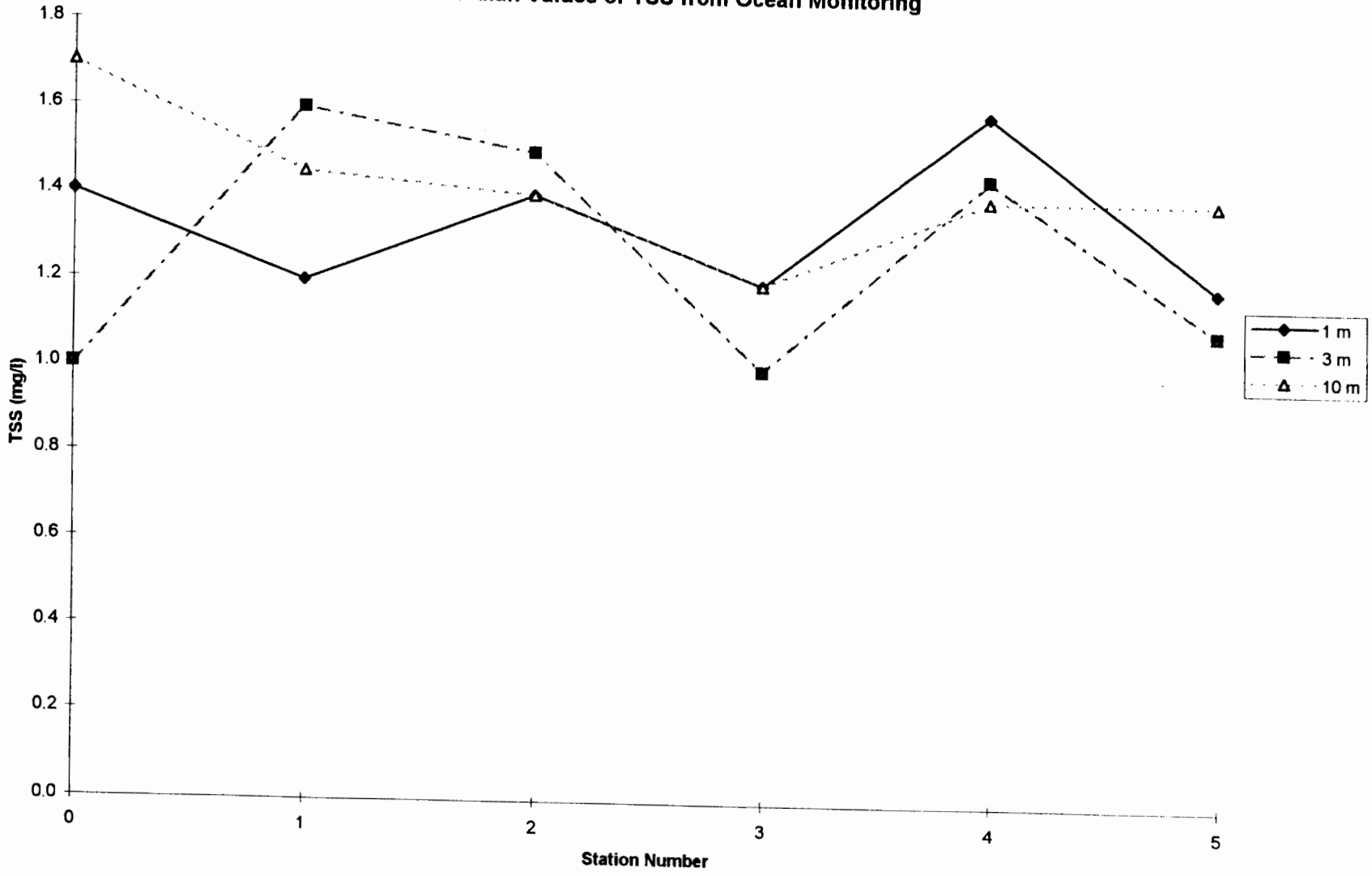


Figure 4.2
Median Values of TVSS from Ocean Monitoring

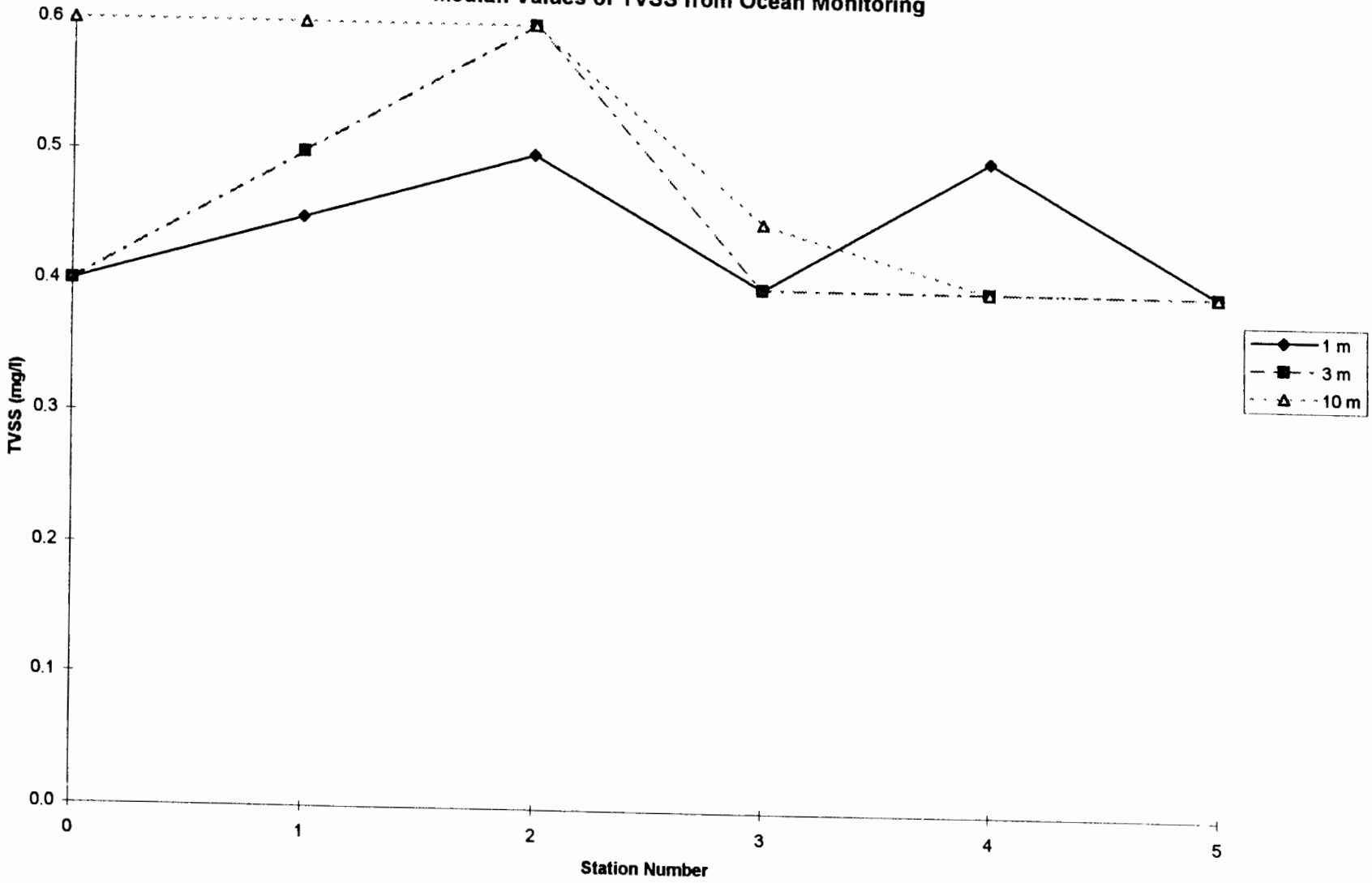


Figure 4.3
Median Values of O&G from Ocean Monitoring

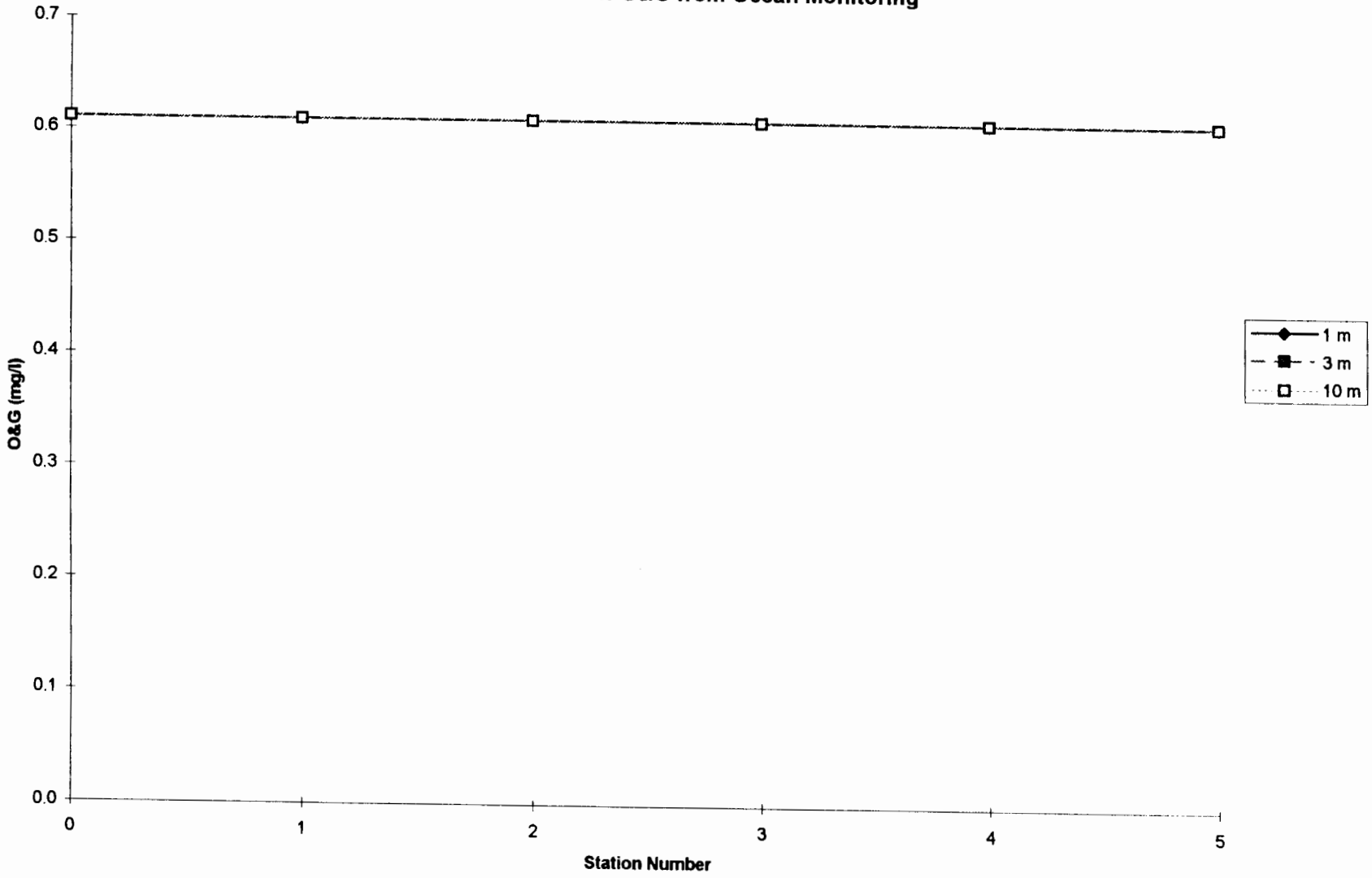


Figure 4.4
Median Values of Total Phosphorus from Ocean Monitoring

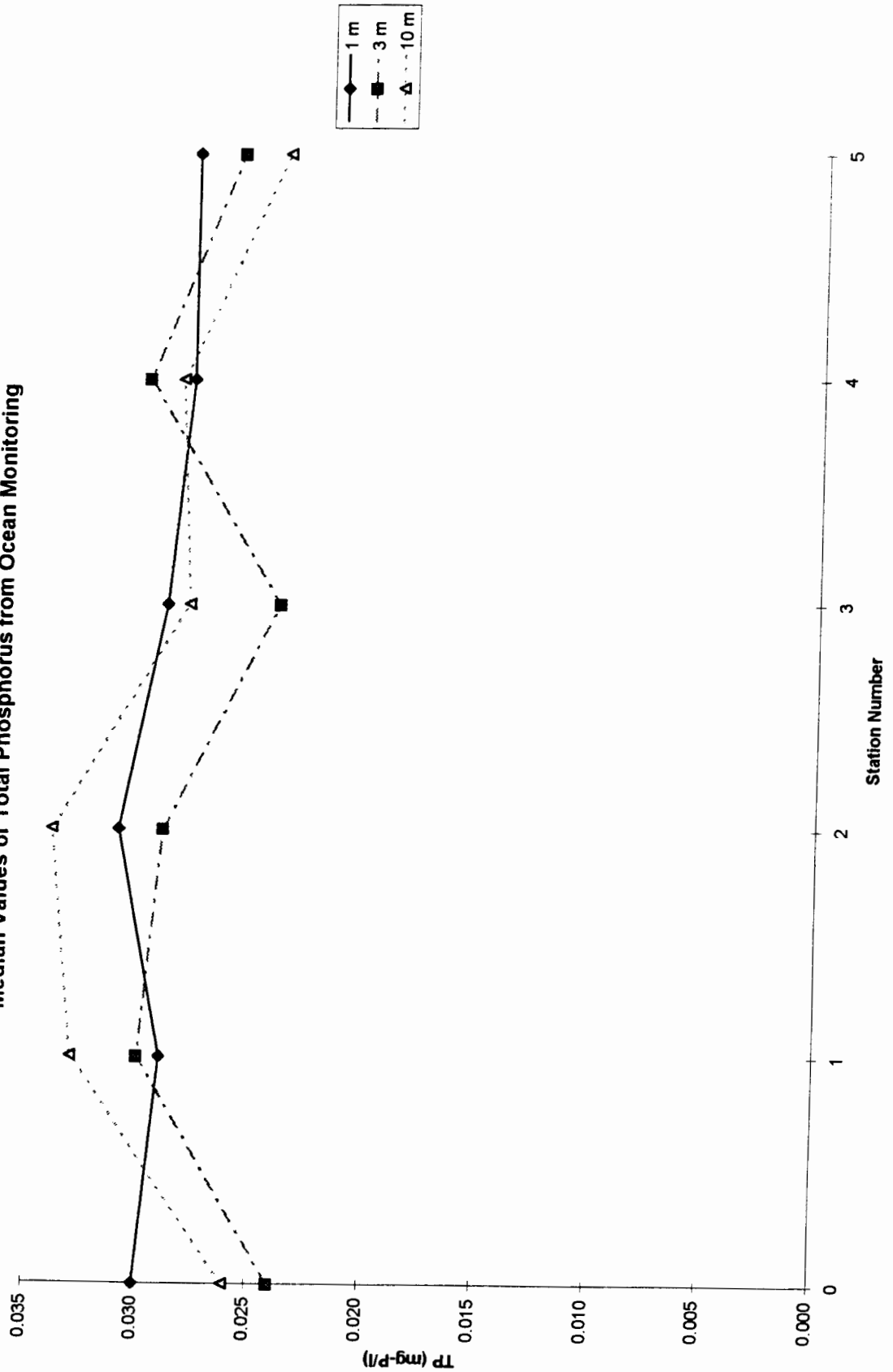


Figure 4.5
Median Values of Total Nitrogen from Ocean Monitoring

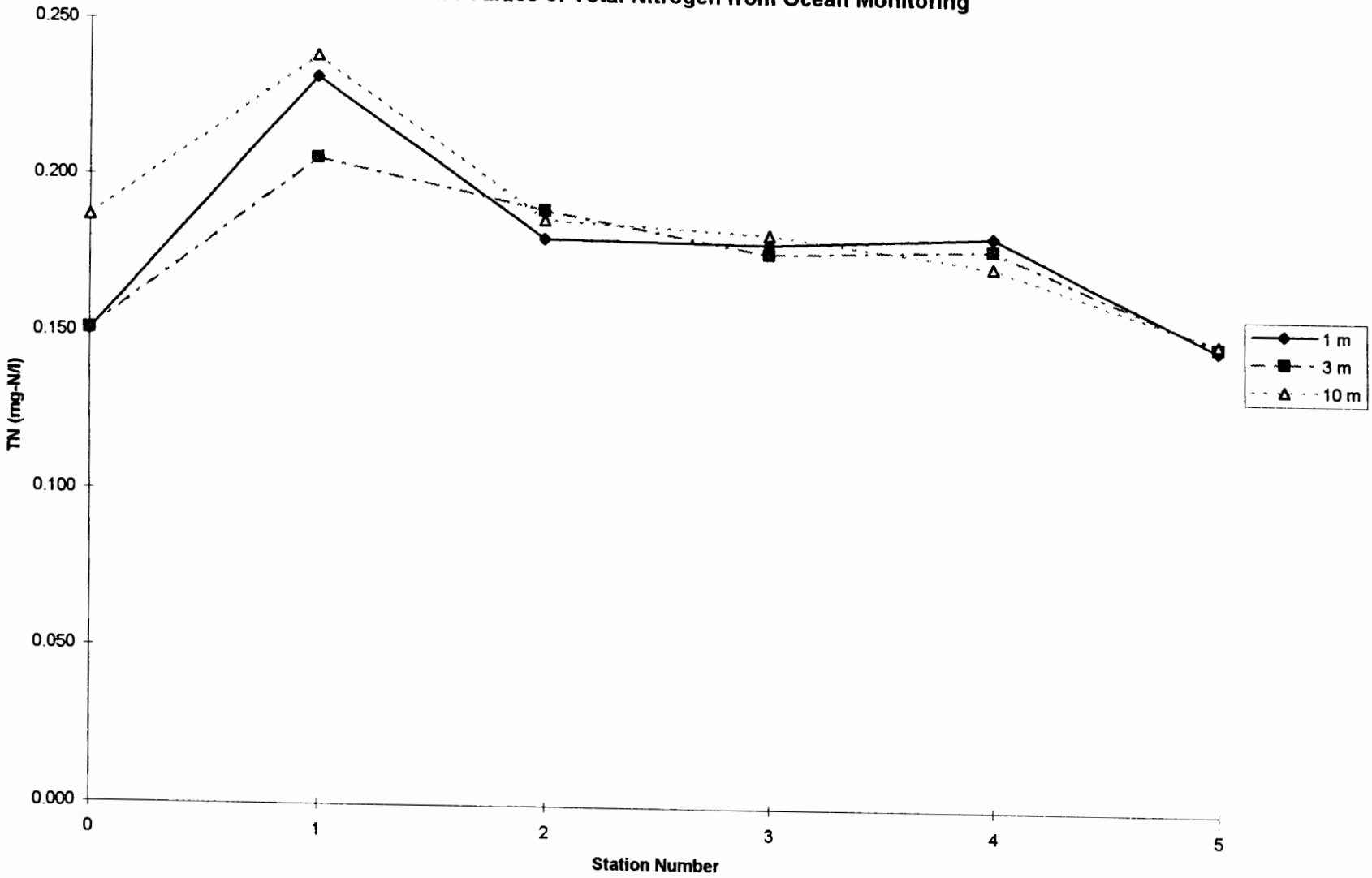
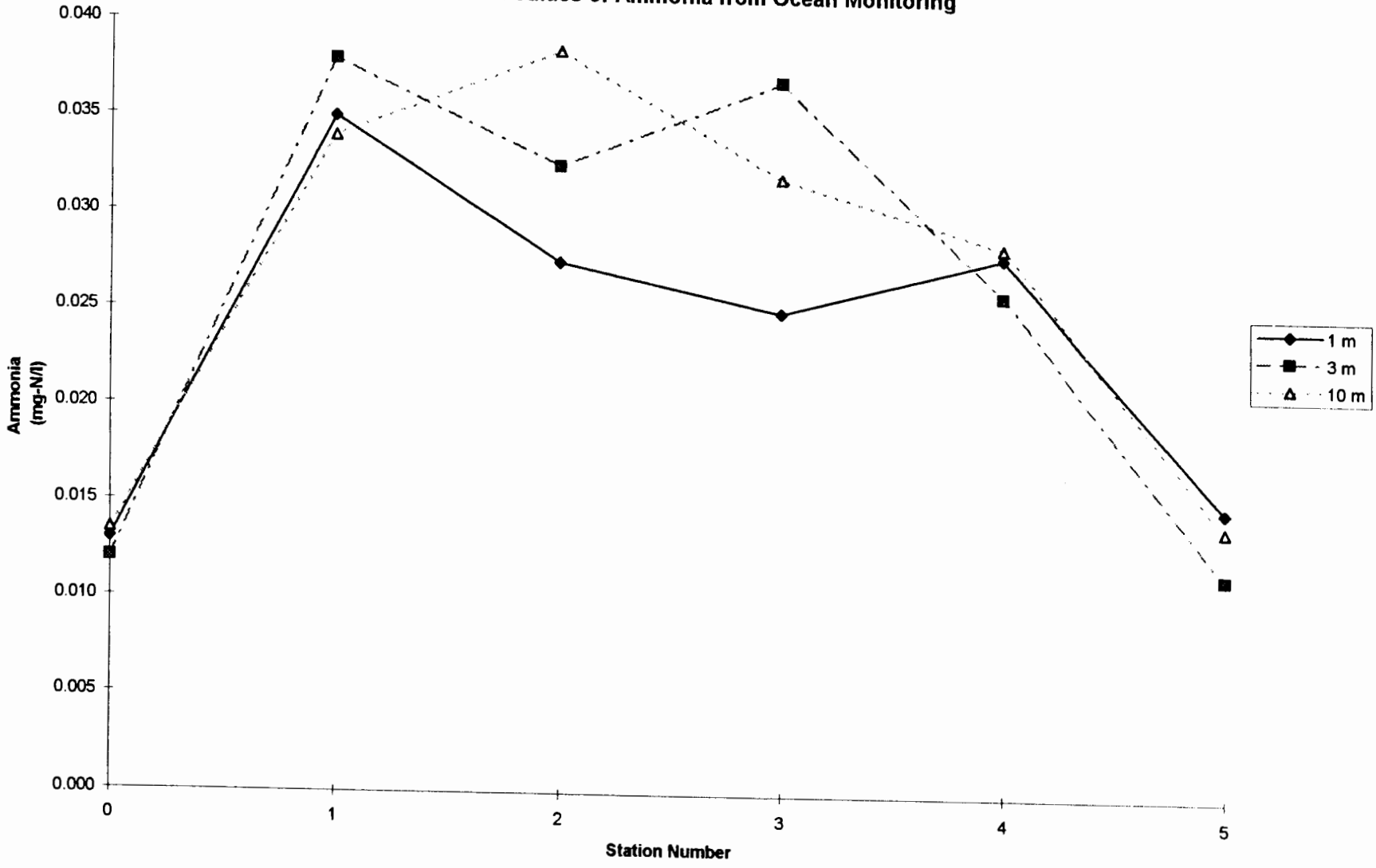


Figure 4.6
Median Values of Ammonia from Ocean Monitoring



5. Conclusions and Recommendations

This section presents the overall conclusions drawn from the model predictions, the model limitations, and recommendations based on the results of the study.

Conclusions

Table 5.1 shows the prediction of total dilution and final concentration prior to the point where the plume reaches the edge of the dumping zone (taken as 2.5 nautical miles down current). In the table, C/C_0 is the ratio of final to initial concentration and can be applied to calculate the concentration of any known constituent in the waste. The final concentration is also given in terms of an approximate value for the whole waste in mg/l, assuming the waste is about the density of water. At the edge of the dump zone the maximum predicted concentration of the waste is diluted to about 0.00025 percent HSW (Table 5.1: summer, ocean current 0.8 knots, vessel speed 10 knots). Reference to Table 3.1 shows that the lowest LC50 of all bioassays conducted was 0.12 percent HSW. Therefore, the concentration at the edge of the permitted dumping zone is 0.0021·LC50.

Table 5.2 shows the same information described above for the plume prior to reaching the shoreline (taken as 5 nautical miles down current). The model was formulated and implemented in a conservative fashion and the dilutions are expected to be underpredicted (concentrations over predicted). Available monitoring data indicates that the dilutions predicted by the model in the farfield (approximately 1.4 nautical miles from the dump zone) are in fact under predicted by a substantial degree.

Limitations

Most numerical models of the type used here contain coefficients (e.g. friction factors, diffusion coefficients) that are often study site specific. Although there are generally accepted values for these coefficients, the range observed in nature is high and the models can be somewhat sensitive to the values selected. The process of calibration and verification generally uses measured values of forcing functions and responses to determine the appropriate coefficients for the model configuration at the study site. Typically a set of field data is used to determine the correct values to use for the coefficients. However, there is little or no available and appropriate data for formal model verification. In this case the model sensitivity determination, the use and justification of reasonable values from the literature and similar studies, and the incorporation of a prudent level of conservatism is required and was accomplished. The available monitoring data were examined and evaluated and confirm the conclusions drawn from the model predictions.

Recommendations

CH2M HILL project staff, on the basis of the results of the study, have no recommendations for additional studies of this type.

Table 5.1
Predicted Dilution and Concentration at the Down Current Edge of the Ocean Dumping Zone (at 2.5 Nautical Miles)

Season	Ocean Current (knots)	Vessel Speed (knots)	Loading (gpm)	Dumping Dilution Sd	Nearfield Dilution Sn	Farfield Dilution Sf	Total Dilution St	Final Concentration 1/(St)	Final Concentration (mg/l)
Winter	0.4	6	840	796.2	41.5	29.6	978,052	0.000001022	1.022
Winter	0.4	10	1400	731.4	41.5	17.9	543,320	0.000001841	1.841
Winter	0.8	6	840	796.2	41.5	27.6	911,967	0.000001097	1.097
Winter	0.8	10	1400	731.4	41.5	16.6	503,861	0.000001985	1.985
Summer	0.4	6	720	931.6	41.5	20.0	773,190	0.000001293	1.293
Summer	0.4	10	1200	855.7	41.5	12.1	429,709	0.000002327	2.327
Summer	0.8	6	720	931.6	41.5	18.6	719,067	0.000001391	1.391
Summer	0.8	10	1200	855.7	41.5	11.2	397,747	0.000002514	2.514

Note: St=Sd*Sn*Sf

Table 5.2
Predicted Dilution and Concentration near the Closest Reefline or Shoreline (at 5 nautical miles)

Season	Ocean Current (knots)	Vessel Speed (knots)	Loading (gpm)	Dumping Dilution Sd	Nearfield Dilution Sn	Farfield Dilution Sf	Total Dilution St	Final Concentration 1/(St)	Final Concentration (mg/l)
Winter	0.4	6	840	796.2	41.5	76.6	2,531,040	0.000000395	0.395
Winter	0.4	10	1400	731.4	41.5	46.1	1,399,278	0.000000715	0.715
Winter	0.8	6	840	796.2	41.5	59.1	1,952,800	0.000000512	0.512
Winter	0.8	10	1400	731.4	41.5	35.5	1,077,535	0.000000928	0.928
Summer	0.4	6	720	931.6	41.5	51.5	1,990,964	0.000000502	0.502
Summer	0.4	10	1200	855.7	41.5	31.1	1,104,458	0.000000905	0.905
Summer	0.8	6	720	931.6	41.5	39.7	1,534,782	0.000000652	0.652
Summer	0.8	10	1200	855.7	41.5	23.9	848,764	0.000001178	1.178

Note: St=Sd*Sn*Sf

6. References

American Society for Testing and Materials, ASTM. 1992. Standard Practice for Conducting Static Acute Toxicity Tests with Embryos/Larvae of Four Species of Saltwater Bivalve Molluscs. Designation E724-92. Annual Book of Standards, Vol:11.04. ASTM, Philadelphia, PA.

Baumgartner, D.J., W.E. Frick, and P.J.W. Roberts, 1993. Dilution Modeling for Effluent Discharges (Second Edition). Office of Research and Development, U.S. Environmental Protection Agency, EPA/600/R-93/139. July 1993.

Brooks, N.H., 1960. "Diffusion of Sewage Effluent in an Ocean Current," Proceedings of the First Conference on Waste Disposal in Marine Environment, Pergamon Press, NY.

CH2M HILL, 1995a. Bioassay Testing of High Strength Waste: StarKist Samoa, Inc. and VCS Samoa Packing. Memorandum from Steve Costa/CH2M HILL to Pat Young/USEPA, 26 January 1995.

CH2M HILL, 1995b. Bioassay Testing of High Strength Waste: StarKist Samoa, Inc. and VCS Samoa Packing (23 June 1995 Sampling). Memorandum from Steve Costa/CH2M HILL to Pat Young/USEPA, 7 August 1995.

CH2M HILL, 1995c. Summary of Ocean Dumping Modeling Results: StarKist Samoa, Inc. and VCS Samoa Packing. Memorandum from Steve Costa/CH2M HILL to Pat Young/USEPA, 7 August 1995.

CH2M HILL, 1994. Bioassay Testing of StarKist Samoa, Inc. and VCS Samoa Packing High Strength Waste. Memorandum form Steve Costa/CH2M HILL to Pat Young/USEPA, 1 July 1994.

CH2M HILL, 1993. Draft Study Plan for Joint Cannery Ocean Dumping Studies in American Samoa. Prepared for StarKist Samoa and VCS Samoa Packing, 11 November 1993.

Fischer, H.B. et al., 1979. Mixing in Inland and Coastal Waters. Academic Press, New York.

Grace, R.A., 1978. Marine Outfall Systems: Planning, Design, and Construction. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Liou, Y.-C. and J.B. Herbich, 1976. Sediment Movement Induced by Ships in Restricted Waterways. Texas A&M University, Sea Grant Report TAMU-SG-76-209. August, 1976.

Sobey, Rodney, 1994. CE 105 Environmental Fluid Mechanics Course Notes, Fall Semester 1994, University of California at Berkeley.

SOS Environmental, Inc. and Environmental & Ocean Technology, Inc., 1990. Mathematical/Computer Modeling for Fish Waste Disposal at an Ocean Disposal Site off Tutuila Island, American Samoa. March 1990.

Soule, D.F. and M. Oguri, 1983. A Report on Ocean Disposal of Fish Processing Wastes off Pago Pago, American Samoa. Prepared for EPA Region 9 and NOAA for StarKist Foods and Ralston Purina. June 1983.

United States Environmental Protection Agency, Region 9. 1993 -1996. Ocean Dumping Discharge Monitoring Reports and Dumpsite Monitoring Reports prepared and submitted by StarKist Samoa and VCS Samoa Packing.

United States Environmental Protection Agency. 1991. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. Fourth Edition. EPA/600/4-90/027. September 1991. 293 pp.

United States Environmental Protection Agency, United States Army Corps of Engineers. 1991. Evaluation of Dredged Material Proposed for Ocean Disposal: Testing Manual. EPA-503/8-91/001. February, 1991.

U.S. Environmental Protection Agency, Region 9, 1989. Final Environmental Impact Statement for the Designation of an Ocean Disposal Site off Tutuila Island, American Samoa for Fish Processing Wastes. San Francisco, CA, 3 February 1989.

Yearsley, J.R., 1989. "Diffusion in Near-shore and Riverine Environments," EPA 910/9-87-168. EPA Region 10, Seattle, Washington.

Appendix 1
Special Condition 3.3.5 of
Ocean Dumping Permits

3.3.5. Eighteen months from the effective date of this special permit, the permittee shall submit a report to EPA and ASEPA on the results of suspended phase bioassay tests and reevaluation of the model used to predict the concentrations of fish processing wastes disposed at the designated site. The suspended phase bioassays shall be conducted using at least one species from each of the following three groups: Group 1 = *Mytilus* sp. (mussel), *Crassostrea* sp. (oyster), *Acartia tonsa* (copepod), or *Trypneustes* sp. (sea urchin) larvae; Group 2 = *Holmesimysis costata* (mysid shrimp) or *Penaeus vannamei* (white shrimp); and Group 3 = *Citharicthys stigmaeus* (speckled sanddab) or *Coryphaena hippurus* (dolphinfish) juveniles.

Appropriate suspended phase bioassay protocols, either protocols approved by EPA or protocols published by the American Society for Testing and Materials (ASTM), shall be followed. Suspended particulate phase bioassays shall be run using the following fish processing waste concentrations: 100%, 75%, 50%, 25%, 10%, 5%, and a control (0%). A minimum of five replicates are required per dilution concentration. Concurrent reference toxicant tests shall be conducted when the suspended phase bioassays are run.

A sampling and testing plan shall be submitted to EPA Region IX and ASEPA by October 1, 1993 for approval before the bioassay tests are conducted. Samples for the suspended particulate phase bioassays shall be composited from the permittee's onshore storage tanks. Three samples shall be taken from the onshore storage tank transfer line at 10 minute intervals. These samples shall be composited to produce one sample for analysis. The permittee's samples shall not be combined with fish processing waste from any other permittee. The permittee shall take samples on the following dates: November 30, 1993, February 28, 1994 and May 31, 1994. Samples shall be collected and shipped to the testing laboratory according to EPA-approved methods to

ensure that the samples do not change before the bioassay tests begin. All suspended particulate phase bioassays shall be started within 10 days of sampling.

The testing plan submitted by October 1, 1993 should also include a proposal to reevaluate the disposal site model using results obtained from the new series of suspended phase bioassays. These bioassays are being required to confirm the toxicity of the fish processing wastes and to reevaluate the disposal operations based on the use of a different disposal vessel.

The bioassay and computer model confirmation report shall contain the following information:

3.3.5.1. INTRODUCTION AND PROJECT DESCRIPTION

The project description should include the following information about fish processing waste toxicity, previous bioassay test results, previous modelling at the ocean disposal site, and the design of the new bioassay tests.

3.3.5.2. MATERIALS AND METHODS

Fish processing waste sampling and sample handling procedures should be described or referenced.

References for laboratory protocols for suspended phase bioassay tests.

1) EPA-approved methods and references.

2) Test species used in each test, the supplier or collection site for each test species, and QA/QC procedures for maintaining the test species.

3) Source of seawater used in reference, control and bioassay tests.

4) Data and statistical analysis procedures.

5) Limiting Permissible Concentration (LPC) calculations.

6) Description of model selected to evaluate dispersal of fish processing wastes at the ocean disposal site. Use of this model shall be approved by EPA Region IX and ASEPA before it is used by the permittee to evaluate the fish processing waste disposal plume.

3.3.5.3. DESCRIPTION OF SAMPLING PROCEDURES

QA/QC procedures and actual sampling procedures used during fish processing waste stream sampling and handling of the samples.

3.3.5.4. FINAL RESULTS, ANALYSIS OF DATA AND DISCUSSION

1) Complete bioassay data tables and summary bioassay tables shall be furnished in the report. All data tables should be typed or produced as a computer printout.

2) The permittee shall analyze the bioassay data and calculate the LPC of the material as defined at 40 C.F.R. § 227.27(a-b).

3) The permittee shall use the LPC in the approved plume model to determine the concentration of fish processing wastes disposed at the designated ocean disposal site which complies with EPA's Ocean Dumping Criteria defined at 40 C.F.R. Parts 227 and 228.

3.3.5.5. REFERENCES

This list should include all references used in the field sampling program, laboratory protocols, LPC calculations, modelling analyses, and historical data used to evaluate the fish processing waste disposal operations at the designated ocean disposal site.

3.3.5.6. DETAILED QA/QC PLANS AND INFORMATION

The following topics should be addressed in the QA Plan:

1) QA objectives.

2) Organization, responsibilities and personnel qualifications, internal quality control checks.

3) Sampling and analytical procedures.

4) Equipment calibration and maintenance.

5) Sample custody and tracking.

6) documentation, data reduction, and reporting.

7) Data validation.

8) Performance and systems audits.

9) Corrective action.

10) Reports.

Appendix 2
Study Plan (Draft and Incorporated EPA Comments)

DRAFT STUDY PLAN

FOR

JOINT CANNERY OCEAN DUMPING STUDIES

IN

AMERICAN SAMOA

Prepared for

StarKist Samoa
(Permit OD 93-01 Special)

and

VCS Samoa Packing
(Permit OD 93-02 Special)

Prepared by

CH2M HILL

11 November 1993

STUDY PLAN
FOR
JOINT CANNERY OCEAN DUMPING STUDIES
IN
AMERICAN SAMOA

Special ocean dumping permits have been issued to StarKist Samoa, Inc. and VCS Samoa Packing, Inc. because the Regional Administrator of EPA Region IX has determined that disposal of fish processing wastes off American Samoa meets EPA's ocean dumping criteria at 40 CFR Parts 227 and 228. Special condition 3.3.5 of both permits requires bioassay testing of the waste from each cannery and a re-evaluation of the model previously used to predict concentrations of fish processing wastes disposed of at the designated site. A copy of this special condition is provided in Appendix 1 of the study plan.

The special permit condition addresses two distinct efforts: bioassay testing and model re-evaluation. Although the results of the bioassay testing will be used in the final steps of the model re-evaluation, the two parts of the study are quite different and are best described independently. Therefore, this study plan is presented in two parts:

- Part I: Plan of Study for Bioassay Toxicity Tests
- Part II: Plan of Study for Modeling Re-evaluation

The two portions of the study will be conducted independently except as noted above. References are provided separately for part of the study plan. Additional information is provided in Appendices.

Part I

PLAN OF STUDY FOR BIOASSAY TOXICITY TESTS

INTRODUCTION

Under special conditions 3.3.5 of the Ocean Disposal Dumping Permits, StarKist Samoa and VCS Samoa Packing are required to conduct and submit the results of toxicity tests on fish processing wastes generated at the permittees' American Samoa packing plants. The toxicity tests are to be initiated within 10 days following sampling on November 30, 1993, February 28, 1994, and May 31, 1994. The wastes to be tested include DAF sludge and other high strength waste streams that are barged to sea for disposal at the permitted dump site. This part of the study plan describes the methods proposed to conduct the bioassay tests. The results of the tests will also be incorporated into the modeling re-evaluation described below in Part II of the study plan.

General guidance for these tests is provided by USEPA (1991), ASTM (1992), and the EPA/COE "Green Book" (1991). Specific guidance for performing biological-effects tests for Ocean Disposal permits are outlined in Part III, Section 11 of the Green Book; *Evaluation of Dredged Material Proposed for Ocean Disposal: Testing Manual* (EPA and COE, 1991). However, the fish processing wastes to be disposed under this permits are not similar to solid dredged materials. The high strength waste materials are mostly liquid phase wastes which are positively to neutrally buoyant with a small fraction of negatively buoyant solid particles. This waste is not expected to behave in a fashion typical of solid, generally negatively buoyant, dredge spoil material when disposed of by dumping at sea. Therefore, the physical and chemical nature of the wastes requires modifications to the suspended bioassay tests as outlined in the Green Book.

The following Methods sections include the specific modifications required to properly evaluate the toxicity of the tuna cannery high strength wastes. A description of the proposed reporting schedule and format for the bioassay test results is provided in the Reports section.

SAMPLING METHODS

Sample Composition

High strength waste samples will be collected at each cannery from the existing sampling ports in the storage tank transfer lines. Three samples will be taken at 10 minute intervals while waste is being transferred from the storage tanks to the barge. Samples for the

bioassay tests will be composited from the three discrete samples. Waste from each cannery will be collected and shipped separately and shall not be combined.

Sampling Times

Sampling will be conducted on the following days, if possible:

- Tuesday, November 30, 1993
- Monday, February 28, 1994
- Tuesday, May 31, 1994

If a cannery is shut down, or material is not being transferred to the barge on that day, sampling will be done at the first available time.

Sample Shipping and Handling

EPA approved chain-of custody, sample shipping and handling, and record keeping will be conducted to preserve and monitor the integrity of the samples used for the required bioassays. Samples will be cooled at the canneries after collection and then packed in ice for shipment. The permit requires tests will be initiated within 10 days of sample collection. There are significant and well recognized problems with shipment of material from American Samoa. Every reasonable effort will be made to meed the required 10-day maximum holding time. If the holding times are exceeded for some reason, EPA Region IX will be contacted to determine if the tests should be initiated or if new samples should be collected and shipped.

TEST METHODS

Selected Species

The permit condition requires testing of three species selected from three groups listed in section 3.3.5 of the permit. We propose tests be conducted with the pacific mysid shrimp (*Holmesimysis costata*) juveniles, pacific sanddab (*Citharicthys stigmaeus*) juveniles, and purple sea urchin (*Strongylocentrotus purpuratus*) larvae. These species and life stages were chosen because they represent sensitive crustacean, fish, and zooplankton components of the marine community, tolerate laboratory conditions, and can be readily tested as young life-stages. These species are also routinely used in conducting bioassays for the ocean disposal

permit program. Of great importance are the practicality and year-round availability of the appropriate life-stages of all three of the above species.

The shrimp and fish species were selected from the lists (Group 2 and Group 3, respectively) specified in the permit special condition. The sea urchin species (*Strongylocentrotus purpuratus*) was not listed in the permit (Group 1). We have recommended a different species because it is important that the same species and life-stages be used for each test series conducted. Three test series of bioassays will be conducted over approximately 9 months. The rationale for recommending a different species is as follows:

- The mollusc species listed in Group 1 (*Mytilus* sp. and *Crassostrea* sp.) and the copepod (*Acartia tonsa)* are potentially difficult to obtain at the appropriate life stage at all of the times specified in the permit condition.

- Therefore, sea urchin larvae, also listed in Group 1, are proposed for these tests instead of mollusc or copepod because of their availability at all times of the year.

- However, the sea urchin specifically listed (*Trypneustes* sp.) is not readily available and may be difficult to obtain, particularly at the specific times as required in the permit and an alternate sea urchin species (*Strongylocentrotus purpuratus*) is recommended.

With a limited number of opportunities to evaluate the toxicity of the material to be disposed, it is important to compare the results of bioassay tests using the same species and life-stages.

If necessary, *Mytilus* sp. (mussels) will be used as a backup species to the sea urchin and white shrimp (*Paneaus vannamai*) will be used as a back-up test species for the mysid shrimp should the primary test species be unavailable at the time of the bioassays. All reasonable efforts will be made to consistently use the primary test species.

Acclimation and Holding

All test organisms will be brought into the laboratory and gently acclimated to test conditions and control water (dilution water) for a minimum of 24 hours prior to test initiation. Salinity, temperature, and dissolved oxygen conditions during test organism holding and acclimation will be monitored to ensure proper acclimation is obtained prior to starting the bioassay tests.

Sample Preparation

Properly refrigerated wastewater samples will brought up to test temperature prior to further test solution preparation. If the salinity of the waste solution is greater than 2 grams per liter less than that of the disposal site receiving water, salinity of the test waste solution will be adjusted with anhydrous sea salts up to the receiving water salinity. Time will be allowed for waste solution pH and salinity equilibration prior to bioassay initiation. Similarly, test control water will be adjusted to appropriate test salinity prior to test initiation.

Initial dissolved oxygen demand (IDOD) has been determined to be a problem with cannery effluent and high strength waste streams. Preliminary IDOD measurements were done at the canneries in October of 1993. The results are given in Appendix 2 of the study plan. IDOD determinations will be conducted and recorded for the samples prior to the start of the bioassays. The results of these IDOD measurements will be used to determine sample dissolved oxygen (DO) conditions and aeration procedures required for the bioassays.

Experimental Conditions

Serial dilutions using filtered natural seawater obtained from the Bodega Bay Marine Laboratory, California will be prepared by volumetric addition of diluent and high strength waste effluents from each cannery. Glass graduated cylinders and other non-contaminating labware will be used to prepare the test solutions. The permit condition requires dilutions of 100, 75, 50, 25, 10, and 5% waste concentrations, as well as a control. Based on previous bioassay results for both the high strength wastes and the joint cannery effluent discharged through the outfall, we recommend that the dilutions used be concentrations of 50, 25, 10, 5, 2.5, 1.25, 0.62, and 0.31 % waste. Control water consisting of diluent water only will also be tested. Five replicate test vessels will be prepared for each test solution and control.

Test vessels will be maintained in controlled temperature incubators or water baths and allowed to acclimate to test conditions prior to the test initiation. Temperature, salinity, pH, ammonia and DO will be measured prior to test organism assignment into the test vessels. If DO concentrations are less than 40-percent of saturation or less than 4 mg/liter in any test solution or control, aeration will be initiated sufficient to maintain adequate DO levels in all test vessels and in all test concentrations (and controls) to maintain DO concentrations at a levels sufficient to support the organisms. Test photoperiod will be controlled by automatic timers to ensure adequate light for the bioassays.

Test temperatures for the fish, crustacean, and sea urchin bioassays will be 15, 15 and 18 degrees celsius respectively. Salinity for these tests will be that of the receiving water at the disposal site. Test organisms will be randomly assigned into the test vessels. Test vessels will be covered with loose fitting glass or non-contaminating covers and placed into the temperature controlled incubators.

The bioassays will be conducted for 96 hours (4 days). Daily observations to enumerate live fish and mysids and to monitor water quality parameters will be conducted throughout the bioassays. Equal volumes of food will be added to only the mysids to reduce cannibalization of this species within the test vessels.

The effect measured in the fish and mysid bioassays is mortality as defined as: no observed movement exhibited by the test organism after gentle swirling of the test container or probing. The test endpoint for the sea urchin larvae bioassay is mortality and/or larval abnormality as compared to the control organisms.

QUALITY CONTROL AND QUALITY ASSURANCE

The quality assurance objective is to characterize the potential toxicity of each of the canneries high strength waste to marine organisms by collecting bioassay test data of known and acceptable quality. The qualifications of the laboratory and personnel conducting the tests is provided in Appendix 3. The procedures described in the Test Methods section above describe the QA/QC procedures for sampling, analytical procedures, equipment calibration, sample custody, and data reduction and analysis.

Mortality in the controls of less than 10-percent in the fish and crustacean tests and 30-percent in the sea urchin tests after 96 hours will indicate successful tests. If these criteria are not met then EPA will be consulted to determine whether additional tests should be considered. Concurrent reference toxicant tests with the fish and mysid test species will be conducted using sodium chloride and reference toxicant tests with the sea urchin will use copper sulfate solutions with test concentrations bracketing the known acute toxic concentration (LC50) for each species tested. These tests will be conducted for a 24 hour duration. If the concurrent reference toxicant test LC50 falls within ± 2 standard deviations of the testing laboratory's cumulative sum LC50 for that species the tests will be considered acceptable.

DATA ANALYSIS AND REPORTING

Test data analysis and calculations

Acute mortality and/or larval abnormality data will be used to calculate an acute median lethal (LC50) or effect (EC50) concentration. A computer program (TOXDAT) will facilitate the calculation of the 96 hour LC50 (or EC50 for the zooplankton tests) by either: Probit, Spearman-Karber, or the Trimmed Spearmean-Karber Methods. The analysis used will depend on the distribution of the mortality data obtained from these toxicity tests. These LC50 or EC50 values will then be used to calculate Limiting Permissible Concentrations (LPC's).

Reports

A report of the results of the bioassay tests will be prepared following each of the tests. The report format will be as described in the permit conditions (Sections 3.3.5.1 through 3.3.5.5). Specific information including bioassay materials and methods, sampling procedures, results, data analysis, and discussion will be included in the report. General guidance for the bioassay reports will be that of EPA (1991).

REFERENCES

American Society for Testing and Materials, ASTM. 1992. Standard Practice for Conducting Static Acute Toxicity Tests with Embryos/Larvae of Four Species of Saltwater Bivalve Molluscs. Designation E724-92. Annual Book of Standards, Vol:11.04. ASTM, Philadelphia, PA.

United States Environmental Protection Agency. 1991. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. Fourth Edition. EPA/600/4-90/027. September 1991. 293 pp.

United States Environmental Protection Agency, United States Army Corps of Engineers. 1991. Evaluation of Dredged Material Proposed for Ocean Disposal: Testing Manual. EPA-503/8-91/001. February, 1991.

Part II

PLAN OF STUDY FOR MODELING RE-EVALUATION

INTRODUCTION

Permit condition 3.3.5 of the Ocean Disposal Dumping Permits for StarKist Samoa and VCS Samoa Packing requires that the bioassay results be used re-evaluate the previous model predictions of dispersion of the plume created by dumping fish processing wastes at sea. The previous predictions are presented in the FEIS (EPA, 1989) and in a supplementary study (SOS, 1990). A field study of the fate of the wastes is described by Soule and Oguri (1983). A description of the previous model and the details of the past modeling results are found in Appendix B of the FEIS.

We propose to conduct the model re-evaluation in three phases:

[1] The existing model formulation, as described in the 1989 FEIS (Appendix B) will be used "as is" with model predictions evaluated using the new bioassay test results. Any differences in conclusions between earlier work and the reevaluation will be presented and discussed.

[2] The input data and assumptions used in the model will be examined and evaluated. Sensitivity studies will be done for critical parameters, including assumed values for diffusion coefficients, initial dilution, and ambient conditions. The appropriateness and applicability of previously assumed values will be discussed.

[3] A different, more sophisticated model(s), and/or modifications to the previous model, using appropriate assumptions, will be applied as an independent check of the previous model predications. The model selection will be based on the results of step [2] above. The objectives of the re-evaluation with a different model is to account for changes in vessel characteristics and operational methods and to develop a more representative model.

The previous model, based on an approach originally developed by Norman Brooks, is typically very conservative in similar applications. Other assumptions in the model are also conservative. The use of a different or modified model will allow an evaluation of the degree of conservatism being applied. The initial dilution assumptions will also be examined. The propeller stream of the vessel will be modeled, using an established model developed at Texas A&M and modified by CH2M HILL, to assess the actual degree of the initial mixing.

Conclusions and recommendations will be presented based on the independent assessment. The three phases of the model re-evaluation are described below.

MODELING METHODS

Re-evaluation of Previous Model Predictions

The results of the previous model are presented in terms of dilution (or concentration) of fish processing waste versus distance from the initial dump site. Based on the results of the bioassay tests, the distance from the dump site where the effluent is diluted to the limiting permissible concentration (LPC) level can be determined.

The previous model provided results parametricly with assumed ocean current speed, pumping rate, settling velocity, and other variables. The re-evaluation will examine the range of ambient receiving water conditions, pumping rates, and effluent characteristics for the new bioassay results to determine worst case conditions.

Appropriate changes in model input parameters, such as vessel beam, vessel speed, or pumping rate, will be incorporated but the model formulation will remain as originally developed. A verification run using identical input for a previous model run will be done to confirm the same formulation is being used. A discussion of any differences between previous predictions and those for the new bioassay test results and compliance with permit conditions will be developed from the results of this phase of the model re-evaluation.

Re-evaluation of Model Assumptions and Input

The model assumptions and input can be considered in three categories:

- Model formulation assumptions: assumptions involved in the basic formulation of the model involving the fundamental physics and mathematics used

- Model development assumptions and input: the assumptions and methodology used to chose the magnitudes of the variables describing the important physical processes

- Model execution assumptions and input: the values used for the description of ambient conditions and characteristics of the waste material.

Each of these categories of model assumptions and input will be examined and re-evaluated. Each of the categories of assumptions and input is discussed in more detail below. In addition to the direct re-evaluation of the model assumptions and inputs, the sensitivity of the model will to important variables will be assessed. The results of the model predictions, and the conclusions drawn from the previous model results (for previous bioassay tests and the new bioassay tests) will be examined and discussed in terms of model assumptions and inputs. Evaluations of the degree of conservatism in the previous model formulation and execution will be presented.

Model Formulation Assumptions. The previous model formulation was based on the approach presented by Brooks (1960), and is essentially the same basic model as CDIFF (Yearsley, 1989). The formulation developed by Brooks calculates the lateral diffusion of a discharge plume as it is advected in the longitudinal direction and does not account for longitudinal dispersion.

As initially developed by Brooks, the approach does not account for vertical diffusion, does not provide for the settlement of negatively buoyant constituents in the plume, and does not account for the dispersion of a positively buoyant plume or positively buoyant components of the discharged material. In addition the model, as implemented in the FEIS, assumes a line source of constant source strength and does not simulate the discharge from a vessel traveling in an arbitrary path for a finite length of time.

The FEIS model provides for a settling velocity by redefining the longitudinal coordinate at a downward angle defined by the relationship between the longitudinal current speed and assumed vertical settling velocity such that:

$$x' = x \bullet \cos(\theta)$$

where

$\theta = \tan(u/w_s)$

u = ambient horizontal, longitudinal velocity

w_s = settling velocity

The FEIS model also accounts for vertical diffusion by applying a concentration reduction factor based on a Fickian diffusion coefficient (K_v). This factor is applied to the calculated centerline concentration (C_{max}) by

$$C_{max} \bullet \{(H/4) \bullet (2K_v t + H^2/16)^{-0.5}\}$$

to calculate an adjusted value of C_{max} accounting for vertical diffusion, where H is the initial vertical plume dimension and t is travel time along the plume trajectory.

Each of the basic assumptions of the model and the modifications made for the FEIS model, as discussed above, will be evaluated. In particular the assumption of a continuous line source will be examined and the implications of applying the model to a source discharge of a finite time interval will be evaluated.

Model Development Assumptions. The values chosen to describe the physical processes will be evaluated. These values include the lateral and vertical diffusion coefficients. In addition the model formulation assumptions include the spatial and temporal scales over which the model predictions are used.

Model Execution Input Variables. The previous model input variables, not discussed in the model assumptions section above, include ambient current speed, initial dilution, settling velocity, and initial plume dimensions. An evaluation of the methodology and assumptions used to select the values used for these variables will be done. Changes in the values due to changes in vessel and operational procedures will be addressed. This evaluation will be extended by the sensitivity study descried below.

Model Sensitivity. The sensitivity of the model to each of input variables and to assumptions about the parameters used to describe the physical processes will be evaluated. This will be done by running the model for a range of values.

Development of Independent Model

An independent model will be developed and used to evaluate the dispersion of waste discharged from the barge. The purpose of this model is to provide a more sophisticated alternative to more realistically describe the fate and transport of the discharge. The model will, at a minimum, include the effects of diffusion in both horizontal directions (longitudinal and lateral) and will model a discharge of finite time. In addition the model will account for the spatial pattern of the discharge.

The model will use initial dilutions as determined from the size of the propeller slipstream. Vertical diffusion will be accounted for using a technique similar to that used in the FEIS model. It is anticipated that the major difference in the model predictions will be reflected in the degree of conservatism involved in the model formulations and development. Any differences in model inputs and predictions will be justified and explained.

QUALITY CONTROL AND QUALITY ASSURANCE

The objective of the quality control and quality assurance (QA/QC) effort is to provide a high level of confidence that the models are providing physically realistic predictions. QA/QC will be achieved through use of the proven models executed by staff familiar with those models. Specific QA/QC measures include: validation of model code and that the models are providing physically realistic predictions, addressing a range of potential conditions where appropriate, sensitivity analyses, and documentation and maintenance of input and output files generated during modeling activities.
The models employed in the study are mathematical representations of physical processes. The mathematical equations used are solved numerically (approximate solutions) using a digital computer. It is important that this process, which is considerably removed from the actual physical processes and behavior of the ocean, accurately simulate what happens in the ocean. The process of validation uses representative parameters for simplified system configurations to determine if the predictions reflect reality. The process of validation begins as the initial model computer code is written and continues as long as the model code is used. It is particularly important that any changes in model code be checked for validity. The final element of validation is a determination of how sensitive a model is to changes in input parameters. An extremely sensitive model probably does not provide results with a high confidence level. Sensitivity checks will be carried out for each of the models for potentially critical parameters.

Most numerical models of the type used here contain coefficients (e.g. friction factors, diffusion coefficients) that are often study site specific. Although there are generally accepted values for these coefficients, the range observed in nature is high and the models can be somewhat sensitive to the values selected. The process of calibration and verification uses measured values of forcing functions and responses to determine the appropriate coefficients for the model configuration at the study site. Typically a set of field data is used to determine the correct values to use for the coefficients. However, this is beyond the scope of the present study and there is little or no available and appropriate data for this task. In this case the model sensitivity studies, the use and justification of reasonable values for the literature and similar studies, and the incorporation of a prudent level of conservatism is required.

DATA ANALYSIS AND REPORTING

A report documenting the results of all analyses will be prepared. The report will include summaries of all input data, modeling procedures, and model results. All pertinent model results and output files (as appropriate) will be reproduced as an appendix to the report.

Model results will be presented both in tabular form and graphically (i.e. contour plots) as appropriate. The report will include: an executive summary; an introduction describing the background, rationale, and general approach of the study; a description of the methods used including model formulation and input data; a description of the model results; an evaluation of the model validity for predicting dilution and plume characteristics; and, an evaluation of the concentration of the fish processing wastes within and at the boundary of the permitted ocean dumping site.

REFERENCES

Brooks, N.H., 1960. "Diffusion of Sewage Effluent in an Ocean Current," Proceedings of the First Conference on Waste Disposal in Marine Environment, Pergamon Press, NY.

SOS Environmental and Environmental & Ocean Technology, 1990. "Mathematical/Computer Modeling of Fish Waste Disposal at an Ocean Disposal Site off Tutuila Island, American Samoa". Report prepared for StarKist Seafood and Van Camp Seafood

Soule, D.F. and M. Oguri, 1983. "A report on Ocean Disposal of Fish Processing Wastes off Pago Pago , American Samoa. Report to EPA and NOAA for StarKist Foods and Van Camp Seafood. Los Angeles, California

U.S. Environmental Protection Agency, 1989. Final Environmental Impact Statement for the Designation of an Ocean Disposal Site off Tutuila Island, American Samoa for Fish Processing Waste. EPA Region 9, San Francisco, CA.

Yearsley, J.R., 1989. "Diffusion in Near-shore and Riverine Environments," EPA 910/9-87-168. EPA Region 10, Seattle, Washington.

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REGION IX
75 Hawthorne Street
San Francisco, CA 94105

RECEIVED
DEC 14 1993
CH2M HILL
SAN FRANCISCO

December 10, 1993

Steven L. Costa
Project Manager
CH2M Hill
P.O. Box 12681
Oakland, CA 94604-2681

Re: Comments to Draft Study Plans for Joint Cannery Ocean Disposal Bioassay Toxicity Tests and Modeling Re-evaluation

Dear Steve:

We have reviewed the draft study plans for the biotoxicity tests and modeling re-evaluation. Attached are comments on the bioassay toxicity tests which should be addressed before the plan will be approved. Questions regarding these comments should be addressed to Amy Wagner at (510) 412-2329. A final study plan should be submitted for approval upon resolution of these comments.

Due to the delay in submittal of the draft study plan, we are allowing the first sampling episode to occur in January 1994, rather than in November 1993, as indicated in the ocean disposal permits. Thus we approve your request that each of the subsequent three sampling episodes be delayed by the same amount to maintain the desired spacing. However, the completion date for the overall study will not be changed.

The modeling re-evaluation study plan is approved as submitted. However, as we previously discussed, the additional, more sophisticated model referenced in the plan has not been selected yet and will be submitted for EPA's review prior to its utilization.

Please call Pat Young at 415/744-1594 if you have any questions.

Sincerely,

Norman L. Lovelace, Chief
Office of Pacific Island and Native American Programs (E-4)

cc: Jim Cox, Van Camp Seafood Company
Norman Wei, StarKist Seafood Company
Tony Tausaga, American Samoa EPA
Sheila Wiegman, American Samoa EPA

Attachment

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

DEC 09 1993

SUBJECT: Review of Draft Bioassay and Modeling Re-evaluation Plans for Tuna Cannery Ocean Disposal Permits

TO: Pat Young
American Samoa Program Manager

FROM: Amy Wagner
Laboratory Section

Debra Denton, Permits Issuance Section, and I have reviewed Part I (Bioassay Toxicity Tests) in the above entitled document. We do not recommend approval of the plan until the following issues are addressed or considered. Any questions concerning these comments can be adressed to me at (510) 412-2329.

1.Introduction, I-1: Considering the nature of the waste discharge, we agree that the fish processing wastes should be considered as whole effluent and not tested in the suspended particulate phase.

2.Sample Shipping and Handling, page I-2: Understanding the logistical difficulties in shipping samples from the South Pacific, it should be recognized that a 10 day hold time could result in an increase or decrease of toxicity. It is likely that the BOD will increase over time as reflected by IDOD values determined in the last toxicity tests on cannery effluent. Every effort to minimize the hold time should be made.

3.Selected Species, page I-2: Holmesimysis costata may not be an appropriate surrogate crustacean due to the low test temperature required and the crustacean's sensitivity to aeration. The use of the 96-hour static renewal acute test with Mysidopsis bahia is recommended as a more representative tropical species relevant to the study area.

4.Sample Preparation, page I-4: Artificial sea salts for brine manipulations of effluents can often cause toxicity. Use of natural seawater brine effluents (obtained from freezing or evaporating natural seawater) is recommended.

5.Experimental Conditions, I-4: The dilution series proposed seems more appropriate than the permit requirements based on toxicity seen at low concentrations of the cannery effluent. This dilution series may have to be modified after the first round of testing.

6.Experimental Conditions, I-5: The test temperatures proposed for the crustacean and sea urchin bioassays are higher than standard method requirements. Tests with M. bahia and P. vannamei are run at 20C, while tests using S. purpuratus are normally run at 12-15C.

7. Experimental Conditions, I-5: Methods for fish, mysid, and sea urchin toxicity tests should be cited (manual or reference) in this section since all test conditions (ie. static renewals, number test organisms) are not listed.

8. Quality Control and Quality Assurance, I-5: Sodium chloride is not a standard reference toxicant used in marine fish and mysid tests. In addition, this salt may cause an osmoregulatory rather than a toxicity response in the test organism causing variable sensitivity and dose-responses. Sodium dodecyl chloride, copper sulfate, or zinc sulfate are recommended reference toxicants for these test organisms.

cc: Terry Oda, Chief
Permits Issuance Section (W-5-1)

Appendix 3
SOP for Sample Collection

Standard Operating Procedures
High Strength Waste Sampling
for Bioassay Toxicity Tests

Introduction

Starkist Samoa, Inc. and VCS Samoa Packing are each required under their Ocean Disposal Dumping Permits to conduct definitive acute bioassays on their high strength waste (HSW) streams that are barged to sea for disposal at the permitted dump site. The following gives detailed procedures for collecting, preparing, and shipping samples for these analyses.

Each cannery is required to collect a composite sample of high strength waste while the waste is being transferred from the storage tanks to the barge. Currently a one gallon composite is required for the bioassay tests. The procedures described below are applicable to sampling at each of the canneries.

List of Equipment/Supplies

The following supplies will be required for collecting composite high strength waste samples and preparing them for delivery to the laboratories:

- Three (3) 1/2 to 1 gallon sampling containers
- One 1-gallon cubitainer or other appropriate container (container should be heavy-duty plastic with secure cap, <u>do not ship samples in glass containers</u>)
- Permanent marker for marking sample containers
- Cooler with ice (or refrigerator space) for storing sample
- Cooler for shipping samples (note: Cooler should be sized to hold sample(s) with sufficient room for ice.)
- Cubed ice (enough ice to fill airspace in cooler)
- Chain of Custody Forms (supplied by CH2M HILL or by laboratory conducting the analysis)

Sampling

The following describes the general sampling procedures:

1) **Collect "Grab" Samples.** Sampling should take place the day of or evening before the samples are shipped to the lab. Collect <u>three</u> 1/2 to 1-gallon grab samples from existing sampling ports in the storage tank transfer lines at the time waste is being transferred from the storage tanks to the barge. The samples should be collected at <u>10 minute intervals</u>. Record the time each grab was taken. Store all samples in coolers on ice or in a

refrigerator at a temperature of approximately 4°C. Do **NOT** store samples in a freezer or using a method that would otherwise freeze the samples.

2) **Composite Samples.** Using a permanent marker, label the 1-gallon cubitainer with the following information:
   - Facility samples were collected from
   - Date
   - Time each grab sample was collected

   Combine the three grab samples by measuring 1/3 gallon of each into the 1-gallon cubitainer. Seal the sample container by placing plastic inside the cap and taping the cap down.

3) **Complete Chain of Custody Form.** One chain-of-custody form is required for each cooler in which samples are shipped. An example of a completed chain-of-custody form is included as Attachment A, along with a blank copy. Fill out the chain-of-custody form in triplicate or copy keeping one copy and sending two with the samples to the laboratory.

Shipping

The samples should be shipped the fastest way possible to:

Dr. Kurt Kline
Advanced Biological Testing, Inc.
3150 Paradise Drive, Building 50
Tiburon, CA 94920

Phone: (415) 435-7878; Fax: (415) 435-7882

The samples from each cannery can be shipped in separate coolers or in the same cooler. Place the composite sample into the cooler in which sample(s) is to be shipped. Ice, or an equivalent means such as chemical cold packs, should be used to fill in the empty space in the cooler and keep the sample(s) cold during shipping. Do not use dry ice to ship the sample. If cubed ice is used, precautions should be taken to prevent the melted ice from leaking out of the cooler during shipping. These include taping any drain plugs in the cooler shut with duct tape or strapping tape, and "double-bagging" the ice cubes in zip-lock bags, i.e. sealing the ice cubes in one bag, then sealing the bag containing ice in a second bag. As much air as possible should be removed from the bags prior to sealing. (Too much air inside the bags will expand during flight and pop the bag open).

The chain-of-custody form should signed, placed in a zip-lock bag, and taped with duct tape to the inside of the cooler lid. The cooler should be taped securely with strapping tape or other strong packaging tape to prevent it from opening during shipping.

Attachment A
Example Chain-of-Custody Form

CH2M HILL

QUALITY ANALYTICAL LABORATORIES

CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES

CH2M HILL Project #: OPE3Ø7Ø2.DS.BT

Purchase Order #:

Project Name: OCEAN DUMPING PERMIT HIGH STRENGTH WASTE BIOASSAY

Company Name/CH2M HILL Office: CH2M HILL /SFO

Project Manager & Phone #: Mr. [ ] Ms. [ ] Dr. [X] STEVE COSTA 510 251-2888 X2251

Report Copy to: SAME

Requested Completion Date: A.S.A.P.

Sampling Requirements: SDWA [ ] NPDES [ ] RCRA [ ] OTHER OCN

Sample Disposal: Dispose [X] Return [ ]

LAB TEST CODES

ANALYSES REQUESTED

SHADED AREA - FOR LAB USE ONLY: Lab 1 #, Lab 2 #, Quote #, KI Request #, Project #, No. of Samples, Page, of, COC Rev, Login, EMS Ver, Ack Gen

Sampling Date	Sampling Time	Type COMP	Type GRAB	Matrix WATER	Matrix SOIL	CLIENT SAMPLE ID (9 CHARACTERS)	# OF CONTAINERS	BIOASSAY GROUP 1	BIOASSAY GROUP 2	BIOASSAY GROUP 3	REMARKS	LAB 1 ID	LAB 2 ID
10/18	1000	X		X		STARKIST	1	X	X	X	1-1gal cubitainer ON ICE		

EXAMPLE DO NOT USE

Sampled By & Title (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time
Cliff Johnson CLIFF JOHNSON	10/18 1000		
Received By (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time
Received By (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time
Received By (Please sign and print name)	Date/Time	Shipped Via: UPS BUS Fed-Ex Hand Other DHL	Shipping #
Work Authorized By (Please sign and print name)	Remarks: SAMPLE IS COMPOSITE OF 3 GRAB SAMPLES TAKEN AT 10 MINUTE INTERVALS		

HAZWRAP/NESSA Y N

QC Level 1 2 3 Other

COC Rec ICE

Ana Req TEMP

Cust Seal PH

Instructions and Agreement Provisions on Reverse Side

DISTRIBUTION: ORIGINAL - LAB, Yellow - LAB, Pink - Client

REV 11 FORM 3

CH2M HILL

QUALITY ANALYTICAL LABORATORIES

CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES

CH2M HILL Project #

Purchase Order #

Project Name

Company Name/CH2M HILL Office

Project Manager & Phone #
Mr. [ ]
Ms. [ ]
Dr. [ ]

Report Copy to:

Requested Completion Date:

Sampling Requirements: SDWA ☐ NPDES ☐ RCRA ☐ OTHER ____

Sample Disposal: Dispose ☐ Return ☐

Sampling		Type		Matrix		CLIENT SAMPLE ID (9 CHARACTERS)	# OF CONTAINERS	LAB TEST CODES	SHADED AREA - FOR LAB USE ONLY
Date	Time	COMP	GRAB	WATER	SOIL			ANALYSES REQUESTED	REMARKS

SHADED AREA - FOR LAB USE ONLY

Lab 1 # | Lab 2 #

Quote # | Kit Request #

Project #

No. of Samples | Page | of

COC Rev | Login | LIMS Ver | Ack Gen

LAB 1 ID | LAB 2 ID

Sampled By & Title (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time	HAZWRAP/NESSA	Y N
Received By (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time	QC Level: 1 2 3 Other: ____	
Received By (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time	COC Rec / ICE / Ana Req / TEMP / Cust Seal / Ph	
Received By (Please sign and print name)	Date/Time	Shipped Via: UPS BUS Fed-Ex Hand Other____		Shipping #	
Work Authorized By (Please sign and print name)	Remarks				

Instructions and Agreement Provisions on Reverse Side

DISTRIBUTION: ORIGINAL - LAB, Yellow - LAB, Pink - Client

REV 11/92 FORM 340

Appendix 4
EPA Communications on Bioassay Testing

OPINAP FAX TRANSMISSION
USEPA Region 9
Office of Pacific Island and Native American Programs (E-4)
75 Hawthorne Street
San Francisco, CA 94105
FAX NO: (415) 744-1604
VERIFICATION NO: (415) 744-1599

DATE: July 7, 1995 PAGES (incl. cover): 1

TO: Kurt Kline
Advanced Biological Testing Inc.

FAX: 415/435-7882 Phone: 415/435-7878

SUBJECT: Bioassay Test of Cannery Waste on Bi-valve Larvae

FROM: Pat Young, American Samoa Program Manager
USEPA Region 9
Phone: (415) 744-1594

Amy Wagner discussed with me the problems you were having with spawning the mussel larvae necessary for conducting bioassay tests on the cannery waste, and whether you should continue with the tests even though the cannery waste sample is now over 10 days old. Although the sample has been stored properly and refrigerated, we are concerned that given its high organic content and the waste's tendency to increase its ammonia content over time, no meaningful comparison or correlation of results could be made among the results of bioassay tests conducted on mussel larvae using 10-day-old cannery waste and the results obtained with the sand dab and mysid using the fresh sample. Rather than having you conduct the entire series again with the three species using new samples, and given the unrealibility of the mussel spawning, we waive the requirement to conduct the bioassay test on the mussel larvae for this round of sampling.

Should you have any questions, please feel free to call me.

cc: Steve Costa, CH2MHill
Jim Cox, Van Camp Seafoods
Norman Wei, Star-Kist Samoa
Amy Wagner, EPA Lab
Alan Ota, EPA (W-3-3)
Sheila, Wiegman, ASEPA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

September 30, 1994

1994

Steven L. Costa
Project Manager
CH2M Hill
P.O. Box 12681
Oakland, CA 94604-2681

Re: Third Bioassay Test of Ocean Disposed High-Strength Waste of StarKist Samoa, Inc. and VCS Samoa Packing Company

Dear Steve:

We have reviewed the two options proposed in your letter of September 14, 1994 for the timing of the third bioassay test required by the canneries' ocean disposal permits. We believe that information obtained during the different seasons would prove valuable. Thus, your proposal to change the schedule of the final bioassay test from December 1994 to June 1995 is approved. We understand that this will extend the term of the study beyond that stated in the permits. Since the modeling and evaluation will have been started on the first sets of data, we would expect to see the final study results by October 1995. As you know, the permits expire on August 31, 1996, and the canneries should reapply for permit renewal a few months prior to this expiration date. Because of the implications this report has for the designated ocean disposal site, we would like to receive the modeling and evaluation report with ample time to review it prior to the reapplication period.

Please call me at (415) 744-1594 if we need to discuss this further.

Sincerely,

Pat Young

Pat Young
American Samoa Program Manager
Office of Pacific Island and Native American Programs (E-4)

cc: Jim Cox, Van Camp Seafood Company
Norman Wei, StarKist Seafood Company
Tony Tausaga, American Samoa EPA
Sheila Wiegman, American Samoa EPA
Allan Ota, W-3-3
Amy Wagner, P-3-1

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

August 29, 1994

Steven L. Costa
Project Manager
CH2M Hill
P.O. Box 12681
Oakland, CA 94604-2681

Re: Comments on Bioassay Testing of Ocean Disposed High-Strength Waste of StarKist Samoa, Inc. and VCS Samoa Packing Company

Dear Steve:

We have reviewed the report of June 29, 1994 for the first of three rounds of bioassays of high-strength waste, as required by the canneries' ocean disposal permits. The report is based on two sampling events: the first was collected on February 16, 1994; and, a second sample was required and tested in March 1994, due to test failure of the echinoderms in the first sample. Your proposed changes to the study methods, as outlined in your memo of July 1, 1994, are acceptable. Enclosed is a memo from Amy Wagner of EPA's Laboratory Support Section, detailing the acceptable changes. Please call Amy at (510) 412-2329 if you have any questions on her comments.

We note that the second and third rounds of testing were scheduled for May and August 1994, and we would like to know if these tests were conducted as scheduled and, if not, the rescheduled dates, and when we can anticipate the reports on these bioassays. Please relay this information to Pat Young, American Samoa Program Manager, or if you have any questions, call her at (415) 744-1594.

Sincerely,

for M. T. Lee
Norman L. Lovelace, Chief
Office of Pacific Island and Native
American Programs (E-4)

Enclosure

cc: Jim Cox, Van Camp Seafood Company
Norman Wei, StarKist Seafood Company
Tony Tausaga, American Samoa EPA
Sheila Wiegman, American Samoa EPA
Allan Ota, W-3-3
Amy Wagner, P-3-1

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX LABORATORY
1337 S. 46TH STREET BLDG 201
RICHMOND, CA 94804-4698

AUG 2 9 1994

MEMORANDUM

SUBJECT: Review of Bioassay Testing of Starkist, Samoa, Inc. and VCS Samoa Packing High Strength

FROM: BB for ALW
Amy Wagner
Laboratory Section (P-3-1)

THRU: Brenda Bettencourt
Brenda Bettencourt, Chief
Laboratory Section (P-3-1)

TO: Pat Young
OPINAP (E-4)

Allan Ota
Wetlands and Sediment Management Section (W-3-3)

At your request, I have reviewed "Results of a Bioassay Conducted on Two High Strength Waste Samples from the Van Camp and Starkist Tuna Canneries in American Samoa." The following recommendations are based on the results of the first round of testing.

1. p. 11. The salinity of the *Mysidopsis bahia* tests were 25 ppt, presumably based on the salinity of the shipping water. An effort should be made to find a supplier that raises mysids in a salinity closer to that of the discharge site, between 30-35 ppt.

2. Appendix, p. 1. It is recommended that the water quality measurements pH, dissolved oxygen, and initial salinity be measured for all samples upon receipt.

3. Appendix, Table 10. The salinities of 26-28 ppt most likely caused the high mortality in controls with the sea urchin toxicity test. If necessary, brine adjustments should be used to increase the salinity of test samples to the test method requirements of 30 ± 2 ppt.

4. To reduce salinity elevation throughout the tests, an attempt should be made to cover test containers to reduce evaporation.

Based on the results of these tests, the following changes in the bioassay methods recommended by CH2M Hill in the cover memo are acceptable.

1. The series of the concentrations for toxicity tests can be reduced to 2.0%, 1.0%, 0.5%, 0.25%, 0.125%, and 0.0625% instead of the suggested series.

2. *Mytilus edulis* can be used instead of *Strongylocentrotus purpuratus* as the third test organism. The oyster *Crassostrea virginica* may be substituted for the mussel test during the months when mussels cannot be spawned.

3. Aeration should be provided in the mussel test containers due to high biological oxygen demand of the effluent. In addition to a control with aeration, a control without aeration should be run. A t-test should be used to determine if the there is any significant effect of aeration.

Any questions on the comments can be addressed to me at (510) 412-2329.

cc: Jeff Rosenbloom, Chief
Wetlands and Sediment Management Section (W-3-3)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

RECEIVED
DEC 14 1993
CH2M HILL
SAN FRANCISCO

December 10, 1993

Steven L. Costa
Project Manager
CH2M Hill
P.O. Box 12681
Oakland, CA 94604-2681

Re: Comments to Draft Study Plans for Joint Cannery Ocean Disposal Bioassay Toxicity Tests and Modeling Re-evaluation

Dear Steve:

We have reviewed the draft study plans for the biotoxicity tests and modeling re-evaluation. Attached are comments on the bioassay toxicity tests which should be addressed before the plan will be approved. Questions regarding these comments should be addressed to Amy Wagner at (510) 412-2329. A final study plan should be submitted for approval upon resolution of these comments.

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The modeling re-evaluation study plan is approved as submitted. However, as we previously discussed, the additional, more sophisticated model referenced in the plan has not been selected yet and will be submitted for EPA's review prior to its utilization.

Please call Pat Young at 415/744-1594 if you have any questions.

Sincerely,

Norman L. Lovelace, Chief
Office of Pacific Island and Native
American Programs (E-4)

cc: Jim Cox, Van Camp Seafood Company
Norman Wei, StarKist Seafood Company
Tony Tausaga, American Samoa EPA
Sheila Wiegman, American Samoa EPA

Attachment

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

DEC 09 1993

SUBJECT: Review of Draft Bioassay and Modeling Re-evaluation Plans for Tuna Cannery Ocean Disposal Permits

TO: Pat Young
American Samoa Program Manager

FROM: Amy Wagner
Laboratory Section

Debra Denton, Permits Issuance Section, and I have reviewed Part I (Bioassay Toxicity Tests) in the above entitled document. We do not recommend approval of the plan until the following issues are addressed or considered. Any questions concerning these comments can be adressed to me at (510) 412-2329.

1.Introduction, I-1: Considering the nature of the waste discharge, we agree that the fish processing wastes should be considered as whole effluent and not tested in the suspended particulate phase.

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8.Quality Control and Quality Assurance, I-5: Sodium chloride is not a standard reference toxicant used in marine fish and mysid tests. In addition, this salt may cause an osmoregulatory rather than a toxicity response in the test organism causing variable sensitivity and dose-responses. Sodium dodecyl chloride, copper sulfate, or zinc sulfate are recommended reference toxicants for these test organisms.

cc: Terry Oda, Chief
Permits Issuance Section (W-5-1)

Appendix 5
Laboratory Results Submitted by ABT - First Test

RESULTS OF A BIOASSAY CONDUCTED ON TWO HIGH STRENGTH WASTE SAMPLES FROM THE VAN CAMP AND STARKIST TUNA CANNERIES IN AMERICAN SAMOA

Prepared for:

CH2M Hill California, Inc.
1111 Broadway
Oakland, CA 94607
Project # PDX 30702

Prepared by:

Advanced Biological Testing Inc.
98 Main St., # 419
Tiburon, Ca. 94920

June 29, 1994

Ref: 9309-2

1.0 INTRODUCTION

At the request of CH2M Hill (Project # PDX 30702), Advanced Biological Testing conducted acute effluent bioassay testing on *Mysidopsis bahia*, *Mytilus edulis*, *Strongylocentrotus purpuratus* and *Citharichthys stigmaeus* using high strength wastes (HSW) collected separately from the Van Camp (HSW-1) and Starkist (HSW-2) tuna canneries in American Samoa. The study was run using methods generally specified in EPA 1991 and in a Sampling and Testing Plan submitted to the EPA.

The study was conducted at the Advanced Biological Testing Laboratory in Tiburon, California, and was managed by Mr. Mark Fisler.

2.0 METHODS

2.1 EFFLUENT SAMPLING

The high strength wastes were sampled as composites on February 16, 1994 by personnel from CH2M Hill. Due to shipping and airline scheduling problems, frequently encountered in this region, the sample was received by the laboratory on February 19, 1994. Two five gallon carboys were provided from each cannery defined as HSW-1 (VCS) and HSW-2 (SK) and were maintained in ice-filled coolers from the date of sampling until laboratory receipt. The sample were at 2-3°C upon receipt.

Due to the test failure in the echinoderms, both of the HSW were resampled on March 30, 1994, and shipped to ABT arriving on April 4, 1994.

2.2 SAMPLE PREPARATION

2.2.1 Testing on the speckled sanddab, *Citharichthys stigmaeus*

After extensive discussions with the EPA regarding the proposed testing concentrations, the high strength wastes were tested at eight concentrations starting from 3.0% and dropping using a 50% dilution factor. The final concentrations were 3.0, 1.5, 1.25, 0.8, 0.4, 0.2, 0.1 and 0.05% as vol:vol dilutions in seawater. The diluent was filtered seawater from the Bodega Bay Marine Laboratory. The dilutions were brought up to the test temperature (14°C) and aerated continuously. Based upon data provided by CH2M Hill, and subsequently supported by information from the EPA, these effluents have an extremely high biological oxygen demand, therefore aeration was carried out from the beginning of the test.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 25, 12.5, 6.25, 3.1, and 1.6 mg/L in 30 ppt seawater in a 24 hour test.

2.2.2 Testing on the mysid, *Mysidopsis bahia*

Both of the high strength wastes were tested twice, once in a concentration series of 25, 12.5, 6.25, 3.1, 1.6, 0.8, and 0.4% vol:vol in seawater, and after discussions with the EPA, a second

time at a lower concentration series of 1.6, 0.8, 0.4, 0.2, 0.1 and 0.05% vol:vol dilutions. The diluent was filtered seawater from the Bodega Bay Marine Laboratory. The dilutions were brought up to the test temperature (20°C) and aerated continuously.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 20, 10, 5, 2.5 and 1.25 mg/L in 30 ppt seawater in a 96 hour test.

2.2.3 Echinoderm and Bivalve Larval Bioassay

Test solutions used in the bioassays were prepared using San Francisco Bay seawater at 28 ppt in serial dilution (0.5) to create 0.08%, 0.15%, 0.3%, 0.6% and 1.2% test concentrations for the bioassays. The echinoderm test failed control survival in two testing attempts using the initial HSW delivered on February 19, 1994. A second sample was requested from each cannery which was delivered on April 4, 1994. The echinoderm test again marginally failed the controls and the results of the study are presented for information. The bivalve study conducted concurrently with the echinoderm bioassay passed the control criteria.

The reference toxicant for the echinoderm and bivalve larval bioassays was copper at test concentrations of 0.56, 3.2, 10, 32, and 56 µg/L.

2.2.4 *Citharichthys stigmaeus*

The bioassays were carried out on juvenile *Citharichthys stigmaeus*, supplied by J. Brezina and Associates in Dillon Beach, California. The animals were received at ABT on February 19, 1994. The test conditions are summarized in Table 1. Five replicates of each concentration were tested with ten juvenile fish per replicate. Water quality was monitored daily as initial quality on Day 0 and final water quality on Days 1-4. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature.

2.2.5 *Mysidopsis bahia*

The first bioassay was carried out on 7-10 day old larval *Mysidopsis bahia*, supplied by J. Brezina and Associates in Dillon Beach, California. The animals were received at ABT on February 19, 1994. The test conditions for this test are summarized in Table 2. The second test was carried out on larval mysids supplied by Aquatox from Hot Springs, Arkansas. The animals

were received at ABT on February 26, 1994. The test conditions for the second test are summarized in Table 3.

Five replicates of each concentration were tested with ten larval mysids per replicate. Water quality was monitored daily as initial quality on Day 0 and final water quality on Days 1-4. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature.

2.2.6 Echinoderm Larval Development Test

The echinoderm larvae survival and development test followed draft ASTM methods (ASTM, 1994). Purple urchins, *Strongylocentrotus purpuratus,* were obtained from A. K. Siewers, Santa Cruz, California. Adults were induced to spawn by intercoelomic injection of 0.5M KCl. Released eggs were placed in individual containers of filtered seawater, and sperm was collected dry and held on ice. Gametes were mixed and allowed to fertilize for up to two hours. Fertilized eggs were then separated from sperm and debris by filtering the suspension at 20 µm. Egg stock density was estimated by counting an aliquot of dilute stock concentrate. Equal volumes of concentrate were added to each replicate to an initial density of 15-30 embryos per mL. Initial stocking density was confirmed by counting a 5 mL aliquot from at least three control replicates.

Testing was conducted at 16 ± 2°C under a 14 hour light and 10 hour dark photoperiod. Temperature, pH, dissolved oxygen, and salinity were recorded at 0, 24, 48 and 72 hours in water quality replicates. Total ammonia was measured in the 1.2% sample at 0 and 48 hours. At the end of the exposure period, a 5 mL sub-sample was taken from each test replicate and preserved with buffered formalin. Sub-samples were counted in a Sedgwick-Rafter cell, and the total number of normal and abnormal larvae were counted.

2.2.7 *Mytilus edulis* Larval Survival and Development Test

The bivalve larvae survival and development test was run in parallel with the echinoderm using the second set of effluents. The test followed methods in ASTM (1993). Bay mussels, *Mytilus edulis,* were obtained from A. K. Siewers, Santa Cruz, California. Adults were induced to spawn by heat shocking. Released gametes were placed in individual containers of filtered seawater and examined for viability. Gametes were mixed and allowed to fertilize for up to two hours, under gentle aeration. Fertilized eggs were then separated from sperm and debris by filtering the suspension at 20 µm. Egg stock density was estimated by counting an aliquot of dilute stock concentrate. Equal volumes of concentrate were added to each replicate to an initial density of

15-30 embryos per mL. Initial stocking density was confirmed by counting a 5 mL aliquot from at least three control replicates.

Testing was conducted at 16 ± 2°C under a 14 hour light and 10 hour dark photoperiod. Temperature, pH, dissolved oxygen, and salinity were recorded at 0 and 48 hours; temperature was also recorded at 24 hours. Total ammonia was measured in 1.2% sample at 0 and 48 hours. At the end of the exposure period, a 5 mL sub-sample was taken from each test replicate and preserved with buffered formalin. Sub-samples were counted in a Sedgwick-Rafter cell, and the total number of normal and abnormal larvae were counted.

Dissolved oxygen levels of test solutions of HSW-2 fell below 60% saturation in both the bivalve and echinoderm tests. Gentle aeration was started on Day 1, and continued for the duration of the tests. To assess the effects of aeration, control replicates 4 and 5 were aerated beginning on Day 1 for both the bivalve and echinoderm tests. No statistical differences were observed between aerated and unaerated control replicates.

2.3 STATISTICAL ANALYSIS

At the conclusion of the test, the survival data were evaluated statistically using ToxCalc™ to determine ECp, NOEC, and TU values where appropriate. ToxCalc™ is a comprehensive statistical application that follows standard guidelines for acute and chronic toxicity data analysis.

At the conclusion of the echinoderm tests, data were evaluated statistically to estimate the LC50 and IC50 values for the elutriate tests. The LC50 and IC50 values were estimated using the Probit or the Linear Interpolation (Bootstrap) Method.

The LC50 and the IC50 for the bivalve larvae copper reference toxicant test were both within two standard deviations of the laboratory means of 26.3 µg/L and 8.9 µg/L, respectively, indicating normal sensitivity of the test organisms. No laboratory means for the echinoderm larvae copper reference toxicant test have yet been established.

Statistical effects can be measured by the ECp, the estimated concentration that causes any effect, either lethal (LC) or sublethal (IC), on p% of the test population. The LCp is the point estimate of the concentration at which a lethal effect is observed in p% of the test organisms. ECp values include 95% confidence limits if available.

The NOEC (No Observable Effect Concentration) is the highest tested concentration at which mortality is not significantly different from the control.

3.0 RESULTS

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 20 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected at approximately 1 hour after test initiation in all of the concentration even with supplemental aeration therefore aeration was maintained in all chambers for the duration of the test. Ammonia was measured in two replicates from each concentration daily and was a potentially significant toxic component of the test for all concentrations.

3.1 *Citharichthys stigmaeus*

The LC50 for HSW-1 was 0.59%. Mortality in the effluent was rapid at the highest concentrations, occurring in 2-4 hours. There was significant mortality at 3.0, 1.5, and 0.8% concentrations compared to the control at 96 hours. The NOEC was 0.4% and the LOEC was 0.8%

The LC50 for HSW-2 was 0.27%. Mortality in the effluent was rapid at the highest concentrations, generally occurring in 2-4 hours. There was significant mortality at 3, 1.5, 0.8 and 0.4% concentrations compared to the control at 96 hours. The NOEC was 0.2%, and the LOEC was 0.4%.

The reference toxicant test required the use of the Trimmed Spearman-Karber method and generated an LC50 of 4.34 mg/L, an NOEC of 3.1 mg/L, and an LOEC of 6.25 mg/L. This is the first reference toxicant test on *Citharichthys* at this laboratory, therefore no database has been established by this laboratory.

3.2 *Mysidopsis bahia*

The LC50 results for both HSW effluents in the initial tests were <0.4%. Based upon the fact that no definitive LC50 could be calculated, the tests were rerun as described in the methods.

The LC50 for HSW-1 was 0.59%. Mortality in the 1.6% and 0.8% effluent was incomplete at 24 hours. At 96 hours, there was significant mortality at 1.6, 0.8, 0.4, and 0.1% concentrations compared to the control. The NOEC was 0.05% and the LOEC was 0.1%.

In the second test series the LC50 for HSW-2 was 0.12%. Mortality in the 1.6% and 0.8% effluent was complete at 24 hours. There was significant mortality at 96 hours in the 1.6, 0.8, 0.4, 0.2 and 0.1% concentrations compared to the control. The NOEC was 0.05%, and the LOEC was 0.1%.

The reference toxicant test had an LC50 of 8.90 mg/L, with an NOEC of <1.25 mg/L and an LOEC of 1.25 mg/L. This is the first reference toxicant test on *Mysidopsis* at this laboratory, therefore no database has been established.

3.3 ECHINODERM LARVAL BIOASSAY

Control survival was marginal and unacceptable according to the protocol at 64.4% with 5.7% abnormal development. Total survival was relatively high and equal to control survival in all concentrations, however all of the embryos were abnormally developed at 0.15% to 1.2% in HSW-1 and from 0.08% to 1.2% in HSW-2. The LC50 for both effluents was greater than 1.2% however the IC50 was 0.1% for HSW-1 and <0.08% for HSW-2.

The reference toxicant analysis yielded an LC50 of 11.8 µg/L and an IC50 of 10.1 µg/L. The use of the echinoderm larval bioassay is still limited and no data is available for comparison.

3.4 BIVALVE LARVAL BIOASSAY

Control survival was acceptable at 98.1% with 6.3% abnormal development. Total survival was relatively high in all concentrations, however all of the embryos were abnormally developed at 0.15% to 1.2% in HSW-1 and HSW-2. The LC50 for both effluents was greater than 1.2% however the IC50s were <0.08% for both HSW-1 and HSW-2.

The LC50 and IC50 for the bivalve larvae copper reference toxicant test were both within two standard deviations of the laboratory means of 26.3 µg/L and 8.9 µg/L, respectively, indicating normal sensitivity of the test organisms.

3.5 AMMONIA MEASUREMENTS

Ammonia in both of the HSW was very high. When measured in a 25% dilution in seawater, ammonia levels ranged from 160 to 180 mg/L. If converted to the 100% concentration, the

ammonia level would be above 640 mg/L. Tested concentrations in the *Citharichthys* bioassay ranged from 0.08 to 0.17 mg/L in the lowest concentration (0.05%) to 3.44 to 9.65 mg/L in the 3.0% dilution. At each test concentration, HSW-2 generated the higher ammonia levels. The toxicity of ammonia to sanddabs is well documented and the measured levels in the three highest concentrations in HSW-2 and the two highest concentrations in HSW-1 were sufficient to cause toxicity in the test animals in 24 hours. The mysid test results appear to indicate a slightly higher tolerance to ammonia as has been shown in the literature.

TABLE 1

Bioassay Procedure And Organism Data
For the Survival Bioassay
Using *Citharichthys stigmaeus* (U.S. EPA 1991)

Parameter	Data
Test Species	*Citharichthys stigmaeus*
Supplier	J. Brezina and Associates
Collection location	Tomales Bay
Date Acquired	2/19/94
Acclimation Time	24 hours
Acclimation Water	30 ppt seawater
Acclimation Temperature	15±2°C
Age group	Juveniles, 3-5 cm TL
Sample Identification	
Sample ID(s)	940219-1, -2
Date Sampled	2/16/94
Date Received at ABT	2/19/94
Volume Received	Ten gallons
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	96 hour static acute, renewal at 48 hours
Test Dates	2/19/94 to 2/23/94
Control Water	Bodega Bay seawater
Test Temperature	15 ± 1°C
Test Photoperiod	16 L : 8 D
Initial Salinity	30 ± 2 ppt
Test Chamber	20 L polyethylene chamber
Animals/Replicate	10 animals/replicate
Exposure Volume	5 L
Replicates/Treatment	5
Feeding	None
Deviations from procedures	Due to aeration, salinity increased throughout test.

TABLE 2

Bioassay Procedure And Organism Data
For the Survival Bioassay
Using *Mysidopsis bahia* (U.S. EPA 1991)

Parameter	Data
Test Species	*Mysidopsis bahia*
Supplier	J. Brezina and Associates
Date Acquired	2/19/94
Acclimation Time	overnight
Acclimation Water	Shipping water
Acclimation Temperature	20 ± 2°C
Age group	larvae
Sample Identification	
Sample ID(s)	940219-1, -2
Date Sampled	2/16/94
Date Received at ABT	2/19/94
Volume Received	Ten gallons
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute; static; renewal at 48 hours
Test Dates	2/19/94 to 2/23/94
Control Water	Bodega Bay seawater
Test Temperature	20 ± 2°C
Test Photoperiod	14 L : 10 D
Initial Salinity	25 ppt
Test Chamber	1000 mL jars
Animals/Replicate	10 animal/replicate
Exposure Volume	500 mL
Replicates/Treatment	5
Feeding	Brine shrimp (24 hr old nauplii)
Deviations from procedures	Due to aeration, salinity increased throughout test

TABLE 3

Bioassay Procedure And Organism Data For the Survival Bioassay Using *Mysidopsis bahia* (U.S. EPA 1991)

Parameter	Data
Test Species	*Mysidopsis bahia*
Supplier	Aquatox
Date Acquired	2/26/94
Acclimation Time	Overnight
Acclimation Water	Shipping water
Acclimation Temperature	20 ± 2°C
Age group	larvae
Sample Identification	
Sample ID(s)	940219-1, -2
Date Sampled	2/16/94
Date Received at ABT	2/19/94
Volume Received	Ten gallons
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute; static; renewal at 48 hours
Test Dates	2/27/94 to 3/2/94
Control Water	Bodega Bay seawater
Test Temperature	20 ± 2°C
Test Photoperiod	14 L : 10 D
Initial Salinity	25 ppt
Test Chamber	1000 mL jars
Animals/Replicate	10 animal/replicate
Exposure Volume	500 mL
Replicates/Treatment	5
Feeding	Brine shrimp (24 hr old nauplii)
Deviations from procedures	Due to aeration, salinity increased throughout test

TABLE 4

Bioassay Procedure And Organism Data For The Bioassay Using Larvae of *Strongylocentrotus purpuratus* (modified ASTM 1994)

Parameter	Data
Test Species	*Strongylocentrotus purpuratus*
Supplier	A.K. Siewers, Santa Cruz, CA
Date Acquired	4/7/94
Acclimation Time	None
Acclimation Water	Not applicable
Acclimation Temperature	Not applicable
Age group	Fertilized embryos, 2 hours
Sample Identification	
Sample ID(s)	940404-3, -4
Date Sampled	3/30/94
Date Received at ABT	4/4/94
Volume Received	Two liters
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute/static; 96 hours
Test Dates	4/7/94 to 4/11/94
Control Water	San Francisco Bay seawater, 0.45 µm filtered and uv-sterilized
Test Temperature	16 ± 2°C
Test Photoperiod	14 L : 10 D
Salinity	30 ± 2 ppt
Test Chamber	125 mL beakers
Animals/Replicate	Approximately 30 embryos per mL
Exposure Volume	100 mL
Replicates/Treatment	5
Feeding	None
Deviations from procedures	Chambers were gently aerated with low bubble aeration

TABLE 5

Bioassay Procedure And Organism Data
For The 48 Hour Bioassay
Using Larvae of *Mytilus edulis* (ASTM 1993)

Parameter	Data
Test Species	*Mytilus edulis*
Supplier	A.K. Siewers, Santa Cruz, CA
Date Acquired	4/7/94
Acclimation Time	None
Acclimation Water	Not applicable
Acclimation Temperature	Not applicable
Age group	Fertilized embryos, 2 hours
Sample Identification	
Sample ID(s)	940404-3,-4
Date Sampled	3/30/94
Date Received at ABT	4/4/94
Volume Received	Two liters
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute; static; 48 hours
Test Dates	4/7/94 to 4/9/94
Control Water	San Francisco Bay seawater, 0.45 µm filtered and uv-sterilized
Test Temperature	16 ± 2°C
Test Photoperiod	14 L : 10 D
Salinity	30 ± 2 ppt
Test Chamber	125 mL beakers
Animals/Replicate	Approximately 30 embryos per mL
Exposure Volume	100 mL
Replicates/Treatment	3
Feeding	None
Deviations from procedures	Chambers were gently aerated with low bubble aeration

TABLE 6

SUMMARY OF RESULTS FOR THE HIGH STRENGTH WASTE BIOASSAYS

Species	Test	Endpoint	HSW-1	HSW-2
Citharichthys stigmaeus	96 hr static	LC50	0.59%	0.27%
Mysidopsis bahia	96 hr static	LC50	0.59%	0.12%
Strongylocentrotus purpuratus	96 hr static	LC50	>1.2%	>1.2%
		IC50	0.10%	<0.08%
Mytilus edulis	48 hr static	LC50	>1.2%	>1.2%
		IC50	<0.08%	<0.08%

Note:
HSW-1: Van Camp
HSW-2: Starkist

TABLE 7

SUMMARY OF RESULTS FOR THE REFERENCE TOXICANT (S.D.S.) TEST

Citharichthys stigmaeus

Concentration (mg/L)	% Survival	ECp (mg/L)		NOEC (mg/L)	LOEC (mg/L)
Control	93.3	**EC50**	4.3449	3.1	6.25
1.6	80.0				
3.1	100.0				
6.2	0.0				
12.5	0.0				
25	0.0				

Mysidopsis bahia

Concentration (mg/L)	% Survival	ECp (mg/L)		NOEC (mg/L)	LOEC (mg/L)
Control	90.0	**EC50**	8.90 (3.04-69.22)	<1.25	1.25
1.25	70.0				
2.5	56.7				
5	46.7				
10	46.7				
20	36.7				

* Statistically significant.
ICp/LCp: Inhibition/Lethal Concentration for p% of the organisms.
NOEC: No Observable Effect Concentration.
TU: 100%/NOEC.

4.0 REFERENCES

U.S. EPA. 1991. Methods for measuring acute toxicity of effluents to freshwater and marine organisms, 4th ed. EPA 600/4-90/027, September, 1991.

ASTM. 1993. Annual Book of Standards. Vol. 11.04. Standard guide for conducting static acute toxicity tests starting with embryos of four species of saltwater bivalve mollusca. E-724-89.

ASTM. 1994. Annual Book of ASTM Standards Vol. 11.04. Guide for conducting static acute toxicity tests with echinoid embryos. Proposed Standard in review.

APPENDIX A

ANALYTICAL DATA

APPENDIX TABLE 1

SAMPLE WATER QUALITY

Date	Day	Sample	pH (units)	DO (mg/L)	Total NH3 (mg/L)	Initial Salinity (ppt)
4/7/94	0	HSW-1, 1.2%	7.62	8.0	62.5	26
	0	HSW-2, 1.2%	6.87	7.9	51.6	26
4/9/94	2	HSW-1, 1.2%	-	-	26.4	-
	2	HSW-2, 1.2%	-	-	41.2	-
4/11/94	4	HSW-1, 1.2%	-	-	33.5	-
	4	HSW-2, 1.2%	-	-	41.9	-

APPENDIX TABLE 2

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.02	6.2	0.02	14.0	32.0	8.07	5.5	0.01	13.2	31.5	8.08	5.5		13.8	32.9	8.03	6.0		14.0	35.0	8.06	6.1	0.02	14.4	36.0
	2						8.11	5.8		13.7	31.0	8.13	5.6	0.12	14.2	31.7	8.12	6.0		14.3	33.0	8.13	6.1		15.0	33.0
	3						8.10	6.0		13.8	30.9	8.12	5.7		14.2	31.8	8.11	6.0		14.4	32.0	8.12	5.8		15.2	33.0
	4						8.10	6.0		13.2	31.6	8.13	5.7		13.6	33.1	8.11	6.0	<0.10	13.9	35.0	8.13	5.6		14.6	36.0
	5						8.10	6.0		13.3	31.7	8.12	5.6		13.9	33.3	8.12	6.0		14.0	34.0	8.13	5.8		14.7	37.0
0.05	1	8.00	6.3	0.19	14.0	32.2	8.04	6.0	0.08	13.5	33.8	8.07	5.6		13.9	36.2	8.07	6.0		14.0	38.0	8.07	5.8	0.10	14.8	40.0
	2						8.03	6.0		13.6	33.8	8.07	5.5	0.05	13.9	36.4	8.04	6.0		14.1	38.0	8.06	5.6		14.7	40.0
	3						8.05	6.0		13.5	32.7	8.10	5.5		14.1	33.6	8.08	6.0		14.2	35.0	8.10	5.6		14.6	35.0
	4						8.01	6.0		13.5	32.3	8.07	5.6		14.1	33.4	8.06	6.0	<0.10	14.2	34.0	8.04	5.8		14.7	35.0
	5						8.05	5.9		13.6	33.1	8.09	5.6		14.1	34.1	8.09	6.0		14.2	35.0	8.10	5.8		14.9	36.0
0.1	1	8.01	6.2	0.25	14.0	32.1	8.06	6.0	0.13	13.5	31.8	8.12	5.6		13.9	32.6	8.11	6.0		14.1	34.0	8.13	5.8	0.12	14.9	34.0
	2						8.03	5.9		13.8	31.7	8.10	5.7	0.08	14.2	32.6	8.10	6.0		14.4	33.0	8.10	5.8		14.9	34.0
	3						8.01	5.8		13.3	32.8	8.08	5.7		13.8	34.8	8.06	5.9		14.0	37.0	8.06	5.6		14.4	39.0
	4						8.04	5.9		13.8	32.6	8.12	5.8		14.5	33.9	8.11	6.0	<0.10	14.6	35.0	8.11	5.7		14.9	36.0
0.2	1	8.01	6.0	0.54	14.0	32.1	8.04	5.7	0.20	14.2	30.0	8.14	5.9		14.4	31.1	8.13	6.0		14.3	32.0	8.13	6.0	0.17	14.9	34.0
	2						8.01	5.8		14.1	29.9	8.14	5.8	0.17	14.5	30.5	8.16	6.0		14.6	31.0	8.16	5.9		14.9	32.0
	3						7.98	5.8		13.9	29.8	8.12	5.8		14.2	30.3	8.13	5.9		14.9	31.0	8.14	5.9		15.0	32.0
	4						8.02	5.8		13.9	29.8	8.15	5.8		14.2	30.5	8.15	6.3	NT	14.9	31.0	8.16	5.8		15.0	32.0
	5						8.03	5.8		13.8	29.8	8.13	5.8		14.2	30.5	8.15	6.3		14.9	31.0	8.17	5.8		15.0	32.0
0.4	1	7.93	6.1	0.89	14.0	32.0	7.95	5.4	0.33	13.7	30.1	8.12	5.4		14.2	30.8	8.14	6.3		14.3	32.0	8.17	5.8	0.31	15.0	32.0
	2						7.98	5.6		14.4	30.2	8.13	5.8	0.25	14.8	31.1	8.17	6.3		14.9	32.0	8.18	5.8		14.7	33.0
	3						8.00	5.9		14.4	30.2	8.15	5.7		14.3	31.6	8.18	6.3		14.6	33.0	8.06	5.8		14.6	34.0
	4						7.76	4.6		14.0	29.9	8.06	5.8		14.5	30.3	8.09	6.2	0.17	14.7	31.0	8.11	5.8		14.6	36.0
	5						7.93	5.2		13.5	30.4	8.11	5.6		14.0	31.4	8.13	6.2		14.0	32.0	8.19	5.6		14.3	34.0
0.8	1	7.68	6.1	2.01	14.0	32.0	7.89	5.2	0.64	13.7	30.8	8.15	5.6		14.1	31.7	8.15	6.2		14.2	33.0	8.10	5.8	0.51	14.7	33.0
	3						7.82	5.1		13.1	31.2	8.09	5.6	0.40	13.7	32.6	8.06	6.3		13.90	34.0	8.10	5.8		14.20	36.0
	4						7.95	5.4		14.1	30.8	8.16	5.5		14.5	32.0	8.17	6.4	0.48	14.3	34.0	8.18	5.8		14.4	35.0
	5						7.88	5.4		13.2	31.5	8.13	5.7		14.5	32.7	8.16	6.3		14.5	34.0	8.21	5.8		14.3	35.0
1.5	1	7.51	6.0	3.56	14.0	32.2	7.83	5.2	1.43	13.3	32.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.76	4.8		13.5	31.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.75	5.0		12.9	32.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.76	5.2		12.9	32.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.76	5.1		12.9	32.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3.0	1	7.23	5.9	11.1	14.0	32.1	7.85	5.6	3.44	13.6	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.74	4.6		13.9	33.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.81	5.0		13.9	33.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.75	4.7		14.1	33.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.81	5.0		19.2	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		7.23	5.9	0.02	14.0	32.0	7.74	4.6	0.01	12.9	29.8	8.06	5.4	0.05	13.6	30.3	8.03	5.9	<0.10	13.9	31.0	8.04	5.6	0.02	14.2	32.0
Max		8.02	6.3	11.1	14.0	32.2	8.11	6.0	3.44	19.2	33.8	8.16	5.9	0.40	14.8	36.4	8.18	6.4	0.48	14.9	38.0	8.21	6.1	0.51	15.2	40.0

Note: — = All animals dead.
NT = Not taken.
0.1 replicate 5 not stocked.
0.8 replicate 2 lost due to lab error.

APPENDIX TABLE 2 (Cont'd)

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.02	6.2	0.02	14.0	32.0	8.08	5.5	0.01	13.2	31.5	8.02	5.5		13.8	32.9	8.03	6.0		14.0	35.0	8.06	6.1	0.02	14.4	36.0
	2						8.11	5.8		13.7	31.0	8.13	5.6	0.12	14.2	31.7	8.12	6.0		14.3	33.0	8.13	6.1		15.0	33.0
	3						8.10	6.0		13.8	30.9	8.12	5.7		14.2	31.8	8.11	6.0		14.4	32.0	8.12	5.8		15.2	33.0
	4						8.10	6.0		13.2	31.6	8.13	5.7		13.6	33.1	8.11	6.0	<0.10	13.9	35.0	8.13	5.6		14.6	36.0
	5						8.10	6.0		13.3	31.7	8.12	5.6		13.9	33.3	8.12	6.0		14.0	34.0	8.13	5.8		14.7	37.0
0.05	1	7.89	6.1	0.32	14.0	32.0	7.98	6.0		13.5	36.2	8.02	5.6		13.9	41.1	8.02	6.4		14.0	38.0	8.03	5.2	0.13	14.4	40.0
	2						8.03	6.2	0.17	14.5	34.0	8.11	5.6	0.12	15.0	35.4	8.13	6.4		15.2	38.0	8.15	5.6		15.2	40.0
	3						8.01	6.0		13.6	33.7	8.05	5.7		14.1	34.9	8.10	6.3		14.4	36.0	8.10	5.6		14.2	37.0
	4						8.02	6.0		13.3	34.5	8.04	5.8		13.7	36.9	8.07	6.3	<0.10	13.9	38.0	8.06	5.6		14.0	40.0
	5						8.01	6.0		13.3	34.5	8.04	5.6		13.8	36.5	8.05	6.3		14.0	38.0	8.06	5.6		14.0	40.0
0.1	I	7.96	6.0	0.56	14.0	32.2	8.02	6.1		13.3	35.0	8.03	5.4		13.7	37.8	8.04	6.2		13.9	40.0	8.06	5.8	0.12	13.9	40.0
	2						8.03	6.1	0.24	14.2	33.6	8.09	5.5	0.13	14.9	34.5	8.11	6.3		14.9	35.0	8.13	5.8		14.6	36.0
	3						8.02	6.0		13.8	34.2	8.05	5.7		14.2	36.1	8.06	6.3		14.4	38.0	8.08	5.8		14.3	40.0
	4						8.02	5.9		14.3	33.5	8.07	5.5		14.9	34.2	8.09	6.3	<0.10	15.0	35.0	8.11	5.8		14.7	36.0
	5						8.04	6.1		13.2	33.6	8.07	5.6		14.8	34.4	8.11	6.3		14.0	35.0	8.13	5.8		13.9	36.0
0.2	1	7.87	6.1	1.32	14.0	32.0	8.03	6.0		13.2	33.5	8.11	5.6		13.9	34.3	8.12	6.3		14.1	35.0	8.15	5.8	0.20	13.8	36.0
	2						8.02	6.0	0.53	13.2	33.6	8.10	5.7	0.20	13.9	34.6	8.12	6.3		14.1	35.0	8.14	5.8		13.7	37.0
	3						8.03	6.0		13.5	33.5	8.10	5.8		14.1	34.1	8.13	6.3		14.3	35.0	8.15	5.8		13.9	36.0
	4						8.01	6.0		13.5	33.7	8.09	5.8		14.0	34.8	8.12	6.3	0.22	14.3	36.0	8.14	5.8		13.9	37.0
	5						8.02	6.0		13.8	33.8	8.10	5.7		14.2	34.8	8.04	6.3		14.3	35.0	8.15	5.8		14.2	36.0
0.4	1	7.66	6.0	3.00	14.0	32.1	7.95	5.8		13.2	35.1	7.99	5.4		13.8	38.2	8.08	6.3		13.9	41.0	8.05	5.8	0.30	13.7	40.0
	2						7.97	5.8	0.86	13.2	34.5	8.06	5.3	0.32	13.9	36.3	8.10	6.3		14.1	38.0	8.08	5.8		13.7	41.0
	3						7.99	6.0		14.5	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.99	5.9		14.4	33.5	7.89	5.1		15.0	34.1	—	—	—	—	—	—	—	—	—	—
	5						7.99	5.9		14.4	33.6	8.04	5.4		14.8	34.5	8.13	6.3	0.23	14.9	35.0	8.15	5.8		15.2	36.0
0.8	1	7.35	6.0	6.34	14.0	32.0	7.88	5.4		13.5	35.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.93	5.7	1.95	14.1	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.91	5.7		13.9	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.93	5.7		13.9	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.92	5.8		14.2	33.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.5	2	7.00	5.9	14.6	14.0	32.0	7.84	5.5		14.1	33.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.80	5.4	4.23	14.2	33.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.85	5.4		13.9	33.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.85	5.4		13.9	33.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3.0	1	6.81	5.7	28.5	14.0	32.0	7.89	5.7		13.9	33.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.86	5.9	9.65	13.8	33.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.88	5.9		13.6	33.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.81	5.8		13.0	34.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.81	5.8		12.9	34.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		6.81	5.7	0.02	14.0	32.0	7.80	5.4	0.17	12.9	30.9	7.89	5.1	0.12	13.6	31.7	8.02	6.0	<0.10	13.9	32.0	8.03	5.2	0.12	13.7	33.0
Max		8.02	6.2	28.50	14.0	32.2	8.11	6.2	9.65	14.5	36.2	8.13	5.8	0.32	15.0	41.1	8.13	6.4	0.23	15.2	41.0	8.15	6.1	0.30	15.2	41.0

Note: — = All animals dead.

APPENDIX TABLE 3

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	**1**	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.05	**1**	10	10	10	10	10	100	
	2	10	10	9	9	9	90	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.1	**1**	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	9	90	
	4	10	10	10	10	10	100	97.5
0.2	**1**	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	9	9	90	98.0
0.4	**1**	10	10	10	10	10	100	
	2	10	7	6	6	6	60	
	3	10	10	8	8	8	80	
	4	10	9	9	9	9	90	
	5	10	10	9	9	9	90	84.0
0.8	**1**	10	5	3	3	1	10	
	3	10	10	9	9	9	90	
	4	10	9	1	1	0	0	
	5	10	5	5	3	3	30	32.5
1.5	**1**	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
30	**1**	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Notes: — = All animals dead.

APPENDIX TABLE 3 (Cont'd)

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.05	1	10	10	10	10	9	90	
	2	10	10	10	10	9	90	
	3	10	10	10	10	10	100	
	4	10	10	10	10	9	90	
	5	10	10	10	10	10	100	94.0
0.1	1	10	10	10	9	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.2	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	9	9	9	90	
	5	10	10	9	9	9	90	96.0
0.4	1	10	4	3	2	2	20	
	2	10	4	3	3	2	20	
	3	10	0	—	—	—	0	
	4	10	3	0	—	—	0	
	5	10	3	3	3	3	30	14.0
0.8	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
1.5	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
3	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Notes: — = All animals dead.

APPENDIX TABLE 4

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal
Control	**1**	8.02	5.8	15.9	32	7.20	5.7	15.2	31
	2					7.31	5.0	15.1	31
	3					7.31	4.7	15.1	31
1.6	**1**	8.03	5.8	15.9	32	7.49	4.7	15.1	31
	2					7.52	4.2	15.1	31
	3					7.51	4.1	15.2	31
3.1	**1**	8.03	5.8	15.9	32	7.49	4.0	15.1	31
	2					7.43	4.0	15.2	30
	3					7.51	3.9	15.1	31
6.25	**1**	8.03	5.8	15.9	32	7.49	4.1	15.1	31
	2					7.48	4.1	15.1	30
	3					7.47	4.0	15.1	31
12.5	**1**	8.04	5.8	15.9	32	7.40	3.9	15.1	31
	2					7.44	3.7	15.1	31
	3					7.51	3.7	15.1	31
25	**1**	8.03	5.7	15.9	32	7.44	3.0	15.1	31
	2					7.42	3.1	15.1	31
	3					7.36	3.2	15.0	31
Min		8.02	5.7	15.9	32	7.20	3.0	15.0	30
Max		8.04	5.8	15.9	32	7.52	5.7	15.2	31

APPENDIX TABLE 5

Citharichthys stigmaeus
SURVIVAL DATA
FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	% Survival	Average % Survival
Control	1	5	4	80	
	2	5	5	100	
	3	5	5	100	93.3
1.6	1	5	2	40	
	2	5	5	100	
	3	5	5	100	80.0
3.1	1	5	5	100	
	2	5	5	100	
	3	5	5	100	100.0
6.25	1	5	0	0	
	2	5	0	0	
	3	5	0	0	0.0
12.5	1	5	0	0	
	2	5	0	0	
	3	5	0	0	0.0
25	1	5	0	0	
	2	5	0	0	
	3	5	0	0	0.0

APPENDIX TABLE 6

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.06	5.4		18.0	32.0	8.14	5.2	<0.01	19.6	32.0	8.11	5.1		19.8	33.0	8.11	4.6	<0.10	21.7	33.9	8.08	4.9	<0.10	21.1	34.1
	2						8.13	5.2		19.9	32.0	8.08	5.2		20.1	33.0	8.07	4.6		21.6	33.6	8.07	5.1		21.1	34.1
	3						8.16	5.1		19.7	32.0	8.12	5.4		20.2	33.6	8.11	4.5		21.6	34.7	8.09	5.1		21.1	34.0
	4						8.16	5.2		19.7	32.0	8.12	5.4		20.2	33.3	8.14	4.5		21.6	33.9	8.12	5.0		21.0	33.8
	5						8.15	5.2		19.7	32.0	8.11	5.5		20.2	33.1	8.11	4.5		21.5	34.0	8.10	4.9		21.0	34.1
0.05	1	8.08	5.4	0.13	18.0	32.0	8.14	5.2	0.12	19.8	32.0	8.13	5.4	0.14	20.1	33.6	8.13	4.5	0.13	21.7	34.8	8.12	5.0	0.13	20.9	34.1
	2						8.15	5.2		19.8	32.0	8.14	5.6		20.2	32.7	8.15	4.4		21.6	33.6	8.13	5.0		21.1	34.1
	3						8.13	5.2		19.6	32.0	8.11	5.6		20.2	32.8	8.13	4.5		21.6	33.6	8.14	5.1		21.1	34.3
	4						8.10	5.0		19.6	32.0	8.11	5.6		20.1	32.3	8.12	4.5		21.4	32.8	8.12	5.1		20.0	34.2
	5						8.04	5.1		19.5	32.0	8.08	5.5		20.1	32.4	8.06	4.5		21.3	33.3	8.10	5.0		20.0	34.0
0.1	1	8.06	5.4	0.25	18.0	32.0	8.02	5.0	0.19	19.6	32.0	8.09	5.4	0.29	20.2	33.1	8.06	4.6	0.23	21.7	33.9	8.12	5.0	0.24	21.0	35.1
	2						7.92	5.0		19.6	32.0	8.03	5.4		20.1	33.1	8.02	4.4		21.5	34.1	8.10	5.1		21.0	35.0
	3						7.99	4.9		19.5	32.0	8.10	5.3		19.9	33.0	8.13	4.4		21.3	35.0	8.13	4.9		20.9	35.1
	4						8.00	5.0		19.4	32.0	8.10	5.3		19.9	33.3	8.10	4.5		21.2	34.7	8.10	5.0		20.9	35.1
	5						8.02	5.0		19.3	32.0	8.10	5.3		19.9	33.5	8.16	4.6		21.1	35.4	8.09	5.0		20.9	35.7
0.2	1	8.04	5.2	0.61	18.0	32.0	7.91	5.0	0.38	19.6	32.0	8.11	5.4	0.38	20.0	32.6	8.14	4.8	0.41	21.5	34.2	8.18	4.9	0.52	21.0	34.8
	2						7.75	4.4		19.1	32.0	8.07	5.4		19.6	36.0	8.05	4.6		20.9	41.1	8.21	5.0		21.0	41.2
	3						7.58	3.8		19.0	32.0	8.04	5.5		19.5	35.2	8.04	4.5		20.7	38.7	8.20	5.0		21.1	38.7
	4						7.76	4.2		18.9	32.0	8.06	5.5		19.6	35.6	8.05	4.5		20.9	38.3	8.17	5.1		21.0	38.9
	5						7.81	4.4		19.0	32.0	8.07	5.4		19.5	35.0	8.11	4.5		20.9	35.9	8.17	5.1		21.0	36.2
0.4	1	8.02	5.2	1.17	18.0	32.0	7.83	4.2	0.71	19.5	32.0	8.16	5.4	0.74	19.9	32.9	8.20	4.6	0.82	21.4	34.0	8.21	5.1	1.09	20.9	34.8
	2						7.87	4.6		19.5	32.0	8.18	5.4		19.9	32.9	8.20	4.6		21.0	33.7	8.18	5.2		20.9	34.0
	3						7.73	3.8		19.5	32.0	8.19	5.2		19.9	33.0	8.20	4.6		21.2	33.8	8.19	5.1		20.9	33.9
	4						7.79	4.8		19.4	32.0	8.17	5.1		19.9	32.9	8.15	4.5		21.2	33.5	8.21	5.1		20.8	33.9
	5						7.91	4.4		19.4	32.0	8.19	5.1		19.9	33.0	8.20	4.5		21.0	33.6	8.21	5.1		20.8	33.9
0.8	1	7.92	5.3	3.62	19.9	32.0	7.62	3.8	1.52	19.5	32.0	8.22	5.3	1.38	19.9	33.2	8.23	4.6	1.42	21.3	33.9	8.22	5.1	1.53	21.0	34.1
	2						7.70	3.4		19.5	32.0	8.21	5.2		19.9	32.4	8.21	4.5		21.2	33.5	8.22	5.0		21.1	34.2
	3						7.61	3.4		19.4	32.0	8.19	5.1		19.9	33.2	8.19	4.4		21.1	34.0	8.21	5.0		21.0	34.7
	4						7.82	3.8		19.4	32.0	8.22	5.0		19.9	32.9	8.23	4.4		21.2	34.0	8.27	5.1		21.0	34.7
	5						7.59	3.0		19.4	32.0	8.24	5.0		19.9	33.0	8.23	4.4		21.2	34.0	8.24	5.0		21.0	34.2
1.6	1	7.88	5.2	7.14	20.2	32.0	7.61	1.4	3.27	19.6	32.0	8.25	5.2	3.45	20.1	32.7	8.23	4.6	3.27	21.3	33.8	8.28	4.9	3.12	21.1	34.1
	2						7.67	1.8		19.4	32.0	8.25	5.1		19.9	32.9	8.22	4.5		21.1	33.7	8.24	4.9		21.1	34.2
	3						7.68	1.8		18.6	32.0	8.15	5.0		19.5	34.4	—	—	—	—	—	—	—	—	—	—
	4						7.51	0.4		19.1	32.0	8.24	5.0		19.6	32.4	—	—	—	—	—	—	—	—	—	—
	5						7.70	2.4		18.9	32.0	8.19	5.0		19.4	36.1	8.12	4.5		20.6	40.8	8.31	5.0		20.9	33.9
Min		7.88	5.2	0.13	18.0	32.0	7.51	0.4	<0.01	18.6	32.0	8.03	5.0	0.14	19.4	32.3	8.02	4.4	<0.10	20.6	32.8	8.07	4.9	<0.10	20.0	33.8
Max		8.08	5.4	7.14	20.2	32.0	8.16	5.2	3.27	19.9	32.0	8.25	5.6	3.45	20.2	36.1	8.23	4.8	3.27	21.7	41.1	8.31	5.2	3.12	21.1	41.2

Note: — = All animals dead.

APPENDIX TABLE 6 (Cont'd)

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.06	5.4		18.0	32.0	8.14	5.2	<0.01	19.6	32.0	8.11	5.1		19.8	33.0	8.11	4.6	<0.10	21.7	33.9	8.08	4.9	<0.10	21.1	34.1
	2						8.13	5.2		19.9	32.0	8.08	5.2		20.1	33.0	8.07	4.6		21.6	33.6	8.07	5.1		21.1	34.1
	3						8.16	5.1		19.7	32.0	8.12	5.4		20.2	33.6	8.11	4.5		21.6	34.7	8.09	5.1		21.1	34.0
	4						8.16	5.2		19.7	32.0	8.12	5.4		20.2	33.3	8.14	4.5		21.6	33.9	8.12	5.0		21.0	33.8
	5						8.15	5.2		19.7	32.0	8.11	5.5		20.2	33.1	8.11	4.5		21.5	34.0	8.10	4.9		21.0	34.1
0.05	1	8.04	5.2	0.13	19.9	32.0	8.00	5.0	0.11	19.2	32.0	8.11	4.9	0.12	19.9	32.7	8.12	4.6	0.12	21.1	33.6	8.18	5.0	0.11	21.0	34.1
	2						7.97	4.8		19.1	32.0	8.09	4.9		19.6	33.0	8.08	4.5		20.9	33.7	8.19	5.1		21.1	34.2
	3						7.96	4.8		18.9	32.0	8.07	4.8		19.4	34.0	8.06	4.4		20.6	34.7	8.22	5.1		21.1	34.1
	4						7.96	4.8		18.6	32.0	8.08	4.8		19.2	34.2	8.05	4.4		20.4	35.8	8.21	5.1		21.1	34.1
	5						8.03	4.9		18.6	32.0	8.09	4.8		19.3	34.4	8.04	4.5		20.4	36.6	8.19	5.0		21.0	34.2
0.1	1	8.05	5.2	0.25	19.6	32.0	8.00	5.0	0.18	19.1	32.0	8.12	4.9	0.16	19.6	34.7	8.15	4.4	0.17	20.9	36.0	8.19	5.0	0.17	21.0	36.3
	2						7.97	5.0		19.1	32.0	8.15	5.0		19.6	34.6	8.15	4.5		20.7	33.7	8.20	5.0		21.1	36.4
	3						8.01	5.0		18.9	32.0	8.15	4.9		19.4	35.4	8.15	4.6		20.5	34.7	8.16	5.0		21.1	34.7
	4						7.97	4.9		18.8	32.0	8.15	4.9		19.4	35.2	8.14	4.4		20.3	36.0	8.17	5.0		21.1	35.2
	5						8.07	4.9		18.7	32.0	8.17	5.0		19.3	34.6	8.18	4.4		20.2	39.0	8.19	5.0		21.1	39.7
0.2	1	7.96	5.2	0.61	20.1	32.0	7.74	4.4	0.57	19.0	32.0	8.16	5.0	0.30	18.7	31.8	8.14	4.4	0.32	19.4	32.5	8.21	5.0	0.39	21.1	33.4
	2						7.78	4.6		19.1	32.0	8.15	4.9		18.7	32.5	8.13	4.5		19.4	32.8	8.09	5.1		21.0	34.2
	3						7.81	4.5		18.9	32.0	8.14	5.0		18.6	32.4	8.15	4.4		19.2	32.9	8.21	4.9		21.0	34.1
	4						7.85	4.6		18.8	32.0	8.16	5.0		18.4	32.4	8.16	4.4		19.1	33.7	8.23	4.9		21.0	34.1
	5						7.81	4.6		18.6	32.0	8.15	5.0		18.4	33.7	8.15	4.5		19.1	35.1	8.16	5.1		21.1	34.2
0.4	1	7.92	5.2	1.17	20.2	32.0	7.76	3.6	1.08	19.1	31.0	8.15	5.0	1.10	18.9	31.5	8.19	4.6	1.20	19.5	32.4	8.23	5.1	1.16	21.1	33.7
	2						7.75	3.6		19.1	32.0	8.16	5.0		18.6	33.9	8.14	4.5		19.5	35.9	8.18	5.1		21.1	36.2
	3						7.59	1.8		18.7	32.0	8.14	5.0		18.4	34.1	8.10	4.4		19.2	36.5	8.19	5.1		21.1	37.0
	4						7.73	3.4		18.6	32.0	8.16	5.0		18.4	33.7	8.14	4.3		19.2	35.1	8.19	5.0		21.1	36.1
	5						7.80	3.6		18.6	32.0	8.16	5.0		18.5	33.8	8.16	4.3		19.2	35.6	8.22	5.0		21.1	36.1
0.8	1	7.79	5.2	3.62	20.2	32.0	7.52	1.2	2.17	19.0	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.61	1.8		19.0	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.54	2.2		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.71	2.2		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.66	2.6		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.6	1	7.67	5.0	7.14	20.0	32.0	7.58	2.8	4.43	19.0	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.39	2.6		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.46	1.4		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.38	1.6		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.49	1.6		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		7.67	5.0	0.13	18.0	32.0	7.38	1.2	<0.01	18.6	31.0	8.07	4.8	0.12	18.4	31.5	8.04	4.3	<0.10	19.1	32.4	8.07	4.9	<0.10	21.0	33.4
Max		8.06	5.4	7.14	20.2	32.0	8.16	5.2	4.43	19.9	32.0	8.17	5.5	1.10	20.2	35.4	8.19	4.6	1.20	21.7	39.0	8.23	5.1	1.16	21.1	39.7

Note: — = All animals dead.

APPENDIX TABLE 7

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	**1**	10	10	10	9	10	100	
	2	10	10	10	10	9	90	
	3	10	10	10	9	9	90	
	4	10	10	10	10	9	90	
	5	10	10	10	10	9	90	92.0
0.05	**1**	10	9	9	9	9	90	
	2	10	10	10	9	8	80	
	3	10	10	8	8	7	70	
	4	10	9	7	7	6	60	
	5	10	10	9	8	9	90	78.0
0.1	**1**	10	6	5	2	6	60	
	2	10	10	9	5	8	80	
	3	10	8	8	7	6	60	
	4	10	8	6	7	8	80	
	5	10	9	8	8	6	60	68.0
0.2	**1**	10	9	8	4	7	70	
	2	10	8	7	5	7	70	
	3	10	9	7	7	8	80	
	4	10	9	8	7	8	80	
	5	10	10	9	8	8	80	76.0
0.4	**1**	10	8	7	5	6	60	
	2	10	8	7	6	6	60	
	3	10	8	8	6	6	60	
	4	10	8	7	7	8	80	
	5	10	10	9	8	7	70	66.0
0.8	**1**	10	5	*	*	3	30	
	2	10	4	*	*	3	30	
	3	10	6	*	*	3	30	
	4	10	4	*	*	3	30	
	5	10	3	*	*	0	0	24.0
1.6	**1**	10	3	*	*	0	0	
	2	10	2	*	*	0	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	1	*	*	0	0	0.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 7 (Cont'd)

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	**1**	10	10	10	9	10	100	
	2	10	10	10	10	9	90	
	3	10	10	10	9	9	90	
	4	10	10	10	10	9	90	
	5	10	10	10	10	9	90	92.0
0.05	**1**	10	10	10	10	9	90	
	2	10	9	9	8	6	60	
	3	10	10	9	8	7	70	
	4	10	8	8	8	5	50	
	5	10	9	8	8	6	60	66.0
0.1	**1**	10	7	7	7	6	60	
	2	10	8	7	5	4	40	
	3	10	7	6	4	7	70	
	4	10	8	7	4	4	40	
	5	10	7	7	6	3	30	48.0
0.2	**1**	10	6	4	2	2	20	
	2	10	5	5	4	2	20	
	3	10	6	6	3	5	50	
	4	10	6	6	4	6	60	
	5	10	5	4	2	4	40	38.0
0.4	**1**	10	5	*	*	1	10	
	2	10	3	*	*	2	20	
	3	10	4	*	*	1	10	
	4	10	3	*	*	0	0	
	5	10	3	*	*	0	0	8.0
0.8	**1**	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
1.6	**1**	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 8

Mysidopsis bahia
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1				Day 2				Day 3				Day 4			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal
Control	1	8.03	5.6	20.9	32.0	8.00	4.8	21.2	32.0	7.67	5.4	21.6	33.0	7.90	3.8	21.6	33.9	7.93	4.1	21.1	34.0
	2					8.02	4.8	21.2	32.0	7.72	5.4	21.5	33.0	7.91	3.7	21.6	30.9	7.94	4.0	21.1	34.1
	3					8.03	4.8	21.3	32.0	7.70	5.3	21.6	33.0	7.90	3.8	21.8	33.8	7.94	4.0	21.1	34.2
1.25	1	8.04	5.4	20.9	32.0	8.00	4.8	21.3	32.0	7.58	5.2	21.6	33.0	7.90	3.6	21.8	33.8	7.94	4.0	20.9	34.1
	2					8.02	4.8	21.2	32.0	7.54	5.1	21.6	33.0	7.93	3.5	21.8	33.7	7.93	4.0	21.0	34.3
	3					8.03	4.8	21.2	32.0	7.38	5.1	21.6	33.0	7.95	3.5	21.7	33.8	7.95	3.9	21.0	34.7
2.5	1	8.04	5.4	20.9	32.0	8.01	4.8	21.3	32.0	7.62	5.1	21.6	33.0	7.96	3.6	21.8	33.8	7.99	3.9	20.9	34.1
	2					8.02	4.8	21.1	32.0	7.42	5.1	21.6	33.0	7.93	3.6	21.8	33.6	7.92	3.8	20.9	34.0
	3					8.02	4.6	21.1	32.0	7.47	5.0	21.6	33.0	7.93	3.6	21.7	33.9	7.91	3.8	21.0	33.9
5	1	8.04	5.4	21.1	32.0	8.00	4.8	21.1	32.0	7.32	4.7	21.6	33.0	7.98	3.7	21.8	33.1	7.92	3.8	21.0	33.8
	2					8.00	4.7	21.1	32.0	7.38	4.8	21.6	33.0	7.92	3.5	21.8	33.0	7.92	3.9	21.0	33.7
	3					7.98	4.7	21.1	32.0	7.31	4.6	21.5	33.0	7.92	3.5	21.8	33.9	7.91	3.9	21.0	33.9
10	1	8.03	5.4	21.2	32.0	7.91	4.6	21.2	32.0	7.30	4.1	21.5	33.0	7.86	3.6	21.9	33.7	7.89	3.9	20.9	34.0
	2					7.91	4.5	21.2	32.0	7.31	4.2	21.5	33.0	7.88	3.6	21.9	33.8	7.89	3.9	20.9	33.9
	3					7.91	4.3	21.2	32.0	7.31	4.2	21.6	33.0	7.87	3.6	22.0	33.6	7.91	3.9	21.0	34.1
20	1	8.02	5.3	20.8	32.0	7.85	4.4	20.9	32.0	7.20	4.0	21.6	33.0	7.78	3.7	21.8	33.4	7.90	3.9	21.0	33.9
	2					7.85	4.4	20.9	32.0	7.21	4.0	21.6	33.0	7.75	3.8	21.8	33.4	7.88	3.8	21.0	33.4
	3					7.86	4.2	20.9	32.0	7.21	4.0	21.5	33.0	7.78	3.8	21.8	33.2	7.88	3.9	21.0	33.9
Min		8.02	5.3	20.8	32.0	7.85	4.2	20.9	32.0	7.20	4.0	21.5	33.0	7.75	3.5	21.6	30.9	7.88	3.8	20.9	33.4
Max		8.04	5.6	21.2	32.0	8.03	4.8	21.3	32.0	7.72	5.4	21.6	33.0	7.98	3.8	22.0	33.9	7.99	4.1	21.1	34.7

APPENDIX TABLE 9

Mysidopsis bahia
SURVIVAL DATA FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	**1**	10	10	10	9	9	90	
	2	10	10	10	10	9	90	
	3	10	10	10	9	9	90	90.0
1.25	**1**	10	9	9	8	7	70	
	2	10	10	9	6	6	60	
	3	10	9	8	8	8	80	70.0
2.5	**1**	10	9	8	6	5	50	
	2	10	10	8	6	6	60	
	3	10	10	8	6	6	60	56.7
5	**1**	10	11	9	5	5	50	
	2	10	9	7	5	4	40	
	3	10	10	9	7	5	50	46.7
10	**1**	10	10	9	7	5	50	
	2	10	9	9	4	4	40	
	3	10	9	7	5	5	50	46.7
20	**1**	10	7	5	3	2	20	
	2	10	10	8	7	5	50	
	3	10	10	8	5	4	40	36.7

APPENDIX TABLE 10

Strongylocentrotus purpuratus
WATER QUALITY MEASUREMENTS FOR THE EFFLUENT TEST
Test Dates: 4/7-4/11/94

Site	Concentration (%)	Day 0 °C	Day 0 DO	Day 0 pH	Day 0 Sal	Day 1 °C	Day 1 DO	Day 1 pH	Day 1 Sal	Day 2 °C	Day 2 DO	Day 2 pH	Day 2 Sal	Day 3 °C	Day 3 DO	Day 3 pH	Day 3 Sal	Day 4 °C	Day 4 DO	Day 4 pH	Day 4 Sal
Control		16.3	8.0	7.49	26	15.1	8.7	7.77	27	16.2	8.4	7.87	26	15.4	8.4	7.79	26	15.7	8.2	7.89	27
HSW-1	0.08	16.0	8.1	7.42	26	14.5	8.6	7.62	27	15.6	8.4	7.86	26	15.6	7.7	7.84	26	15.9	8.1	7.88	26
	0.15	16.0	8.0	7.43	27	14.5	6.6	7.51	27	15.5	7.4	7.80	27	15.6	6.5	7.80	27	15.7	8.1	7.85	27
	0.3	16.2	8.0	7.83	29	14.5	4.5	7.54	29	15.7	2.2	7.59	28	15.5	3.0	7.47	28	15.8	7.8	7.65	29
	0.6	16.2	8.0	7.51	26	14.5	4.1	7.51	27	15.9	2.3	7.56	26	15.6	2.7	7.49	26	15.7	7.4	7.93	27
	1.2	16.4	8.0	7.62	26	14.5	1.5	7.10	29	15.6	1.3	7.46	28	15.7	1.7	7.51	27	15.1	7.4	7.97	29
HSW-2	0.08	16.2	8.0	7.33	26	14.5	1.2	7.41	27	15.3	7.7	7.93	27	15.6	7.9	7.80	27	15.2	7.6	7.95	27
	0.15	16.4	8.0	7.34	27	14.5	1.6	7.42	27	15.5	7.7	7.96	27	15.7	7.3	7.77	27	15.0	7.8	7.95	27
	0.3	16.4	8.0	7.21	27	14.5	1.3	7.45	27	15.6	7.8	7.82	27	15.6	6.9	7.79	27	15.0	7.8	7.97	27
	0.6	16.0	8.0	7.21	26	15.7	1.3	7.42	27	16.2	3.0	7.52	27	15.7	2.7	7.47	27	16.2	6.6	7.71	27
	1.2	16.2	7.9	6.87	26	15.7	1.3	7.10	27	16.1	1.4	7.42	27	15.7	1.7	7.38	27	16.2	6.4	7.63	27
	Min	16.0	7.9	6.87	26	14.5	1.2	7.10	27	15.3	1.3	7.42	26	15.4	1.7	7.38	26	15.0	6.4	7.63	26
	Max	16.4	8.1	7.83	29	15.7	8.7	7.77	29	16.2	8.4	7.96	28	15.7	8.4	7.84	28	16.2	8.2	7.97	29

APPENDIX TABLE 11

Strongylocentrotus purpuratus
SUMMARY OF SURVIVAL AND DEVELOPMENT FOR THE ECHINODERM LARVAE EFFLUENT TEST
Test Dates: 4/7-4/11/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
Initial Counts	1	156		31.2			
	2	136		27.2			
	3	141		28.2			
	4	168		33.6			
	5	137		27.4			
	Mean			29.5			
Final Control	1	95	14	21.8		12.8	
	2	59	4	12.6		6.3	
	3	109	7	23.2		6.0	
	4	94	1	19.0		1.1	
	5	90	2	18.4		2.2	
	Mean			19.0	64.4	5.7	NA
HSW-1 0.08	1	45	32	15.4		41.6	
	2	63	53	23.2		45.7	
	3	66	43	21.8		39.4	
	4	76	38	22.8		33.3	
	5	78	40	23.6		33.9	
	Mean			21.4	72.4	38.8	0.0
0.15	1	0	79	15.8		100.0	
	2	0	48	9.6		100.0	
	3	0	44	8.8		100.0	
	4	0	89	17.8		100.0	
	5	0	99	19.8		100.0	
	Mean			14.4	48.7	100.0	24.4
0.3	1	0	50	10.0		100.0	
	2	0	53	10.6		100.0	
	3	0	57	11.4		100.0	
	4	0	84	16.8		100.0	
	5	0	58	11.6		100.0	
	Mean			12.1	40.9	100.0	36.4
0.6	1	0	66	13.2		100.0	
	2	0	85	17.0		100.0	
	3	0	74	14.8		100.0	
	4	0	112	22.4		100.0	
	5	0	57	11.4		100.0	
	Mean			15.8	53.4	100.0	17.1
1.2	1	0	106	21.2		100.0	
	2	0	115	23.0		100.0	
	3	0	92	18.4		100.0	
	4	0	60	12.0		100.0	
	5	0	114	22.8		100.0	
	Mean			19.5	66.0	100.0	100.0

APPENDIX TABLE 11 (Cont'd)

Strongylocentrotus purpuratus

SUMMARY OF SURVIVAL AND DEVELOPMENT FOR THE ECHINODERM LARVAE EFFLUENT TEST

Test Dates: 4/7-4/11/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
HSW-2							
0.08	1	0	63	12.6		100.0	
	2	0	61	12.2		100.0	
	3	0	39	7.8		100.0	
	4	0	36	7.2		100.0	
	5	0	58	11.6		100.0	
	Mean			10.3	34.8	100.0	45.9
0.15	1	0	101	20.2		100.0	
	2	0	112	22.4		100.0	
	3	0	129	25.8		100.0	
	4	0	122	24.4		100.0	
	5	0	130	26.0		100.0	
	Mean			23.8	80.5	100.0	0.0
0.3	1	0	89	17.8		100.0	
	2	0	128	25.6		100.0	
	3	0	119	23.8		100.0	
	4	0	119	23.8		100.0	
	5	0	91	18.2		100.0	
	Mean			21.8	74.0	100.0	0.0
0.6	1	0	116	23.2		100.0	
	2	0	119	23.8		100.0	
	3	0	113	22.6		100.0	
	4	0	79	15.8		100.0	
	5	0	104	20.8		100.0	
	Mean			21.2	72.0	100.0	0.0
1.2	1	0	76	15.2		100.0	
	2	0	87	17.4		100.0	
	3	0	92	18.4		100.0	
	4	0	88	17.6		100.0	
	5	0	76	15.2		100.0	
	Mean			16.8	56.8	100.0	11.8

APPENDIX TABLE 12

Strongylocentrotus purpuratus
WATER QUALITY MEASUREMENTS FOR THE REFERENCE TOXICANT (C0PPER) TEST
Test Dates: 4/7-4/11/94

Concentration	Day 0				Day 1				Day 2				Day 3				Day 4			
(µg/L)	°C	DO	pH	Sal	°C	DO	pH	Sal	°C	DO	pH	Sal	°C	DO	pH	Sal	°C	DO	pH	Sal
0.1	15.6	8.9	7.88	29	14.3	NT	NT	NT	14.2	8.1	7.97	29	14.4	8.4	8.01	29	15.0	7.6	7.98	29
0.32	15.8	8.9	7.90	29	14.3	NT	NT	NT	14.2	8.1	8.00	29	14.4	8.4	8.04	29	15.0	7.7	7.99	29
1.8	15.8	8.9	7.92	29	14.4	NT	NT	NT	14.3	8.3	8.02	29	14.5	8.3	8.06	29	14.9	7.9	8.00	29
18	15.8	9.1	7.80	28	14.3	NT	NT	NT	14.2	8.3	8.01	28	14.5	8.3	8.06	29	15.0	7.9	8.00	29
56	15.8	9.1	7.86	26	14.4	NT	NT	NT	14.2	8.6	8.02	25	14.5	8.3	8.06	29	15.0	8.0	8.01	25
Min	15.6	8.9	7.80	26	14.3				14.2	8.1	7.97	25	14.4	8.3	8.01	29	14.9	7.6	7.98	25
Max	15.8	9.1	7.92	29	14.4				14.3	8.6	8.02	29	14.5	8.4	8.06	29	15.0	8.0	8.01	29

Note: NT = Not taken.

APPENDIX TABLE 13

Strongylocentrotus purpuratus

SUMMARY OF SURVIVAL AND DEVELOPMENT FOR THE ECHINODERM LARVAE

REFERENCE TOXICANT (Copper) TEST

Test Dates: 4/7-4/11/94

Concentration (µg/L)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
Copper							
0.1	1	78	14	18.4		15.2	
	2	86	19	21.0		18.1	
	3	86	12	19.6		12.2	
	Mean			19.7	66.7	15.2	0.0
0.32	1	26	1	5.4		3.7	
	2	33	1	6.8		2.9	
	3	96	0	19.2		0.0	
	Mean			10.5	35.5	2.2	44.9
1.8	1	69	4	14.6		5.5	
	2	60	2	12.4		3.2	
	3	96	4	20.0		4.0	
	Mean			15.7	53.1	4.2	17.5
18	1	3	51	10.8		94.4	
	2	0	31	6.2		100.0	
	3	0	28	5.6		100.0	
	Mean			7.5	25.5	98.1	60.4
56	1	0	38	7.6		100.0	
	2	0	24	4.8		100.0	
	3	0	48	9.6		100.0	
	Mean			7.3	24.9	100.0	61.4

APPENDIX TABLE 14

Mytilus edulis

WATER QUALITY MEASUREMENTS FOR THE EFFLUENT TEST

Test Dates: 4/7-4/9/94

Concentration		Day 0				Day 1	Day 2			
(%)	Rep	°C	DO	pH	Sal	°C	°C	DO	pH	Sal
Control	1	16.3	8.0	7.49	26	14.8	16.0	7.2	7.79	26
	2					14.6	16.0	7.2	7.82	26
	3					14.5	16.0	7.5	7.82	26
	4					14.7	16.0	7.5	7.88	26
	5					14.8	16.0	7.6	7.96	26
HSW-1										
0.08	1	16.0	8.1	7.42	26	14.5	16.0	7.6	7.68	26
	2					14.5	16.0	7.5	7.65	26
	3					14.4	16.1	7.3	7.67	26
	4					14.5	16.0	7.2	7.66	26
	5					14.5	16.1	7.1	7.66	26
0.15	1	16.0	8.0	7.43	27	14.5	16.0	4.0	7.46	26
	2					14.4	16.0	4.0	7.40	26
	3					14.4	16.0	3.8	7.38	26
	4					14.4	16.0	3.8	7.38	26
	5					14.5	16.0	3.6	7.40	26
0.3	1	16.2	8.0	7.83	29	14.4	16.0	2.0	7.44	28
	2					14.5	16.0	2.0	7.52	28
	3					14.5	16.0	1.8	7.54	28
	4					14.4	16.0	1.8	7.56	28
	5					14.5	16.0	1.5	7.55	28
0.6	1	16.2	8.0	7.51	26	14.5	16.0	1.6	7.56	26
	2					14.5	16.0	1.7	7.58	26
	3					14.5	16.0	1.7	7.60	26
	4					14.6	16.1	2.1	7.61	26
	5					14.5	16.1	2.0	7.60	26
1.2	1	16.4	8.0	7.62	26	14.4	16.0	4.2	7.62	26
	2					14.5	16.0	4.4	7.67	26
	3					14.5	16.0	4.3	7.64	26
	4					14.5	16.1	4.5	7.67	26
	5					14.5	16.1	4.6	7.83	26
	Min	16.0	8.0	7.42	26	14.4	16.0	1.5	7.38	26
	Max	16.4	8.1	7.83	29	14.8	16.1	7.6	7.96	28

APPENDIX TABLE 14 (Cont'd)

Mytilus edulis

WATER QUALITY MEASUREMENTS FOR THE EFFLUENT TEST

Test Dates: 4/7-4/9/94

Concentration (%)	Rep	Day 0 °C	Day 0 DO	Day 0 pH	Day 0 Sal	Day 1 °C	Day 2 °C	Day 2 DO	Day 2 pH	Day 2 Sal
HSW-2										
0.08	1	16.2	8.0	7.33	26	14.5	16.0	7.4	7.93	26
	2					14.6	16.0	7.7	7.92	26
	3					14.5	16.0	7.5	7.95	26
	4					14.5	16.1	7.5	7.97	26
	5					14.5	16.1	7.6	7.98	27
0.15	1	16.4	8.0	7.34	27	14.5	16.0	7.8	7.91	26
	2					14.5	16.0	8.0	7.94	26
	3					14.4	16.1	8.0	7.94	26
	4					14.5	16.1	7.9	7.86	26
	5					14.5	16.1	7.7	7.85	26
0.3	1	16.4	8.0	7.21	27	14.5	16.0	7.7	7.83	26
	2					14.5	16.0	7.7	7.86	26
	3					14.5	16.0	7.7	7.77	26
	4					14.5	16.1	7.6	7.59	26
	5					14.5	16.1	7.2	7.62	26
0.6	1	16.0	8.0	7.21	26	14.5	16.0	1.7	7.56	26
	2					14.6	16.1	1.7	7.53	26
	3					14.5	16.1	1.8	7.51	26
	4					14.6	16.1	1.8	7.51	26
	5					14.5	16.1	1.8	7.50	26
1.2	1	16.2	7.9	6.87	26	14.5	16.0	2.0	7.47	26
	2					14.5	16.1	1.7	7.37	26
	3					14.5	16.1	1.6	7.39	26
	4					14.5	16.1	2.0	7.42	26
	5					14.5	16.1	2.0	7.45	26
	Min	16.0	7.9	6.87	26	14.4	16.0	1.6	7.37	26
	Max	16.4	8.0	7.34	27	14.6	16.1	8.0	7.98	27

APPENDIX TABLE 15

Mytilus edulis
SUMMARY OF RESULTS FOR BIVALVE LARVAE BIOASSAY
Test Dates: 4/7-4/9/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
Initial Counts	1	129		25.8			
	2	95		19.0			
	3	102		20.4			
	4	76		15.2			
	5	115		23.0			
	Mean			20.7			
Final Control	1	103	13	23.2		11.2	
	2	97	3	20.0		3.0	
	3	86	5	18.2		5.5	
	4	83	5	17.6		5.7	
	5	106	7	22.6		6.2	
	Mean			20.3	98.2	6.3	NA
HSW-1 0.08	1	22	61	16.6		73.5	
	2	2	78	16.0		97.5	
	3	0	72	14.4		100.0	
	4	0	77	15.4		100.0	
	5	5	67	14.4		93.1	
	Mean			15.4	74.2	92.8	24.3
0.15	1	0	74	14.8		100.0	
	2	0	76	15.2		100.0	
	3	0	64	12.8		100.0	
	4	0	86	17.2		100.0	
	5	0	61	12.2		100.0	
	Mean			14.4	69.8	100.0	28.9
0.3	1	0	139	27.8		100.0	
	2	0	120	24.0		100.0	
	3	0	133	26.6		100.0	
	4	0	91	18.2		100.0	
	5	0	82	16.4		100.0	
	Mean			22.6	100.0	100.0	0.0
0.6	1	0	73	14.6		100.0	
	2	0	133	26.6		100.0	
	3	0	90	18.0		100.0	
	4	0	96	19.2		100.0	
	5	0	93	18.6		100.0	
	Mean			19.4	93.7	100.0	4.4
1.2	1	0	90	18.0		100.0	
	2	0	75	15.0		100.0	
	3	0	87	17.4		100.0	
	4	0	80	16.0		100.0	
	5	0	91	18.2		100.0	
	Mean			16.9	81.7		16.7

APPENDIX TABLE 15 (Cont'd)

Mytilus edulis
SUMMARY OF RESULTS FOR BIVALVE LARVAE BIOASSAY
Test Dates: 4/7-4/9/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
HSW-2							
0.08	1	0	109	21.8		100.0	
	2	1	84	17.0		98.8	
	3	0	100	20.0		100.0	
	4	0	110	22.0		100.0	
	5	0	95	19.0		100.0	
	Mean			20.0	96.4	99.8	1.7
0.15	1	0	100	20.0		100.0	
	2	0	90	18.0		100.0	
	3	0	111	22.2		100.0	
	4	0	89	17.8		100.0	
	5	0	115	23.0		100.0	
	Mean			20.2	97.6	100.0	0.5
0.3	1	0	82	16.4		100.0	
	2	0	101	20.2		100.0	
	3	0	97	19.4		100.0	
	4	0	89	17.8		100.0	
	5	0	104	20.8		100.0	
	Mean			18.9	91.4	100.0	6.8
0.6	1	0	144	28.8		100.0	
	2	0	128	25.6		100.0	
	3	0	94	18.8		100.0	
	4	0	103	20.6		100.0	
	5	0	119	23.8		100.0	
	Mean			23.5	100.0	100.0	0.0
1.2	1	0	81	16.2		100.0	
	2	0	94	18.8		100.0	
	3	0	104	20.8		100.0	
	4	0	88	17.6		100.0	
	5	0	87	17.4		100.0	
	Mean			18.2	87.7	100.0	10.5

APPENDIX TABLE 16

Mytilus edulis
WATER QUALITY MEASUREMENTS
FOR THE REFERENCE TOXICANT (C0PPER) TEST
Test Dates: 4/7-4/9/94

Concentration		Day 0				Day 1	Day 2			
µg/L	Rep	°C	DO	pH	Sal	°C	°C	DO	pH	Sal
0.56	1	15.8	9.2	7.91	30	14.3	14.0	7.7	7.95	28
	2					14.3	14.0	7.8	7.96	29
	3					14.3	14.0	7.9	7.96	29
3.2	1	15.7	8.9	7.91	29	14.3	14.1	7.9	7.96	28
	2					14.3	14.0	7.9	7.96	29
	3					14.2	14.0	8.1	7.96	29
10	1	15.6	8.7	7.92	29	14.3	14.0	8.0	7.96	28
	2					14.4	14.1	8.0	7.97	28
	3					14.3	14.1	8.1	7.97	28
32	1	15.6	9.7	7.78	26	14.3	14.0	8.0	7.97	26
	2					14.3	14.1	8.1	7.96	26
	3					14.3	14.1	8.1	7.95	26
56	1	15.8	9.1	7.86	26	14.4	14.0	8.3	7.95	25
	2					14.3	14.0	8.1	7.96	25
	3					14.4	14.0	8.1	7.96	25
	Min	15.6	8.7	7.78	26	14.2	14.0	7.7	7.95	25
	Max	15.8	9.7	7.92	30	14.4	14.1	8.3	7.97	29

APPENDIX TABLE 17

Mytilus edulis
SUMMARY OF RESULTS FOR THE BIVALVE LARVAE
REFERENCE TOXICANT (COPPER) BIOASSAY
Test Dates: 4/7-4/9/94

Concentration (µg/L)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
0.56	1	92	5	19.4		5.2	
	2	76	3	15.8		3.8	
	3	86	6	18.4		6.5	
	Mean			17.9	86.3	5.2	12.0
3.2	1	99	24	24.6		19.5	
	2	95	22	23.4		18.8	
	3	89	17	21.2		16.0	
	Mean			23.1	100.0	18.1	0.0
10	1	88	16	20.8		15.4	
	2	11	91	20.4		89.2	
	3	29	45	14.8		60.8	
	Mean			18.7	90.2	55.1	8.0
32	1	0	34	6.8		100.0	
	2	0	12	2.4		100.0	
	3	0	50	10.0		100.0	
	Mean			6.4	30.9	100.0	68.5
56	1	0	0	0.0		100.0	
	2	0	6	1.2		100.0	
	3	0	13	2.6		100.0	
	Mean			1.3	6.1	100.0	93.8

Appendix 6
Laboratory Results Submitted by ABT - Second Test

RESULTS OF BIOASSAYS CONDUCTED ON TWO HIGH STRENGTH WASTE SAMPLES FROM THE VAN CAMP AND STARKIST TUNA CANNERIES IN AMERICAN SAMOA

Prepared for:

CH2M Hill California, Inc.
1111 Broadway
Oakland, CA 94607
Project # PDX 30702

Prepared by:

Advanced Biological Testing Inc.
98 Main St., # 419
Tiburon, Ca. 94920

November 21, 1994

Ref: 9309-3

1.0 INTRODUCTION

At the request of CH2M Hill (Project # PDX 30702), Advanced Biological Testing conducted acute effluent bioassay testing on *Mysidopsis bahia*, *Mytilus edulis*, and *Citharichthys stigmaeus* using high strength wastes (HSW) collected separately from the Starkist (HSW-1) and Van Camp (HSW-2) tuna canneries in American Samoa. The study was run using methods generally specified in EPA 1991 and in a Sampling and Testing Plan submitted to the EPA.

The study was conducted at the Advanced Biological Testing Laboratory in Tiburon, California, and was managed by Mr. Mark Fisler.

2.0 METHODS

2.1 EFFLUENT SAMPLING

The high strength wastes were sampled as composites on October 20, 1994 by personnel from the two canneries. Due to shipping and airline scheduling problems, frequently encountered in this region, the sample was received by the laboratory on October 24, 1994. A single gallon carboy was provided from each cannery and were labeled at ABT as HSW-1 (HSW-SKS Grab) and HSW-2 (Pipeline Sludge HS-W2, Van Camp). Samples were maintained in ice-filled coolers from the date of sampling until laboratory receipt. The samples were at 2-3°C upon receipt and were stored at 4°C until use.

2.2 SAMPLE PREPARATION AND TESTING METHODS

2.2.1 Testing on the speckled sanddab, *Citharichthys stigmaeus*

In agreement with the EPA regarding the proposed testing concentrations, the high strength wastes were tested at six concentrations starting from 2.0% and dropping using a 50% dilution factor. The final concentrations were 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% as vol:vol dilutions in seawater. The diluent was filtered seawater from San Francisco Bay. The dilutions were brought up to the test temperature (17 ± 2°C) and aerated continuously. These effluents have an extremely high biological oxygen demand, therefore aeration was carried out from the beginning of the test.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 25, 12.5, 6.25, 3.1, and 1.6 mg/L in 30 ppt seawater in a 24 hour test.

The bioassays were carried out on juvenile *Citharichthys stigmaeus*, supplied by J. Brezina and Associates in Dillon Beach, California. The animals were received at ABT on October 24, 1994. The test conditions are summarized in Table 1. Five replicates of each concentration were tested with ten juvenile fish per replicate. Water quality was monitored daily as initial quality on Day 0 and final water quality on Days 1-4. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature.

2.2.2 Testing on the mysid, *Mysidopsis bahia*

In agreement with the EPA regarding the proposed testing concentrations, the high strength wastes were tested at six concentrations starting from 2.0% and dropping using a 50% dilution factor. The final concentrations were 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% as vol:vol dilutions in seawater. The diluent was filtered seawater from San Francisco Bay The dilutions were brought up to the test temperature (16 ± 2°C) and aerated continuously.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 40, 20, 10, 5, 2.5 and 1.25 mg/L in 30 ppt seawater in a 96 hour test.

The first bioassay was carried out on 7-10 day old larval *Mysidopsis bahia*, supplied by Aquatox from Hot Springs, Arkansas. The animals were received at ABT on November 1, 1994. The test conditions for this test are summarized in Table 2. Five replicates of each concentration were tested with ten larval mysids per replicate. Water quality was monitored daily as initial quality on Day 0 and final water quality on Days 1-4. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature.

2.2.3 Bivalve Larval Bioassay

Test solutions used in the bioassays were prepared using San Francisco Bay seawater at 30 ppt in serial dilution (0.5) to create 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% test concentrations for the bioassays. The bivalve study was conducted under ASTM 1993 guidelines.

The reference toxicant for the bivalve larval bioassays was copper sulfate at test concentrations of 3.75, 7.5, 15, 30, and 60 µg/L.

The bivalve larvae survival and development test was run following methods in ASTM (1993). Bay mussels, *Mytilus edulis,* were obtained from A. K. Siewers, Santa Cruz, California. Adults were induced to spawn by heat shocking. Released gametes were placed in individual containers of filtered seawater and examined for viability. Gametes were mixed and allowed to fertilize for up to two hours, under gentle aeration. Fertilized eggs were then separated from sperm and debris by filtering the suspension at 20 µm. Egg stock density was estimated by counting an aliquot of dilute stock concentrate. Equal volumes of concentrate were added to each replicate to

an initial density of 15-30 embryos per mL. Initial stocking density was confirmed by counting a 5 mL aliquot from at least three control replicates.

Testing was conducted at 16 ± 2°C under a 14 hour light and 10 hour dark photoperiod. Temperature, pH, dissolved oxygen, and salinity were recorded at 0 and 48 hours; temperature was also recorded at 24 hours. Total ammonia in the 2% concentration was 3.6 mg/L at test initiation for HSW-1 and 6.1 mg/L for HSW-2. Ammonia was not measured on Day 2. At the end of the exposure period, a 5 mL sub-sample was taken from each test replicate and preserved with buffered formalin. Sub-samples were counted in a Sedgwick-Rafter cell, and the total number of normal and abnormal larvae were counted.

Gentle aeration was initiated on Day 0, and continued for the duration of the tests. To assess the effects of aeration, an aeration control was run simultaneously. No statistical differences were observed between aerated and unaerated controls.

2.3 STATISTICAL ANALYSIS

At the conclusion of the testing, the survival data were evaluated statistically using ToxCalc™ to determine ECp, NOEC, and LOEC values where appropriate. ToxCalc™ is a comprehensive statistical application that follows standard guidelines for acute and chronic toxicity data analysis. Data were evaluated statistically to estimate the LC50 and IC50 values for the tests using the Probit or Trimmed Spearman-Karber Method.

3.0 RESULTS

3.1 Initial Effluent Quality

The two High Strength Wastes were tested for basic water quality parameters upon receipt at the laboratory. HSW-1 had a dissolved oxygen level of 0.7 mg/L; a pH of 6.53; a salinity of 23.5 ppt; and a total ammonia level of 480 mg/L. HSW-2 had a dissolved oxygen level of 0.6 mg/L; a pH of 6.39; a salinity of 14.0 ppt; and a total ammonia level of 350 mg/L.

3.1 *Citharichthys stigmaeus*

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 17 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected after test initiation in all of the concentration even with supplemental aeration and aeration was maintained in all chambers for the duration of the test. Ammonia was measured in all replicates from each concentration daily and was a potentially significant toxic component of the test for the highest three concentrations.

The LC50 for HSW-1 was 0.35% based upon a Trimmed Spearman-Karber method. The majority of the observed toxicity again occurred in the first 24 hours. There was significant mortality at 2.0, 1.0, and 0.5% concentrations compared to the control at 96 hours. The NOEC was 0.25% and the LOEC was 0.5%

The LC50 for HSW-2 was 0.37% based upon a Trimmed Spearman-Karber method. The majority of the observed toxicity occurred in the first 24 hours. There was significant mortality at 2.0, 1.0, and 0.5% concentrations compared to the control at 96 hours. The NOEC was 0.25%, and the LOEC was 0.5%.

The reference toxicant test required the use of the Trimmed Spearman-Karber method and generated an LC50 of 3.9 mg/L, an NOEC of 3.1 mg/L, and an LOEC of 6.25 mg/L. This is the third reference toxicant test on *Citharichthys* at this laboratory, therefore no database has been established by this laboratory although the data has been consistent in the 3 - 4 mg/L range. The current laboratory mean is 3.92 mg/L.

3.2 *Mysidopsis bahia*

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 17 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected after test initiation in all of the concentration even with supplemental aeration and aeration was maintained in all chambers for the duration of the test. Ammonia was measured in all replicates from each concentration daily and was a potentially significant toxic component of the test for the highest three concentrations.

The LC50 for HSW-1 was 1.16%. At 96 hours, there was significant mortality at 2.0 and 1.0% concentrations compared to the control. The NOEC was 0.5% and the LOEC was 1.0%.

The LC50 for HSW-2 was 0.79%. again there was significant mortality at 96 hours in the 2.0 and 1.0% concentrations compared to the control. The NOEC was 0.5%, and the LOEC was 1.0%.

The reference toxicant test had an LC50 of 7.27 mg/L, with an NOEC of 1.25 mg/L and an LOEC of 2.5 mg/L. This is the third reference toxicant test on *Mysidopsis* at this laboratory, therefore no database has been established. The current mean is 13.5 mg/L.

3.3 BIVALVE LARVAL BIOASSAY

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 17 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected after test initiation in all of the concentration even with supplemental aeration and aeration was maintained in all chambers for the duration of the test. Ammonia was measured in all replicates from each concentration daily and was a potentially significant toxic component of the test for the highest three concentrations.

Control survival was acceptable at 100% with 1.4% abnormal development. The LC50 for HSW-1 was >2.0%, while the LC50 for HSW-2 was 0.2%. The IC50 for HSW-1 was 0.1% and the IC50 for HSW-2 was 0.18%.

The LC50 (6.1 μg/L) for the copper sulfate reference toxicant test was within two standard deviations of the laboratory mean of 15.9 μg/L indicating normal to higher sensitivity of the test organisms.

3.5 AMMONIA MEASUREMENTS

Ammonia in both of the HSW was very high. When measured in a 25% dilution in seawater, ammonia levels ranged from 88 to 120 mg/L. When converted to the 100% concentration, the ammonia level would be above 350 - 450 mg/L. The un-ionized fraction as NH_3 would range from 17 to 24 mg/L at 100% concentration.

TABLE 1

Bioassay Procedure And Organism Data
For the Survival Bioassay
Using *Citharichthys stigmaeus* (U.S. EPA 1991)

Parameter	Data
Test Species	*Citharichthys stigmaeus*
Supplier	J. Brezina and Associates
Collection location	Tomales Bay
Date Acquired	10/25/94
Acclimation Time	24 hours
Acclimation Water	30 ppt seawater
Acclimation Temperature	12 ± 2°C
Age group	Juveniles, 3-5 cm TL
Sample Identification	
Sample ID(s)	941024-19, -20
Date Sampled	10/20/94
Date Received at ABT	10/24/94
Volume Received	One gallon
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	96 hour static acute, renewal at 48 hours
Test Dates	10/26/94 to 10/30/94
Control Water	San Francisco Bay seawater
Test Temperature	17 ± 2°C
Test Photoperiod	16 L : 8 D
Initial Salinity	31 ± 2 ppt
Test Chamber	10 L polyethylene chamber
Animals/Replicate	10 animals/replicate
Exposure Volume	5 L
Replicates/Treatment	5
Feeding	None
Deviations from procedures	None

TABLE 2

Bioassay Procedure And Organism Data For the Survival Bioassay Using *Mysidopsis bahia* (U.S. EPA 1991)

Parameter	Data
Test Species	*Mysidopsis bahia*
Supplier	Aquatox, Arkansas
Date Acquired	11/1/94
Acclimation Time	None
Acclimation Water	Shipping water
Acclimation Temperature	20 ± 2°C
Age group	7-10 day larvae
Sample Identification	
Sample ID(s)	941024-19, -20
Date Sampled	10/20/94
Date Received at ABT	10/24/94
Volume Received	Five gallons
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute; static; renewal at 48 hours
Test Dates	11/1/94 to 11/5/94
Control Water	San Francisco Bay seawater
Test Temperature	18 ± 2°C
Test Photoperiod	14 L : 10 D
Initial Salinity	30 ppt
Test Chamber	1000 mL jars
Animals/Replicate	10 animal/replicate
Exposure Volume	500 mL
Replicates/Treatment	5
Feeding	Brine shrimp (24 hr old nauplii)
Deviations from procedures	None

TABLE 3

Bioassay Procedure And Organism Data For The 48 Hour Bioassay Using Larvae of *Mytilus edulis* (ASTM 1993)

Parameter	Data
Test Species	*Mytilus edulis*
Supplier	A.K. Siewers, Santa Cruz, CA
Date Acquired	10/25//94
Acclimation Time	None
Acclimation Water	Not applicable
Acclimation Temperature	Not applicable
Age group	Fertilized embryos, 2 hours
Sample Identification	
Sample ID(s)	941024-19, -20
Date Sampled	10/20/94
Date Received at ABT	10/24/94
Volume Received	One gallon
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute; static; 48 hours
Test Dates	10/25/94 to 10/27/94
Control Water	San Francisco Bay seawater
Test Temperature	16 ± 2°C
Test Photoperiod	16 L : 8 D
Salinity	32 ± 2 ppt
Test Chamber	125 mL beakers
Animals/Replicate	Approximately 30 embryos per mL
Exposure Volume	100 mL
Replicates/Treatment	3
Feeding	None
Deviations from procedures	Chambers were gently aerated with low bubble aeration

TABLE 4

SUMMARY OF RESULTS FOR THE HIGH STRENGTH WASTE BIOASSAYS

Species	Test	Endpoint	HSW-1	HSW-2
Citharichthys stigmaeus	96 hr static	LC50	0.35%	0.37%
		NOEC	0.25%	0.25%
		LOEC	0.50%	0.50%
Mysidopsis bahia	96 hr static	LC50	1.16%	0.79%
		NOEC	0.50%	0.50%
		LOEC	1.00%	1.00%
Mytilus edulis	48 hr static	LC50	>2.0	0.20%
		IC50	0.10%	0.18%

Note:
HSW-1: Starkist
HSW-2: Van Camp

TABLE 5

SUMMARY OF RESULTS FOR THE REFERENCE TOXICANT TESTS

Citharichthys stigmaeus Concentration (mg/L)	SDS % Survival	LC50 (mg/L)	NOEC (mg/L)	LOEC (mg/L)
Control	100.0	3.9	3.1	6.25
1.6	100.0			
3.1	83.3			
6.25	0.0*			
12.5	0.0*			
25	0.0*			

Lab LC50 = 3.92.

Mysidopsis bahia Concentration (mg/L)	SDS % Survival	LC50 (mg/L)	NOEC (mg/L)	LOEC (mg/L)
Control	98.0	7.27	1.25	2.5
0.7	90.0			
1.25	90.0			
2.5	73.3*			
5	83.3*			
10	70.0*			
20	10.0*			
40	0.0*			

Lab LC50 = 13.52.

Bivalve larvae Concentration (µg/L)	Copper sulfate Mean Normal Larvae/mL	% Treatment Mortality	LC50 (µg/L)	(%) Abnormal
Initial Counts	23.5		6.1	
Control W/Air	23.5	NA		1.4
Control WO/Air	22.9	NA		3.8
3.75	19.0	6.4		1.8
7.5	2.3*	88.5		51.9
15	4.7*	76.7		100
30	0.0*	100.0		100
60	0.0*	100.0		100

* Statistically significant.

4.0 REFERENCES

U.S. EPA. 1991. Methods for measuring acute toxicity of effluents to freshwater and marine organisms, 4th ed. EPA 600/4-90/027, September, 1991.

ASTM. 1993. Annual Book of Standards. Vol. 11.04. Standard guide for conducting static acute toxicity tests starting with embryos of four species of saltwater bivalve mollusca. E-724-89.

APPENDIX A

ANALYTICAL DATA

APPENDIX TABLE 1

SAMPLE WATER QUALITY

Sample	pH (units)	DO (mg/L)	Total NH3 (mg/L)	Initial Salinity (ppt)
HSW-1	6.53	0.7	480	23.5
HSW-2	6.39	0.6	350	14

APPENDIX TABLE 2

Mytilus edulis

WATER QUALITY MEASUREMENTS FOR THE EFFLUENT TEST

Test Dates: 10/25-10/27/94

Concentration		Day 0				Day 1	Day 2			
(%)	Rep	pH	DO	°C	Sal	°C	pH	DO	°C	Sal
Control	1	8.06	8.8	16.7	32	16.2	8.00	8.8	16.9	32
W/Air	2					16.3	8.01	8.8	16.9	32
	3					16.2	8.02	8.6	16.9	32
Control	1	8.06	8.8	16.7	32	16.2	8.09	8.8	16.9	32
WO/Air	2					16.2	8.11	8.8	16.9	32
	3					16.2	8.13	8.8	16.9	32
HSW-1										
0.06	1	8.04	8.8	16.8	32	16.3	8.12	8.8	16.9	32
	2					16.2	8.09	8.7	16.9	32
	3					16.2	8.11	8.8	16.9	32
0.125	1	7.99	8.8	16.8	32	16.3	8.14	8.6	16.9	32
	2					16.2	8.08	8.6	16.9	33
	3					16.2	8.12	8.7	16.9	32
0.25	1	7.88	8.8	16.7	32	16.2	8.14	8.6	16.9	33
	2					16.2	8.12	8.6	16.9	32
	3					16.3	8.08	8.5	16.9	32
0.5	1	7.68	8.8	16.6	32	16.2	8.02	6.2	16.9	32
	2					16.2	7.75	6.0	16.9	32
	3					16.2	7.68	6.1	16.9	32
1	1	7.34	8.8	16.6	32	16.2	8.01	4.8	16.9	32
	2					16.3	8.00	4.9	16.9	32
	3					16.3	7.93	4.8	16.9	32
2	1	6.96	8.4	16.6	32	16.2	8.04	3.4	16.9	32
	2					16.2	7.99	3.2	16.9	32
	3					16.2	8.05	3.4	16.9	32
	Min	6.96	8.4	16.6	32	16.2	7.68	3.2	16.9	32
	Max	8.06	8.8	16.8	32	16.3	8.14	8.8	16.9	33

APPENDIX TABLE 2 (Cont'd)

Mytilus edulis

WATER QUALITY MEASUREMENTS FOR THE EFFLUENT TEST

Test Dates: 4/7-4/9/94

Concentration		Day 0				Day 1	Day 2			
(%)	Rep	pH	DO	°C	Sal	°C	pH	DO	°C	Sal
HSW-2										
0.06	1	8.06	8.8	16.7	32	16.3	8.12	8.6	16.9	32
	2					16.3	8.15	8.5	16.9	32
	3					16.3	8.16	8.6	16.9	32
0.125	1	8.04	8.9	16.6	32	16.2	8.17	8.5	16.9	32
	2					16.2	8.17	8.5	16.8	32
	3					16.2	8.19	8.5	16.9	32
0.25	1	7.94	8.8	16.7	32	16.2	8.20	8.4	17.0	32
	2					16.2	8.19	8.5	16.9	32
	3					16.3	8.14	8.2	16.9	32
0.5	1	7.77	8.7	16.7	32	16.3	7.73	3.4	16.9	32
	2					16.3	8.11	7.8	16.9	32
	3					16.3	8.15	7.8	16.9	32
1	1	7.40	8.7	16.8	32	16.2	8.09	7.4	17.0	32
	2					16.2	8.19	7.6	16.9	32
	3					16.2	8.20	7.6	16.9	32
2	1	6.92	8.6	16.6	32	16.2	8.03	3.8	16.9	32
	2					16.2	8.03	4.8	16.9	32
	3					16.2	7.98	4.6	16.9	32
	Min	6.92	8.6	16.6	32	16.2	7.73	3.4	16.8	32
	Max	8.06	8.9	16.8	32	16.3	8.20	8.6	17.0	32

APPENDIX TABLE 3

Mytilus edulis

SUMMARY OF RESULTS FOR BIVALVE LARVAE HIGH STRENGTH WASTE BIOASSAY

Test Dates: 10/25-10/27/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
Initial Counts	1	110		22.0			
	2	135		27.0			
	3	108		21.6			
	Mean			23.5			
Final Control W/Air	1	101	0	20.2		0.0	
	2	129	0	25.8		0.0	
	3	117	5	24.4		4.1	
	Mean			23.5	100.0	1.4	NA
Final Control WO/Air	1	104	5	21.8		4.6	
	2	109	3	22.4		2.7	
	3	118	5	24.6		4.1	
	Mean			22.9	100.0	3.8	NA
HSW-1 0.06	1	82	12	18.8		12.8	
	2	89	14	20.6		13.6	
	3	78	15	18.6		16.1	
	Mean			19.3	93.4	14.2	4.8
0.125	1	23	72	19.0		75.8	
	2	18	58	15.2		76.3	
	3	20	71	18.2		78.0	
	Mean			17.5	84.4	76.7	14.0
0.25	1	3	82	17.0		96.5	
	2	1	77	15.6		98.7	
	3	3	85	17.6		96.6	
	Mean			16.7	80.8	97.3	17.6
0.5	1	0	85	17.0		100.0	
	2	0	93	18.6		100.0	
	3	0	81	16.2		100.0	
	Mean			17.3	83.4	100.0	14.9
1	1	0	89	17.8		100.0	
	2	0	94	18.8		100.0	
	3	0	97	19.4		100.0	
	Mean			18.7	90.2	100.0	8.0
2	1	0	95	19.0		100.0	
	2	0	96	19.2		100.0	
	3	0	87	17.4		100.0	
	Mean			18.5	89.5		8.7

APPENDIX TABLE 3 (Cont'd)

Mytilus edulis

SUMMARY OF RESULTS FOR BIVALVE LARVAE HIGH STRENGTH WASTE BIOASSAY

Test Dates: 10/25-10/27/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
HSW-2							
0.06	1	102	3	21.0		2.9	
	2	87	2	17.8		2.2	
	3	117	3	24.0		2.5	
	Mean			20.9	100.0	2.5	0.0
0.125	1	67	13	16.0		16.3	
	2	61	12	14.6		16.4	
	3	52	12	12.8		18.8	
	Mean			14.5	69.9	17.1	28.7
0.25	1	0	38	7.6		100.0	
	2	0	27	5.4		100.0	
	3	0	33	6.6		100.0	
	Mean			6.5	31.6	100.0	67.8
0.5	1	0	27	5.4		100.0	
	2	0	27	5.4		100.0	
	3	0	27	5.4		100.0	
	Mean			5.4	26.1	100.0	73.4
1	1	0	36	7.2		100.0	
	2	0	39	7.8		100.0	
	3	0	31	6.2		100.0	
	Mean			7.1	34.1	100.0	65.2
2	1	0	37	7.4		100.0	
	2	0	31	6.2		100.0	
	3	0	36	7.2		100.0	
	Mean			6.9	33.5	100.0	65.8

APPENDIX TABLE 4

Mytilus edulis
WATER QUALITY MEASUREMENTS
FOR THE REFERENCE TOXICANT (C0PPER) TEST

Concentration		Day 0				Day 1	Day 2			
µg/L	Rep	pH	DO	°C	Sal	°C	pH	DO	°C	Sal
3.75	1	8.08	8.8	16.7	32	16.4	8.15	8.4	17.0	32
	2					16.4	8.13	8.5	16.9	32
	3					16.4	8.15	8.6	16.9	32
7.5	1	8.09	8.8	16.7	32	16.5	8.18	8.6	16.9	32
	2					16.4	8.18	8.4	16.9	32
	3					16.5	8.16	8.4	16.9	32
15	1	8.10	8.7	16.7	32	16.5	8.17	8.5	16.9	32
	2					16.5	8.18	8.5	17.0	32
	3					16.5	8.18	8.4	17.0	32
30	1	8.10	8.7	16.8	31	16.5	8.17	8.4	16.9	32
	2					16.5	8.17	8.4	16.9	32
	3					16.5	8.16	8.5	16.9	32
60	1	8.11	8.7	16.7	30	16.5	8.16	8.5	16.9	32
	2					16.4	8.17	8.6	16.9	32
	3					16.5	8.16	8.6	17.0	32
	Min	8.08	8.7	16.7	30	16.4	8.13	8.4	16.9	32
	Max	8.11	8.8	16.8	32	16.5	8.18	8.6	17.0	32

APPENDIX TABLE 5

Mytilus edulis
SUMMARY OF RESULTS FOR THE BIVALVE LARVAE
REFERENCE TOXICANT (COPPER) BIOASSAY

Concentration (µg/L)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
3.75	1	90	2	18.4		2.2	
	2	97	1	19.6		1.0	
	3	93	2	19.0		2.1	
	Mean			19.0	91.8	1.8	6.4
7.5	1	4	5	1.8		55.6	
	2	6	7	2.6		53.8	
	3	7	6	2.6		46.2	
	Mean			2.3	11.3	51.9	88.5
15	1	0	27	5.4		100.0	
	2	0	21	4.2		100.0	
	3	0	23	4.6		100.0	
	Mean			4.7	22.9	100.0	76.7
30	1	0	0	0.0		100.0	
	2	0	0	0.0		100.0	
	3	0	0	0.0		100.0	
	Mean			0.0	0.0	100.0	100.0
60	1	0	0	0.0		100.0	
	2	0	0	0.0		100.0	
	3	0	0	0.0		100.0	
	Mean			0.0	0.0	100.0	100.0

APPENDIX TABLE 6

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	7.98	7.9	0.03	17.1	32	8.18	8.2		17.2	33	8.16	7.2	0.02	17.1	33	8.17	7.3	0.03	17.4	33	8.05	8.0	0.03	17.9	34
	2						8.23	8.1	0.03	17.0	33	8.23	7.2		16.5	33	8.22	7.2		17.1	33	8.14	8.0		17.7	34
	3						8.22	8.1		16.9	32	8.24	7.2		16.3	33	8.24	7.3		16.9	33	8.17	8.0		17.6	34
	4						8.22	8.4		16.6	33	8.24	7.2		16.2	33	8.24	7.4		16.8	33	8.18	8.1		17.5	34
	5						8.22	8.5		16.5	33	8.24	7.4		16.0	33	8.25	7.4		16.6	33	8.20	8.2		17.2	34
0.06	1	7.93	8.0	0.14	17.3	32	8.17	8.5		17.2	33	8.24	7.6	0.11	16.6	33	8.23	7.6	0.11	17.2	34	8.18	8.2	0.10	17.7	34
	2						8.15	8.5	0.10	17.0	32	8.25	7.5		16.5	33	8.20	7.4		17.0	33	8.13	8.2		17.6	34
	3						8.13	8.3		16.8	32	8.23	7.4		16.4	33	8.20	7.4		16.9	33	8.14	8.1		17.6	34
	4						8.20	8.2		16.5	33	8.19	7.4		16.2	33	8.13	7.4		16.6	34	7.98	8.0		17.3	34
	5						8.21	8.2		16.4	31	8.21	7.4		16.0	33	8.16	7.4		16.5	34	8.09	7.8		17.0	34
0.125	1	7.87	8.0	0.27	17.2	32	8.09	8.4		17.2	33	8.22	7.6	0.19	16.6	33	8.21	7.5	0.21	17.2	34	8.15	8.0	0.20	17.6	34
	2						8.02	8.4	0.22	17.0	33	8.24	7.5		16.5	33	8.21	7.4		17.1	33	8.16	8.0		17.6	34
	3						8.01	8.5		16.8	32	8.21	7.4		16.2	33	8.21	7.4		16.8	33	8.14	8.0		17.4	34
	4						8.03	8.3		16.5	33	8.25	7.4		16.0	33	8.25	7.4		16.5	34	8.21	8.0		17.0	34
	5						8.14	8.4		15.9	33	8.25	7.4		16.0	33	8.26	7.4		16.5	34	8.22	8.0		16.9	34
0.25	1	7.72	8.1	0.51	17.2	32	8.01	8.2		17.2	33	8.27	7.6	0.38	16.7	33	8.26	7.6	0.40	17.1	34	8.21	8.2	0.39	17.5	34
	2						8.01	8.2	0.70	17.0	33	8.26	7.6		16.5	33	8.27	7.6		17.0	34	8.20	8.0		17.5	34
	3						7.85	7.7		16.9	32	8.17	7.4		16.4	33	8.21	7.5		16.9	33	8.12	8.0		17.4	34
	4						8.02	7.8		16.5	33	8.23	7.4		16.0	33	8.22	7.4		16.6	34	8.15	7.8		17.0	34
	5						8.09	8.6		16.0	33	8.24	7.4		16.0	33	8.25	7.4		16.4	34	8.19	7.8		16.9	34
0.5	1	7.55	8.1	0.93	17.2	32	7.97	6.6		17.2	33	8.10	7.6	0.70	16.6	33	8.28	7.6	0.60	17.2	33	8.27	8.0	0.74	17.6	34
	2						7.84	7.7	0.40	17.0	32	8.20	7.4		16.5	33	8.23	7.5		17.0	33	8.19	8.0		17.6	34
	3						7.73	6.8		16.9	32	8.16	7.3		16.5	33	8.21	7.4		16.9	33	8.24	7.9		17.4	34
	4						7.78	7.6		16.6	33	8.13	7.2		16.3	33	8.21	7.4		16.6	34	8.18	7.8		17.2	34
	5						7.77	7.9		16.2	33	8.13	7.2		16.0	33	8.20	7.4		16.5	34	8.13	7.8		16.9	34
1	1	7.18	7.8	1.80	17.2	32	7.66	6.9		17.2	32	8.18	7.4	1.44	16.9	33	8.23	7.6	1.26	17.2	33	8.20	7.8	1.18	17.7	34
	2						7.81	7.1	1.50	17.0	32	8.23	7.3		16.6	33	8.28	7.4		17.1	33	8.26	7.8		17.7	34
	3						7.65	6.3		17.0	32	8.18	7.2		16.5	33	8.27	7.4		17.1	33	8.12	7.6		17.6	34
	4						7.60	5.9		16.7	33	8.14	7.2		16.2	33	8.23	7.3		16.7	32	8.17	7.6		17.3	34
	5						7.51	5.2		16.5	33	8.07	7.2		16.0	33	8.16	7.3		16.3	34	8.14	7.4		17.0	34
2.0	1	6.84	7.7	3.60	17.2	32	7.56	3.5		15.9	33	8.22	7.2	2.82	16.0	33	8.30	7.3	2.16	16.3	34	8.31	7.4	2.07	16.8	34
	2						7.47	2.0	3.70	15.7	33	8.09	7.2		16.0	34	—	—	—	—	—	—	—	—	—	—
	3						7.49	2.0		15.6	33	8.05	6.7		16.0	34	—	—	—	—	—	—	—	—	—	—
	4						7.38	0.6		15.8	33	8.14	6.7		16.0	34	—	—	—	—	—	—	—	—	—	—
	5						7.66	3.8		15.9	34	8.18	6.9		16.0	34	8.30	7.4		16.2	34	8.31	7.6		16.7	34
Min		6.84	7.7	0.03	17.1	32	7.38	0.6	0.03	15.6	31	8.05	6.7	0.02	16.0	33	8.13	7.2	0.03	16.2	32	7.98	7.4	0.03	16.7	34
Max		7.98	8.1	3.60	17.3	32	8.23	8.6	3.70	17.2	34	8.27	7.6	2.82	17.1	34	8.30	7.6	2.16	17.4	34	8.31	8.2	2.07	17.9	34

Note: — = All animals dead.

APPENDIX TABLE 6 (Cont'd)

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
0.06	1	7.84	8.1	0.24	17.6	32	8.15	8.1		17.2	33	8.26	7.2	0.16	16.6	33	8.28	7.6	0.20	17.1	34	8.27	8.2	0.18	17.6	34
	2						8.02	8.0	0.28	16.9	33	8.19	7.2		16.4	33	8.20	7.5		16.9	34	8.18	8.1		17.4	34
	3						8.18	8.0		16.5	33	8.24	7.2		16.0	33	8.26	7.4		16.7	34	8.24	8.1		17.2	34
	4						8.20	8.1		16.3	33	8.26	7.4		16.0	33	8.26	7.4		16.5	34	8.26	8.0		17.0	34
	5						8.20	8.0		16.2	34	8.25	7.4		16.0	33	8.15	7.5		16.5	34	8.27	8.0		17.0	34
0.125	1	7.79	8.1	0.47	17.7	32	8.12	8.1		17.2	33	8.25	7.5	0.27	16.5	34	8.28	7.4	0.32	17.0	34	8.27	8.2	0.28	17.4	34
	2						8.11	8.0	0.32	16.9	33	8.25	7.4		16.4	33	8.27	7.4		16.8	34	8.26	8.2		17.4	34
	3						8.05	8.0		16.6	33	8.21	7.4		16.2	33	8.26	7.4		16.6	34	8.12	8.0		17.2	34
	4						8.15	8.0		16.2	33	8.23	7.3		16.1	33	8.26	7.4		16.5	34	8.21	7.6		17.0	34
	5						8.17	8.1		16.2	33	8.27	7.4		16.0	34	8.27	7.6		16.5	34	8.26	7.6		16.9	34
0.25	1	7.66	8.0	0.84	17.6	32	7.95	7.8		17.1	33	8.24	7.4	0.54	16.4	33	8.26	7.6	0.51	16.9	34	8.25	8.0	0.47	17.4	34
	2						7.89	7.8	0.60	16.9	33	8.18	7.4		16.3	33	8.24	7.4		16.9	34	8.20	8.0		17.4	34
	3						7.93	7.8		16.6	33	8.20	7.2		16.2	33	8.24	7.4		16.6	34	8.21	7.9		17.2	34
	4						7.92	7.8		16.5	33	8.20	7.2		16.1	33	8.22	7.4		16.5	34	8.19	7.8		17.0	34
	5						8.01	7.8		16.2	33	8.20	7.2		16.0	34	8.25	7.4		16.5	34	8.23	7.8		16.9	34
0.5	1	7.43	7.9	1.60	17.6	32	7.89	7.8		17.1	33	8.25	7.4	1.10	16.2	33	8.27	7.5	1.05	16.8	34	8.26	8.0	0.98	17.2	34
	2						7.83	7.8	1.21	16.9	33	8.21	7.4		16.2	33	8.27	7.4		16.7	34	8.27	7.9		17.2	34
	3						7.79	7.4		16.7	33	8.20	7.2		16.1	33	8.27	7.4		16.6	34	8.23	7.8		17.2	34
	4						7.77	7.4		16.5	33	8.16	7.2		16.0	33	8.25	7.4		16.5	34	8.21	7.6		17.0	34
	5						7.94	7.8		16.2	33	8.24	7.2		16.0	34	8.30	7.4		16.5	34	8.28	7.6		16.9	34
1	1	7.10	7.8	3.20	17.6	32	7.64	5.8		16.9	33	8.25	7.3	2.21	16.0	34	—	—	—	—	—	—	—	—	—	—
	2						7.50	0.8	2.57	16.9	33	8.15	7.3		16.0	33	—	—	—	—	—	—	—	—	—	—
	3						7.62	5.2		16.6	33	8.20	7.2		16.0	33	8.24	7.4	2.05	16.5	34	8.28	7.8	2.01	17.0	34
	4						7.62	5.0		16.4	33	8.21	7.2		16.1	33	8.29	7.4		16.5	34	8.31	7.6		16.9	34
	5						7.67	4.8		16.2	33	8.17	7.2		16.0	34	8.25	7.3		16.5	34	8.22	7.6		16.9	34
2.0	1	6.82	7.2	6.10	17.9	32	7.45	0.8		17.0	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.49	0.4	5.28	16.7	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.40	0.6		16.5	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.57	1.8		16.3	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.47	0.6		16.2	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		6.82	7.2	0.24	17.6	32	7.40	0.4	0.28	16.2	33	8.15	7.2	0.16	16.0	33	8.15	7.3	0.20	16.5	34	8.12	7.6	0.18	16.9	34
Max		7.84	8.1	6.10	17.9	32	8.20	8.1	5.28	17.2	34	8.27	7.5	2.21	16.6	34	8.30	7.6	2.05	17.1	34	8.31	8.2	2.01	17.6	34

Note: — = All animals dead.

APPENDIX TABLE 7

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	9	9	9	90	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.06	1	10	10	9	9	9	90	
	2	10	10	9	10	10	100	
	3	10	10	10	9	9	90	
	4	10	9	9	8	8	80	
	5	10	9	9	9	9	90	90.0
0.125	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.25	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.5	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	9	9	90	98.0
1	1	10	10	10	10	9	90	
	2	10	10	10	10	6	60	
	3	10	10	10	10	7	70	
	4	10	10	10	10	6	60	
	5	10	10	8	6	5	50	66.0
2	1	10	*	3	3	1	10	
	2	10	*	0	—	—	0	
	3	10	*	0	—	—	0	
	4	10	*	0	—	—	0	
	5	10	*	2	2	1	10	4.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 7 (Cont'd)

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.06	1	10	10	10	10	10	100	
	2	10	10	7	6	5	50	
	3	10	10	10	10	10	100	
	4	10	10	7	7	6	60	
	5	10	10	9	9	9	90	80.0
0.125	1	10	10	10	10	10	100	
	2	10	10	9	9	8	80	
	3	10	10	10	10	9	90	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	94.0
0.25	1	10	10	10	10	9	90	
	2	10	10	10	10	9	90	
	3	10	10	10	9	9	90	
	4	10	10	10	9	9	90	
	5	10	10	8	8	7	70	86.0
0.5	1	10	10	9	9	9	90	
	2	10	10	10	9	9	90	
	3	10	10	10	9	9	90	
	4	10	10	10	10	9	90	
	5	10	10	9	9	8	80	88.0
1	1	10	*	0	—	—	0	
	2	10	*	0	—	—	0	
	3	10	*	2	2	3	30	
	4	10	*	2	2	2	20	
	5	10	*	2	2	2	20	14.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 8

Mysidopsis bahia
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1				Day 2				Day 3				Day 4			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal
0.7	1	8.06	8.2	15.9	33	8.16	7.2	17.4	33	8.16	7.2	17.4	33	8.03	7.4	17.6	33	7.88	6.8	18.2	33
	2					8.19	7.1	17.2	33	8.16	7.2	17.3	33	8.07	7.4	17.6	33	7.91	6.7	18.2	33
	3					8.20	7.1	17.3	33	8.16	7.1	17.3	33	8.06	7.2	17.6	33	7.88	6.6	18.2	33
1.25	1	8.07	8.1	15.9	32	8.19	7.0	17.2	33	8.17	7.0	17.3	33	8.08	7.2	17.6	33	7.93	6.5	18.2	33
	2					8.19	7.0	17.0	33	8.16	7.0	17.2	33	8.07	7.2	17.6	33	7.93	6.6	18.0	33
	3					8.19	7.0	17.1	33	8.15	7.1	17.2	33	8.07	7.2	17.5	33	7.93	6.6	18.0	33
2.5	1	8.07	8.1	15.8	32	8.16	6.9	17.2	33	8.13	7.0	17.3	33	8.05	7.2	17.6	33	7.93	6.7	18.2	33
	2					8.15	6.5	17.0	33	8.12	7.0	17.0	33	8.05	7.2	17.5	33	7.96	6.6	18.0	33
	3					8.14	6.4	17.0	33	8.12	7.0	17.1	33	8.03	7.2	17.6	33	7.89	6.7	18.0	33
5	1	8.08	8.1	15.9	32	8.11	6.4	17.2	33	8.08	7.0	17.4	33	8.02	7.2	17.6	33	7.90	6.5	18.3	33
	2					8.11	6.0	17.0	33	8.08	6.8	17.3	33	8.01	7.0	17.6	33	7.91	6.5	18.1	33
	3					8.10	5.8	17.0	33	8.09	6.8	17.2	33	8.00	7.0	17.6	33	7.89	6.4	18.2	33
10	1	8.08	8.0	15.8	32	8.05	5.8	17.3	33	8.01	6.4	17.5	33	7.98	7.0	17.9	33	7.89	6.4	18.6	33
	2					8.07	5.8	17.1	33	7.99	6.4	17.3	33	7.98	7.0	17.8	33	7.89	6.4	18.3	33
	3					8.08	5.1	17.2	33	7.98	6.4	17.3	33	7.98	7.0	17.6	33	7.87	6.4	18.3	33
20	1	8.09	8.0	15.8	32	8.05	4.8	17.5	33	7.80	4.5	17.7	33	—	—	—	—	—	—	—	—
	2					8.06	4.7	17.3	33	7.77	4.4	17.6	33	7.83	7.1	18.0	33	7.85	6.4	18.7	33
	3					8.05	4.7	17.2	33	7.78	4.4	17.4	33	7.81	6.4	17.8	33	7.92	6.7	18.6	34
40	1	8.09	8.1	15.7	32	8.12	6.0	17.8	33	—	—	—	—	—	—	—	—	—	—	—	—
	2					8.17	6.2	17.8	33	—	—	—	—	—	—	—	—	—	—	—	—
	3					8.17	6.2	17.8	33	—	—	—	—	—	—	—	—	—	—	—	—
Min		8.06	8.0	15.7	32	8.05	4.7	17.0	33.0	7.77	4.4	17.0	33.0	7.81	6.4	17.5	33.0	7.85	6.4	18.0	33.0
Max		8.09	8.2	15.9	33	8.20	7.2	17.8	33.0	8.17	7.2	17.7	33.0	8.08	7.4	18.0	33.0	7.96	6.8	18.7	34.0

Note: — = All animals dead.

APPENDIX TABLE 9

Mysidopsis bahia
SURVIVAL DATA FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.7	1	10	10	9	8	8	80	
	2	10	10	10	10	10	100	
	3	10	10	9	9	9	90	90.0
1.25	1	10	10	9	9	9	90	
	2	10	10	9	9	9	90	
	3	10	10	10	10	9	90	90.0
2.5	1	10	10	8	8	8	80	
	2	10	10	7	7	7	70	
	3	10	9	8	8	7	70	73.3
5	1	10	10	10	10	10	100	
	2	10	10	7	7	6	60	
	3	10	9	9	9	9	90	83.3
10	1	10	10	9	8	8	80	
	2	10	8	7	7	7	70	
	3	10	8	7	6	6	60	70.0
20	1	10	2	0	—	—	0	
	2	10	2	2	2	2	20	
	3	10	1	1	1	1	10	10.0
40	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	0.0

Note: — = All animals dead.

APPENDIX TABLE 10

Citharichthys stigmaeus

WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST

Study Dates: 10/26-10/30/94

HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.02	8.6	<0.01	16.5	32	8.05	8.2	0.08	16.8	32	8.03	8.8	0.08	14.6	33	7.94	6.8	0.08	15.4	33	7.95	8.2	0.09	15.7	33
	2						7.92	8.3	0.08	16.9	32	7.82	8.8	0.09	14.7	33	7.78	7.0	0.09	15.5	33	7.81	8.2	0.14	15.7	33
	3						7.91	7.8	0.07	16.9	32	7.84	9.0	0.09	14.6	33	7.79	6.8	0.07	15.5	33	7.81	7.2	0.19	15.7	33
	4						8.04	8.1	0.07	16.8	32	7.99	8.7	0.08	14.5	33	8.00	6.6	0.07	15.4	33	7.99	8.1	0.18	15.6	33
	5						8.00	8.2	0.07	16.8	32	7.99	8.8	0.09	14.6	33	7.94	6.6	0.08	15.4	33	7.97	8.1	0.17	15.6	33
0.06	1	7.95	8.6	0.16	16.4	32	7.90	8.1	0.14	16.7	32	8.00	9.0	0.17	14.6	33	7.99	7.2	0.16	15.4	33	8.00	8.1	0.29	15.7	33
	2						7.89	8.0	0.14	16.6	32	8.01	9.0	0.17	14.5	33	8.00	7.2	0.18	15.5	33	8.03	8.1	0.26	15.6	34
	3						7.95	8.0	0.14	16.5	32	8.04	9.0	0.17	14.5	33	8.04	7.0	0.14	15.4	33	8.06	8.3	0.29	15.5	34
	4						7.83	7.6	0.15	16.3	32	8.02	9.0	0.18	14.2	33	7.94	7.2	0.18	15.3	33	7.95	8.2	0.30	15.2	34
	5						7.82	7.8	0.15	16.2	32	7.97	8.9	0.18	14.2	33	7.93	7.2	0.17	15.4	33	7.96	7.9	0.31	15.0	33
0.125	1	7.93	8.6	0.23	16.4	32	7.61	5.1	0.21	16.3	32	7.99	8.9	0.21	14.2	33	7.98	7.4	0.20	15.4	33	8.01	8.1	0.35	15.3	34
	2						7.59	5.0	0.22	16.2	32	7.99	9.0	0.24	14.2	33	7.95	7.2	0.24	15.2	33	8.01	8.1	0.40	15.2	34
	3						7.76	7.2	0.22	16.0	32	8.01	9.1	0.23	14.2	33	7.97	7.2	0.20	15.4	33	8.03	8.2	0.48	15.4	34
	4						7.64	5.6	0.19	16.2	32	8.01	9.1	0.23	14.3	33	7.97	7.0	0.19	15.2	33	8.00	8.1	0.53	15.3	34
	5						7.86	7.3	0.19	16.2	32	8.03	9.1	0.23	14.2	33	8.04	7.0	0.21	15.3	33	8.08	8.0	0.51	15.2	34
0.25	1	7.83	8.6	0.47	16.5	32	7.58	4.6	0.35	16.0	32	7.94	9.0	0.37	13.9	34	7.90	7.2	0.34	15.3	33	7.97	8.1	0.53	14.5	36
	2						7.65	4.7	0.36	16.0	32	8.04	8.8	0.37	14.0	33	8.01	7.3	0.33	15.3	33	8.10	8.0	0.62	14.7	35
	3						7.62	4.6	0.35	16.0	32	8.07	8.9	0.36	14.3	33	8.03	7.3	0.37	15.4	33	8.10	8.2	0.57	14.9	34
	4						7.67	4.7	0.34	15.9	32	8.03	9.0	0.36	14.4	33	7.92	7.3	0.36	15.4	33	8.03	8.2	0.66	15.1	34
	5						7.67	4.8	0.34	16.0	32	8.08	9.1	0.36	14.3	33	8.05	7.2	0.37	15.3	33	8.11	8.3	0.61	14.9	35
0.5	1	7.63	8.5	0.92	16.4	32	7.50	1.2	0.74	16.5	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.50	0.9	0.67	16.6	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.52	0.8	0.76	16.6	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.51	1.3	0.75	16.6	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.57	1.0	0.66	16.6	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	1	7.33	8.5	1.98	16.4	31	7.45	0.8	1.58	16.5	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.46	0.9	1.62	16.5	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.47	0.6	1.59	16.5	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.48	0.8	1.54	16.4	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.46	0.8	1.63	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	1	6.99	8.1	3.95	16.5	31	7.41	0.6	3.18	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.40	0.4	3.20	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.48	0.6	3.12	16.0	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.41	0.8	3.15	16.1	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.45	0.8	3.19	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		6.99	8.1	<0.10	16.4	31	7.40	0.4	0.07	15.9	32	7.82	8.7	0.08	13.9	33	7.78	6.6	<0.10	15.2	33	7.81	7.2	0.09	14.5	33
Max		8.02	8.6	3.95	16.5	32	8.05	8.3	3.20	16.9	32	8.08	9.1	0.37	14.7	34	8.05	7.4	0.37	15.5	33	8.11	8.3	0.66	15.7	36

Note: — = All animals dead.

APPENDIX TABLE 10 (Cont'd)

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 10/26-10/30/94
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
0.06	1	8.00	8.5	0.19	16.5	32	7.76	7.0	0.20	16.5	32	8.03	9.2	0.17	14.8	32	8.07	7.4	0.17	15.5	33	8.09	8.2	0.17	15.5	33
	2						7.84	7.2	0.17	16.4	32	8.03	9.1	0.17	14.4	33	8.04	7.2	0.16	15.4	33	8.08	8.3	0.20	15.5	33
	3						7.84	7.2	0.18	16.3	32	8.02	9.1	0.18	14.2	33	8.05	7.2	0.18	15.5	33	8.08	8.3	0.21	15.3	34
	4						7.75	6.2	0.17	16.4	32	8.00	9.0	0.18	14.2	33	8.01	7.0	0.17	15.5	33	8.06	8.2	0.19	15.2	34
	5						7.79	6.6	0.18	15.9	32	8.04	8.9	0.18	14.5	33	8.05	7.1	0.19	15.4	33	8.10	8.2	0.23	14.4	36
0.125	1	7.94	8.6	0.30	16.5	32	7.70	6.4	0.27	16.2	32	7.99	8.9	0.26	14.2	33	8.02	7.5	0.21	15.4	33	8.06	8.3	0.31	15.3	34
	2						7.81	6.2	0.27	16.3	32	8.03	9.1	0.27	14.3	33	8.04	7.3	0.25	15.4	33	8.09	8.1	0.34	15.3	34
	3						7.81	6.0	0.27	16.4	32	8.04	9.2	0.26	14.3	33	8.05	7.2	0.25	15.5	33	8.10	8.3	0.29	15.3	34
	4						7.58	6.1	0.29	15.9	32	8.04	9.2	0.26	13.8	33	8.06	7.2	0.27	15.3	33	8.11	8.3	0.31	14.8	35
	5						7.76	6.2	0.29	15.9	32	8.06	9.2	0.25	13.8	33	8.07	7.2	0.27	15.3	33	8.13	8.3	0.34	14.8	34
0.25	1	7.79	8.6	0.62	16.4	32	7.70	4.2	0.57	15.9	32	7.94	9.2	0.47	13.9	33	8.00	7.4	0.44	15.2	33	8.05	8.3	0.47	14.9	34
	2						7.70	4.5	0.58	15.9	32	7.91	8.9	0.47	13.8	33	7.96	7.2	0.41	15.3	33	8.02	8.2	0.49	14.9	34
	3						7.64	4.6	0.55	15.9	32	7.98	8.8	0.47	13.8	33	7.99	7.2	0.41	15.3	33	8.07	8.0	0.41	14.8	34
	4						7.61	4.6	0.53	16.1	32	7.89	8.8	0.46	14.0	33	7.92	7.3	0.40	15.3	33	8.00	8.1	0.47	15.2	34
	5						7.59	4.6	0.52	16.2	32	7.92	8.8	0.47	14.2	33	7.91	7.2	0.43	15.3	33	7.98	7.9	0.49	15.2	34
0.5	1	7.54	8.7	1.24	16.5	32	7.57	1.6	1.07	16.2	32	7.97	8.7	0.87	14.0	33	8.04	7.0	0.79	15.4	33	8.08	8.2	0.74	14.9	34
	2						7.49	1.8	1.16	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.54	1.8	1.09	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.56	1.8	1.08	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.57	1.9	1.03	16.3	32	8.05	8.8	0.86	14.2	33	8.09	7.0	0.83	15.4	33	8.15	8.2	0.69	15.0	35
1	1	7.23	8.6	2.41	16.5	32	7.61	0.9	2.10	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.62	0.9	2.24	16.3	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.54	1.0	2.22	16.4	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.54	0.8	2.31	15.8	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.51	0.8	2.31	15.7	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2.0	1	6.86	8.3	5.15	16.5	31	7.80	0.6	4.88	15.8	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.56	0.6	4.47	15.9	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.60	0.8	4.65	15.9	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.60	0.8	4.40	16.0	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.56	0.6	4.32	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		6.86	8.3	0.19	16.4	31	7.49	0.6	0.17	15.7	32	7.89	8.7	0.17	13.8	32	7.91	7.0	<0.10	15.2	33	7.98	7.9	0.19	14.4	33
Max		8.00	8.7	5.15	16.5	32	7.84	7.2	4.88	16.5	32	8.06	9.2	0.87	14.8	33	8.09	7.5	0.83	15.5	33	8.15	8.3	0.74	15.5	36

Note: — = All animals dead.

APPENDIX TABLE 11

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.06	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.125	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.25	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.5	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
1	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Note: — = All animals dead.

APPENDIX TABLE 11 (Cont'd)

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.06	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.125	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	9	10	10	100	100.0
0.25	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.5	1	10	4	2	2	2	20	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	2	2	2	2	20	8.0
1	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Note: — = All animals dead.

APPENDIX TABLE 12

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal
Control	1	7.93	9.4	15.4	31	7.75	5.0	NT	NT
	2					7.73	4.8	NT	NT
	3					7.69	4.8	NT	NT
1.6	1	7.94	9.4	15.2	31	7.62	4.0	NT	NT
	2					7.68	4.4	NT	NT
	3					7.70	4.4	NT	NT
3.1	1	7.95	9.4	15.2	31	7.59	4.1	NT	NT
	2					7.61	4.3	NT	NT
	3					7.64	4.4	NT	NT
6.25	1	7.95	9.4	15.2	31	7.42	2.1	NT	NT
	2					7.72	2.1	NT	NT
	3					7.75	2.2	NT	NT
12.5	1	7.96	9.4	15.2	31	7.42	2.0	NT	NT
	2					7.59	2.1	NT	NT
	3					7.56	2.1	NT	NT
25	1	7.96	9.4	15.2	31	7.40	2.0	NT	NT
	2					7.43	2.0	NT	NT
	3					7.48	2.0	NT	NT
Min		7.93	9.4	15.2	31	7.40	2.0		
Max		7.96	9.4	15.4	31	7.75	5.0		

Note: NT = Not taken.

APPENDIX TABLE 13

Citharichthys stigmaeus
SURVIVAL DATA
FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	% Survival	Average % Survival
Control	1	6	6	100	
	2	6	6	100	
	3	6	6	100	100.0
1.6	1	6	6	100	
	2	6	6	100	
	3	6	6	100	100.0
3.1	1	6	5	83	
	2	6	5	83	
	3	6	5	83	83.3
6.25	1	6	0	0	
	2	6	0	0	
	3	6	0	0	0.0
12.5	1	6	0	0	
	2	6	0	0	
	3	6	0	0	0.0
25	1	6	0	0	
	2	6	0	0	
	3	6	0	0	0.0

Appendix 7
Laboratory Results Submitted by ABT - Third Test

RESULTS OF BIOASSAYS CONDUCTED ON TWO HIGH-STRENGTH WASTE SAMPLES FROM THE VAN CAMP AND STARKIST TUNA CANNERIES IN AMERICAN SAMOA

Prepared for:

CH2M Hill California, Inc.
1111 Broadway
Oakland, CA 94607
Project # PDX 30702

Prepared by:

Advanced Biological Testing Inc.
98 Main St., # 419
Tiburon, Ca. 94920

July 10, 1995

Ref: 9309-8

1.0 INTRODUCTION

At the request of CH2M Hill (Project # PDX 30702), Advanced Biological Testing conducted acute effluent bioassay testing on *Mysidopsis bahia* and *Citharichthys stigmaeus* using high strength wastes (HSW) collected separately from the Starkist (HSW-1) and Van Camp (HSW-2) tuna canneries in American Samoa. The study was run using methods generally specified in EPA 1991 and in a Sampling and Testing Plan submitted to the EPA.

The study was conducted at the Advanced Biological Testing Laboratory in Tiburon, California, and was managed by Mr. Mark Fisler.

2.0 METHODS

2.1 EFFLUENT SAMPLING

The high strength wastes were sampled as composites on June 23, 1995 by personnel from the two canneries. Due to shipping and airline scheduling problems, frequently encountered in this region, the sample was received by the laboratory on June 26, 1995. A single gallon carboy was provided from each cannery and were labeled at ABT as HSW-1 (HSW-SKS Grab) and HSW-2 (Pipeline Sludge HS-W2, Van Camp). Samples were maintained in ice-filled coolers from the date of sampling until laboratory receipt. The samples were at 2-3°C upon receipt and were stored at 4°C until use.

2.2 SAMPLE PREPARATION AND TESTING METHODS

2.2.1 Testing on the speckled sanddab, *Citharichthys stigmaeus*

The bioassays were carried out on juvenile *Citharichthys stigmaeus*, supplied by J. Brezina and Associates in Dillon Beach, California. The animals were received at ABT on June 25, 1995. The test conditions are summarized in Table 1. Five replicates of each concentration were tested with ten juvenile fish per replicate. Water quality was monitored daily. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature. In agreement with the EPA regarding the proposed testing concentrations, the high strength wastes were tested at six concentrations starting from 2.0% and dropping using a 50% dilution factor. The final concentrations were 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% as vol:vol dilutions in seawater. The diluent was filtered seawater from San Francisco Bay. The dilutions were brought up to the test temperature (17 ± 2°C) and aerated continuously. These effluents have an extremely high biological oxygen demand, therefore aeration was carried out from the beginning of the test.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 25, 12.5, 6.25, 3.1, and 1.6 mg/L in 30 ppt seawater in a 24 hour test.

2.2.2 Testing on the mysid, *Mysidopsis bahia*

The bioassay was carried out on 3-5 day old larval *Mysidopsis bahia*, supplied by Aquatox from Hot Springs, Arkansas. The animals were received at ABT on June 27, 1994. The test conditions for this test are summarized in Table 2. Five replicates of each concentration were tested with ten larval mysids per replicate. Water quality was monitored daily as initial quality on Day 0 and final water quality on Days 1-4. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature. In agreement with the EPA regarding the proposed testing concentrations, the high strength wastes were tested at six concentrations starting from 2.0% and dropping using a 50% dilution factor. The final concentrations were 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% as vol:vol dilutions in seawater. The diluent was filtered seawater from San Francisco Bay The dilutions were brought up to the test temperature (16 ± 2°C) and aerated continuously.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 40, 20, 10, 5, 2.5 and 1.25 mg/L in 30 ppt seawater in a 96 hour test.

2.3 STATISTICAL ANALYSIS

At the conclusion of the testing, the survival data were evaluated statistically using ToxCalc™ to determine ECp, NOEC, and LOEC values where appropriate. ToxCalc™ is a comprehensive statistical application that follows standard guidelines for acute and chronic toxicity data analysis. Data were evaluated statistically to estimate the LC50 values for the tests using the Linear Interpolation (Bootstrap) or Trimmed Spearman-Karber methods.

3.0 RESULTS

3.1 Initial Effluent Quality

The two High Strength Wastes were tested for basic water quality parameters upon receipt at the laboratory. HSW-1 had a dissolved oxygen level of 0.8 mg/L; a pH of 6.49; a salinity of 23 ppt; and a total ammonia level of 380 mg/L. HSW-2 had a dissolved oxygen level of 1.4 mg/L; a pH of 6.71; a salinity of 17.0 ppt; and a total ammonia level of 220 mg/L.

3.2 *Citharichthys stigmaeus*

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 17 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected after test initiation in all of the concentration even with supplemental aeration and aeration was maintained in all chambers for the duration of the test. Ammonia was measured in all replicates from each concentration daily and was a potentially significant toxic component of the test for the highest three concentrations.

The LC50 for HSW-1 was 0.396% based upon a Trimmed Spearman-Karber method. The majority of the observed toxicity again occurred in the first 24 hours. There was significant mortality at 2.0, 1.0, and 0.5% concentrations compared to the control at 96 hours. The NOEC was 0.25% and the LOEC was 0.5%.

The LC50 for HSW-2 was 0.626% based upon a Trimmed Spearman-Karber method. The majority of the observed toxicity occurred in the first 24 hours. There was significant mortality at 2.0, 1.0, and 0.5% concentrations compared to the control at 96 hours. The NOEC was 0.25%, and the LOEC was 0.5%.

The reference toxicant test required the use of the Trimmed Spearman-Karber method and generated an LC50 of 4.05 mg/L, an NOEC of 3.2 mg/L, and an LOEC of 6.25 mg/L. This is the fifth reference toxicant test on *Citharichthys* at this laboratory, and the current laboratory mean is 3.95 mg/L (SD = 0.26 mg/L). The results are within one standard deviation of the laboratory mean, indicating a normally sensitive population.

3.3 *Mysidopsis bahia*

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 17 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected after test initiation in all of the concentration even with supplemental aeration and aeration was maintained in all chambers for the duration of the test. Ammonia was measured in all replicates from each concentration daily and was a potentially significant toxic component of the test for the highest three concentrations.

The LC50 for HSW-1 was 0.675%. At 96 hours, there was significant mortality at concentrations to 0.25% compared to the control. The NOEC was 0.125% and the LOEC was 0.25%.

The LC50 for HSW-2 was 0.625%. again there was significant mortality at 96 hours in the 2.0, 1.0 and 0.5% concentrations compared to the control. The NOEC was 0.25%, and the LOEC was 0.5%.

The reference toxicant test had an LC50 of 17.18 mg/L, with an NOEC of 10 mg/L and an LOEC of 20 mg/L. This is the tenth reference toxicant test on *Mysidopsis* at this laboratory, and the current laboratory mean is 14.29 mg/L (SD = 4.11 mg/L). The results are within one standard deviation of the laboratory mean, indicating a normally sensitive population.

3.4 AMMONIA MEASUREMENTS

Total ammonia in both of the HSW samples was very high. When measured in a 25% dilution in seawater, ammonia levels ranged from 55 to 95 mg/L. When converted to the 100% concentration, the ammonia level would be from 220 - 380 mg/L. The measured amount of total ammonia in the 2.0% concentrations on Day 0 in HSW-1 was 6.61 mg/L, and in HSW-2, 4.3 mg/L. In the 1.0% concentrations the total values were 3.32 mg/L and 2.10 mg/L respectively. These levels would be consistent with observed toxicity.

TABLE 1

Bioassay Procedure And Organism Data
For the Acute Bioassay
Using *Citharichthys stigmaeus* (U.S. EPA 1991)

Parameter	Data
Sample Identification	
Sample ID(s)	950626-1(HSW-1), 950626-2 (HSW-2)
Date Sampled	6/23/95
Date Received at ABT	6/26/95
Volume Received	One gallon
Sample Storage Conditions	4°C in the dark
Test Species	*Citharichthys stigmaeus*
Supplier	J. Brezina and Associates
Collection location	Tomales Bay
Date Acquired	June 25, 1995
Acclimation Time	48 hours
Acclimation Water	34 ppt seawater
Acclimation Temperature	17 ± 2°C
Age group	Juveniles, 3-5 cm TL
Test Procedures	
Type; Duration	96 hour static acute, renewal at 48 hours
Test Dates	6/27/95 to 7/1/95
Control Water	Bodega Bay seawater
Test Temperature	17 ± 2°C
Test Photoperiod	16 L : 8 D
Initial Salinity	34 ± 2 ppt
Test Chamber	10 L polyethylene chamber
Animals/Replicate	10 animals/replicate
Exposure Volume	5 L
Replicates/Treatment	5
Feeding	None
Deviations from procedures	None

TABLE 2

Bioassay Procedure And Organism Data For the Acute Bioassay Using *Mysidopsis bahia* (U.S. EPA 1991)

Parameter	Data
Sample Identification	
Sample ID(s)	950626-1(HSW-1), 950626-2 (HSW-2)
Date Sampled	6/23/95
Date Received at ABT	6/26/95
Volume Received	One gallon
Sample Storage Conditions	4°C in the dark
Test Species	*Mysidopsis bahia*
Supplier	Aquatox, Arkansas
Date Acquired	6/27/95
Acclimation Time	None
Acclimation Water	Shipping water
Acclimation Temperature/Salinity	20 ± 2°C/30-32 ppt salinity
Age group	3-5 day old larvae
Test Procedures	
Type; Duration	Acute; static; renewal at 48 hours
Test Dates	6/27/95 to 7/1/95
Control Water	San Francisco Bay seawater
Test Temperature	17 ± 2°C
Test Photoperiod	14 L : 10 D
Salinity	34 ± 2 ppt
Test Chamber	1000 mL jars
Animals/Replicate	10 animal/replicate
Exposure Volume	500 mL
Replicates/Treatment	5
Feeding	Brine shrimp (24 hr old nauplii)
Deviations from procedures	None

TABLE 4

Summary Of Effluent Toxicity
and
Results of the Reference Toxicity Testing

Species	Sample	LC50	95% Confidence Limits
Citharichthys	HSW-1	0.3959%	0.368% -0.426%
	HSW-2	0.6262%	0.569% -0.689%
	Ref Tox (SDS)	4.057 mg/L (acceptable)	3.51-4.69 mg/L
Mysidopsis	HSW-1	0.675%	0.563% -0.764%
	HSW-2	0.625%	0.549% -0.692%
	Ref Tox (SDS)	17.18 mg/L (acceptable)	Not calculated

4.0
REFERENCES

U.S. EPA. 1991. Methods for measuring acute toxicity of effluents to freshwater and marine organisms, 4th ed. EPA 600/4-90/027, September, 1991.

APPENDIX A

ANALYTICAL DATA

APPENDIX TABLE 1

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 6/27 - 7/1/95
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.07	9.1		16.4	33	8.14	8.0	<0.01	15.8	34	8.15	7.3	0.14	18.0	34	8.15	8.6	0.24	17.9	34	8.18	7.6	0.31	18.3	35
	2						8.07	7.8	<0.01	15.7	34	8.08	7.2	0.13	17.9	34	8.08	8.4	0.22	17.8	34	8.13	7.6	0.31	18.3	35
	3						8.01	7.2	<0.01	15.7	34	7.98	6.6	0.14	17.9	34	7.96	7.6	0.22	17.8	34	7.97	6.8	0.32	18.2	35
	4						8.08	7.8	<0.01	15.6	34	8.09	7.2	0.14	17.8	34	8.11	8.4	0.22	17.7	34	8.12	7.5	0.32	18.2	36
	5						8.11	7.8	<0.01	15.6	34	8.12	7.2	0.14	17.9	34	8.12	8.4	0.21	17.9	34	8.14	7.5	0.31	18.3	35
0.06	1	8.03	9.0	0.25	16.3	34	7.88	7.2	0.17	15.7	34	7.99	6.8	0.21	17.9	34	7.92	7.6	0.32	18.0	34	7.96	7.0	0.45	18.4	37
	2						7.99	7.8	0.19	15.5	34	8.09	6.9	0.24	17.8	34	8.09	8.2	0.35	17.9	34	8.13	7.6	0.49	18.3	38
	3						7.95	7.8	0.17	15.6	34	8.08	7.1	0.20	17.9	34	8.03	8.2	0.33	18.2	34	8.06	7.3	0.50	18.6	37
	4						7.97	7.8	0.20	15.5	34	8.09	7.2	0.26	17.9	34	8.09	8.2	0.40	17.7	34	8.12	7.5	0.55	18.0	38
	5						7.92	7.4	0.18	15.5	34	8.04	7.2	0.22	17.8	34	8.02	8.2	0.32	17.7	34	8.05	7.4	0.48	18.0	37
0.125	1	7.99	9.1	0.48	16.2	34	7.80	6.6	0.29	15.5	34	8.02	6.8	0.30	17.8	34	8.04	8.2	0.41	17.8	34	8.06	7.4	0.61	18.6	37
	2						7.84	6.8	0.28	15.5	34	8.04	7.0	0.33	17.8	34	8.06	8.2	0.49	17.9	34	8.10	7.4	0.68	18.2	37
	3						7.80	6.6	0.28	15.6	34	8.02	7.0	0.31	17.9	34	8.04	8.2	0.45	17.9	34	8.07	7.5	0.63	18.4	36
	4						7.90	6.4	0.29	15.4	34	8.09	7.2	0.32	17.6	34	8.13	8.2	0.44	17.8	34	8.15	7.4	0.64	18.2	38
	5						7.75	5.4	0.30	15.5	34	7.96	6.6	0.32	17.9	34	7.96	8.2	0.46	18.2	34	8.02	6.9	0.65	18.6	37
0.25	1	7.90	9.0	0.94	16.2	34	7.68	6.6	0.52	15.8	34	8.06	6.8	0.48	18.0	34	8.03	8.0	0.57	18.0	34	8.09	7.4	0.84	18.4	37
	2						7.62	5.8	0.52	15.7	34	8.03	6.8	0.48	18.0	34	8.01	8.0	0.59	18.0	34	8.07	7.3	0.84	18.4	36
	3						7.54	4.8	0.51	15.8	34	7.97	6.6	0.46	18.0	34	7.96	7.8	0.55	18.0	34	8.00	7.2	0.83	18.4	38
	4						7.55	4.8	0.52	15.7	34	7.95	6.6	0.56	18.0	34	7.95	7.6	0.55	17.9	34	7.99	7.0	0.92	18.4	36
	5						7.57	6.0	0.51	15.7	34	8.01	6.8	0.47	17.9	34	7.99	7.8	0.58	18.0	34	8.05	7.0	0.82	18.4	36
0.5	1	7.83	9.0	1.80	16.2	34	7.54	4.4	1.20	15.7	34	7.90	6.0	1.00	18.0	34	—	—	—	—	—	—	—	—	—	—
	2						7.48	4.3	1.19	15.7	34	7.85	5.9	1.08	18.0	34	—	—	—	—	—	—	—	—	—	—
	3						7.45	4.4	1.22	15.6	34	7.88	6.0	1.02	17.9	34	—	—	—	—	—	—	—	—	—	—
	4						7.52	4.1	1.18	15.7	34	7.86	5.6	1.02	18.0	34	—	—	—	—	—	—	—	—	—	—
	5						7.56	4.0	1.20	15.6	34	7.95	6.4	0.83	17.9	34	8.03	7.9	0.93	18.0	34	8.06	7.2	1.19	18.3	37
1	1	7.52	8.8	3.42	16.2	34	7.45	2.3	2.75	15.7	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.41	0.8	2.78	15.6	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.39	1.2	2.72	15.6	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.40	0.4	2.73	15.1	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.41	0.4	2.73	15.7	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	1	7.46	8.8	6.60	16.2	34	7.43	1.0	5.87	15.7	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.50	2.8	5.84	15.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.45	0.8	5.79	15.5	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.45	3.2	5.80	15.5	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.52	2.4	5.88	15.6	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		7.46	8.8	0.25	16.2	33	7.39	0.4	<0.01	15.1	34	7.85	5.6	0.13	17.6	34	7.92	7.6	0.21	17.7	34	7.96	6.8	0.31	18.0	35
Max		8.07	9.1	6.60	16.4	34	8.14	8.0	5.88	15.8	34	8.15	7.3	1.08	18.0	34	8.15	8.6	0.93	18.2	34	8.18	7.6	1.19	18.6	38

Note: — = All animals dead.

APPENDIX TABLE 1 (Cont'd)

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 6/27 - 7/1/95
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
0.06	1	8.02	9.0	0.17	16.3	34	7.98	7.6	0.20	15.5	34	8.06	7.0	0.19	17.9	34	7.99	8.2	0.34	17.8	34	8.08	7.3	0.47	18.8	37
	2						8.04	7.6	0.20	15.2	34	8.13	7.2	0.19	17.7	34	8.13	8.3	0.29	17.6	34	8.17	7.4	0.42	17.9	38
	3						8.05	7.8	0.20	15.2	34	8.14	7.3	0.19	17.7	34	8.13	8.4	0.29	17.6	34	8.15	7.6	0.41	18.0	37
	4						8.00	7.6.	0.19	15.4	34	8.06	7.1	0.19	17.9	34	8.06	8.4	0.29	17.8	34	8.07	7.3	0.41	18.2	37
	5						7.94	7.6	0.18	15.3	34	8.02	6.8	0.20	17.9	34	8.01	8.2	0.37	17.9	34	8.04	7.4	0.47	18.2	37
0.125	1	8.05	9.2	0.29	16.2	34	7.98	7.6	0.29	15.4	34	8.13	7.2	0.28	17.9	34	8.11	8.2	0.42	17.9	34	8.15	7.4	0.53	18.2	38
	2						7.93	7.5	0.19	15.4	34	8.08	7.1	0.25	18.0	34	8.07	8.4	0.36	18.0	34	8.09	7.5	0.48	18.5	37
	3						7.91	6.4	0.21	15.6	34	8.09	7.2	0.25	18.3	34	8.07	8.2	0.34	18.2	34	8.10	7.4	0.45	18.6	37
	4						7.78	7.4	0.22	15.5	34	7.99	6.6	0.25	18.1	34	7.94	7.6	0.35	18.0	34	7.94	6.6	0.45	18.3	37
	5						7.88	4.5	0.22	15.5	34	8.06	7.0	0.23	18.0	34	8.04	8.2	0.34	18.0	34	8.08	7.3	0.43	18.3	36
0.25	1	7.98	9.1	0.62	16.2	34	7.74	4.8	0.38	15.5	34	8.01	6.6	0.37	18.0	34	7.94	8.2	0.52	18.0	34	8.03	7.1	0.64	18.2	36
	2						7.78	5.8	0.38	15.3	34	8.07	7.0	0.34	18.0	34	8.03	8.0	0.48	17.9	34	8.11	7.2	0.58	18.2	37
	3						7.77	5.8	0.36	15.3	34	8.05	7.0	0.35	18.0	34	8.01	8.2	0.49	17.9	34	8.06	7.2	0.60	18.2	37
	4						7.77	5.9	0.37	15.2	34	8.06	6.7	0.38	17.9	34	8.02	8.0	0.56	17.7	34	8.10	7.1	0.70	18.0	37
	5						7.83	6.6	0.38	15.2	34	8.10	7.0	0.36	17.8	34	8.07	8.2	0.55	17.6	34	8.14	7.5	0.62	17.9	37
0.5	1	7.91	9.0	1.18	16.0	34	7.79	5.6	0.78	15.2	34	8.09	7.0	0.58	17.9	34	8.07	8.2	0.74	17.7	34	8.13	7.5	0.89	18.0	38
	2						7.78	6.0	0.79	15.0	34	8.11	7.1	0.58	17.6	34	8.09	8.4	0.72	17.9	34	8.15	7.5	0.88	18.2	38
	3						7.59	6.0	0.84	15.5	34	8.06	7.0	0.61	18.1	34	8.08	8.2	0.74	18.0	34	8.12	7.4	0.88	18.3	36
	4						7.69	4.9	0.82	15.4	34	8.05	6.8	0.64	18.2	34	8.05	8.0	0.77	18.0	34	8.12	7.2	0.99	18.2	37
	5						7.73	5.3	0.81	15.3	34	8.09	6.8	0.57	18.2	34	8.07	8.0	0.75	18.0	34	8.14	7.2	0.86	18.3	37
1	1	7.63	9.0	2.21	16.0	34	7.64	1.0	1.39	15.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.59	1.1	1.37	15.5	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.52	0.8	1.79	15.5	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.48	0.6	1.70	15.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.47	1.0	1.71	15.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2.0	1	7.42	8.6	4.33	16.0	34	7.44	0.6	3.60	15.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.43	0.6	3.54	15.3	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.45	0.4	3.39	15.2	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.44	0.6	3.25	15.0	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.47	0.6	3.35	15.1	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		7.42	8.6	0.17	16.0	34	7.43	0.4	0.18	15.0	34	7.99	6.6	0.19	17.6	34	7.94	7.6	<0.10	17.6	34	7.94	6.6	0.41	17.9	36
Max		8.05	9.2	4.33	16.3	34	8.05	7.8	3.60	15.6	34	8.14	7.3	0.64	18.3	34	8.13	8.4	0.77	18.2	34	8.17	7.6	0.99	18.8	38

Note: — = All animals dead.

APPENDIX TABLE 2

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	1	10	10	9	9	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.06	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	9	90	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.125	1	10	10	10	10	10	100	
	2	10	10	10	9	9	90	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.25	1	10	10	10	10	10	100	
	2	10	9	9	9	9	90	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.5	1	10	9	0	—	—	0	
	2	10	10	0	—	—	0	
	3	10	8	0	—	—	0	
	4	10	10	0	—	—	0	
	5	10	8	8	8	8	80	16.0
1	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Note: — = All animals dead.

APPENDIX TABLE 2 (Cont'd)

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.06	1	10	10	10	9	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	9	90	96.0
0.125	1	10	10	10	10	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	9	90	
	5	10	9	9	9	8	80	92.0
0.25	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	9	9	8	80	
	4	10	9	9	9	8	80	
	5	10	9	9	9	9	90	90.0
0.5	1	10	10	10	10	8	80	
	2	10	10	10	10	10	100	
	3	10	10	9	9	9	90	
	4	10	10	10	10	10	100	
	5	10	9	9	9	9	90	92.0
1	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Note: — = All animals dead.

APPENDIX TABLE 3

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal
Control	1	8.03	9.0	16.8	34	7.55	5.0	16.2	34
	2					7.55	5.0	16.2	34
	3					7.55	5.0	16.2	34
1.6	1	8.03	9.0	16.9	34	7.53	4.9	16.1	34
	2					7.51	4.9	16.2	34
	3					7.53	4.8	16.2	34
3.1	1	8.03	8.9	17.0	34	7.49	4.8	16.2	34
	2					7.44	4.8	16.2	34
	3					7.49	4.7	16.2	34
6.25	1	8.04	8.8	16.7	34	7.49	4.7	16.2	34
	2					7.50	4.7	16.2	34
	3					7.57	4.7	16.2	34
12.5	1	8.05	8.8	16.7	34	7.44	4.5	16.2	34
	2					7.39	4.6	16.2	34
	3					7.36	4.7	16.2	34
25	1	8.05	8.8	16.6	34	7.33	4.8	16.2	34
	2					7.32	4.9	16.2	34
	3					7.30	4.9	16.3	34
Min		8.03	8.8	16.6	34	7.30	4.5	16.1	34
Max		8.05	9.0	17.0	34	7.57	5.0	16.3	34

APPENDIX TABLE 4

Citharichthys stigmaeus
SURVIVAL DATA
FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	% Survival	Average % Survival
Control	**1**	4	4	100	
	2	4	4	100	
	3	4	2	50	83.3
1.6	**1**	4	4	100	
	2	4	4	100	
	3	4	3	75	91.7
3.1	**1**	4	3	75	
	2	4	3	75	
	3	4	3	75	75.0
6.25	**1**	4	0	0	
	2	4	0	0	
	3	4	0	0	0.0
12.5	**1**	4	0	0	
	2	4	0	0	
	3	4	0	0	0.0
25	**1**	4	0	0	
	2	4	0	0	
	3	4	0	0	0.0

APPENDIX TABLE 5

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 6/27 - 7/1/95
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.07	9.0		17.1	34	8.11	8.0	<0.01	16.5	34	8.25	7.4		18.2	34	8.17	8.4		18.0	34	8.20	7.7		18.3	36
	2						8.14	8.0		16.3	34	8.23	7.4	0.02	18.3	34	8.18	8.6		18.0	34	8.20	7.7		18.4	36
	3						8.13	8.0		16.3	34	8.17	7.4		18.3	34	8.09	8.6	0.03	18.1	34	8.13	7.7		18.4	35
	4						8.14	8.0		16.4	34	8.22	7.4		18.3	34	8.24	8.6		18.1	34	8.20	7.6	0.06	18.5	35
	5						8.16	8.0		16.4	34	8.24	7.4		18.2	34	8.28	8.6		18.0	34	8.26	7.7		18.3	36
0.06	1	8.02	9.0	0.25	17.9	34	7.98	7.8	0.11	16.2	34	8.10	7.2		18.3	34	8.14	8.6		18.0	34	8.11	7.4		18.4	35
	2						8.06	7.8		16.1	34	8.17	7.2	0.08	18.2	34	8.18	8.6		18.0	34	8.15	7.6		18.2	36
	3						8.04	7.8		16.0	34	8.13	7.2		18.2	34	8.12	8.6	0.11	17.9	34	8.11	7.5		18.2	35
	4						8.06	7.8		16.1	34	8.18	7.2		18.2	34	8.17	8.6		17.9	34	8.15	7.5	0.14	18.2	36
	5						8.12	8.0		16.1	34	8.22	7.3		18.2	34	8.22	8.7		17.9	34	8.20	7.6		18.2	36
0.125	1	7.96	8.8	0.48	18.0	34	7.78	6.2	0.22	16.2	34	8.16	7.2		18.2	34	8.13	8.6		18.0	34	8.13	7.6		18.4	35
	2						7.73	6.2		16.2	34	7.95	5.9	0.15	18.2	34	7.90	8.6		17.9	34	8.00	6.6		18.2	35
	3						7.98	7.8		16.1	34	8.10	7.0		18.1	34	8.14	8.4	0.22	17.9	34	8.10	7.5		18.2	35
	4						8.02	7.8		16.0	34	8.18	7.2		18.2	34	8.18	8.6		17.8	34	8.17	7.5	0.26	18.2	35
	5						7.94	7.6		16.2	34	8.14	7.2		18.3	34	8.16	8.6		17.9	34	8.14	7.6		18.3	35
0.25	1	7.90	8.8	0.94	18.0	34	7.75	7.1	0.41	16.2	34	8.04	7.0		18.2	34	8.10	8.5		18.0	34	8.08	7.5		18.4	35
	2						7.82	7.5		16.2	34	8.10	7.0	0.32	18.2	34	8.14	8.4		17.9	34	8.11	7.4		18.2	35
	3						7.86	7.4		16.1	34	8.13	7.2		18.1	34	8.13	8.6	0.47	17.8	34	8.12	7.4		18.2	35
	4						7.95	7.6		16.1	34	8.20	7.4		18.2	34	8.22	8.6		17.7	34	8.20	7.5	0.51	18.2	35
	5						7.90	7.4		16.2	34	8.12	7.2		18.3	34	8.14	8.6		17.9	34	8.14	7.6		18.3	35
0.5	1	7.92	8.8	1.80	17.9	34	7.80	6.9	0.81	16.3	34	8.20	7.2		18.2	34	8.25	8.6		18.0	34	8.23	7.4		18.4	35
	2						7.82	7.3		16.2	34	8.22	7.2	0.63	18.0	34	8.28	8.6		17.9	34	8.23	7.3		18.3	35
	3						7.74	6.2		16.2	34	8.17	7.1		18.0	34	8.23	8.6	0.83	17.9	34	8.26	7.4		18.2	35
	4						7.66	5.5		16.1	34	8.20	7.2		18.2	34	8.26	8.6		17.9	34	8.21	7.4	0.93	18.3	35
	5						7.71	6.2		16.2	34	8.20	7.2		18.3	34	8.30	8.6		17.9	34	8.25	7.4		18.3	36
1	1	7.74	8.6	3.41	17.9	34	7.64	2.8	1.91	16.3	34	8.12	6.6		18.4	34	—	—		—	—	—	—		—	—
	2						7.64	3.4		16.2	34	8.14	6.6	1.32	18.4	34	8.23	8.6		18.2	34	8.24	7.3		18.5	35
	3						7.65	3.6		16.2	34	8.15	6.7		18.3	34	8.26	8.6	1.54	18.0	34	8.29	7.4		18.4	35
	4						7.63	3.2		16.3	34	8.11	6.6		18.4	34	—	—		—	—	—	—		—	—
	5						7.64	3.6		16.2	34	8.13	6.6		18.5	34	8.29	8.6		18.1	34	8.31	7.3	1.61	18.4	35
2.0	1	7.63	8.8	6.60	17.6	34	7.46	1.2	3.51	16.5	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.44	1.0		16.3	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.45	2.0		16.2	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.50	2.7		16.2	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.46	0.6		16.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		7.63	8.6	0.25	17.1	34	7.44	0.6	<0.01	16.0	34	7.95	5.9	0.02	18.0	34	7.90	8.4	0.03	17.7	34	8.00	6.6	0.06	18.2	35
Max		8.07	9.0	6.60	18.0	34	8.16	8.0	3.51	16.5	34	8.25	7.4	1.32	18.5	34	8.30	8.7	1.54	18.2	34	8.31	7.7	1.61	18.5	36

Note: — = All animals dead.

APPENDIX TABLE 5 (Cont'd)

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 6/27 - 7/1/95
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
0.06	1	8.01	9.0	0.17	18.6	34	8.07	7.8	0.19	16.5	34	8.22	7.1		18.4	34	8.18	8.4		18.0	34	8.22	7.7		18.5	35
	2						8.07	7.6		16.4	34	8.18	7.2	0.09	18.4	34	8.15	8.6		18.0	34	8.16	7.6		18.4	35
	3						8.10	7.8		16.4	34	8.20	7.3		18.4	34	8.18	8.6	0.12	17.9	34	8.18	7.6		18.3	35
	4						8.12	7.8		16.3	34	8.22	7.4		18.3	34	8.20	8.6		17.9	34	8.20	7.7	0.15	18.2	35
	5						8.16	7.8		16.3	34	8.24	7.4		18.3	34	8.22	8.6		18.0	34	8.23	7.7		18.3	35
0.125	1	8.02	9.0	0.29	18.6	34	8.12	7.8	0.20	16.4	34	8.23	7.4		18.4	34	8.20	8.6		17.9	34	8.22	7.7		18.4	35
	2						8.14	7.8		16.4	34	8.25	7.3	0.12	18.3	34	8.20	8.6		17.9	34	8.25	7.8		18.3	35
	3						8.05	7.6		16.3	34	8.18	7.2		18.3	34	8.13	8.6	0.18	17.9	34	8.16	7.6		18.2	35
	4						8.09	7.8		16.2	34	8.20	7.3		18.2	34	8.20	8.6		17.9	34	8.22	7.6	0.20	18.2	35
	5						8.12	7.8		16.2	34	8.24	7.4		18.2	34	8.21	8.6		17.9	34	8.23	7.6		18.2	35
0.25	1	7.97	9.0	0.62	18.6	34	7.93	7.0	0.36	16.4	34	8.16	7.2		18.4	34	8.11	8.4		17.9	34	8.18	7.6		18.4	35
	2						7.92	7.4		16.3	34	8.17	7.2	0.25	18.3	34	8.14	8.4		17.9	34	8.22	7.6		18.2	35
	3						7.92	7.3		16.2	34	8.18	7.2		18.3	34	8.12	8.4	0.36	17.9	34	8.21	7.6		18.2	35
	4						8.02	7.4		16.2	34	8.22	7.4		18.2	34	8.12	8.5		17.9	34	8.25	7.6	0.41	18.2	35
	5						8.01	7.6		16.2	34	8.24	7.4		18.2	34	8.21	8.6		17.9	34	8.25	7.7		18.2	35
0.5	1	7.94	9.0	1.18	18.6	34	7.93	6.8	0.62	16.4	34	8.26	7.3		18.3	34	8.22	8.6		17.9	34	8.27	7.6		18.3	36
	2						7.90	6.4		16.3	34	8.25	7.3	0.51	18.3	34	8.20	8.4		17.9	34	8.27	7.6		18.2	35
	3						7.86	6.1		16.2	34	8.22	7.2		18.3	34	8.20	8.6	0.64	17.9	34	8.26	7.5		18.2	35
	4						7.80	4.8		16.3	34	8.22	7.2		18.2	34	8.18	8.5		17.9	34	8.26	7.6	0.73	18.2	35
	5						7.75	4.7		16.2	34	8.18	7.2		18.2	34	8.04	8.4		17.9	34	8.17	7.6		18.2	35
1	1	7.84	8.8	2.21	18.6	34	7.77	6.4	1.33	16.4	34	8.23	7.2		18.3	34	8.27	7.9		17.9	34	8.28	7.4		18.3	35
	2						7.66	5.0		16.3	34	8.15	7.0	1.06	18.3	34	8.26	8.3		17.9	34	8.27	7.4		18.3	35
	3						7.69	6.2		16.3	34	8.18	7.0		18.3	34	8.29	8.4	1.19	17.9	34	8.29	7.4		18.2	35
	4						7.70	5.4		16.2	34	8.20	7.0		18.2	34	8.26	8.6		17.9	34	8.24	7.2	1.36	18.2	35
	5						7.68	5.8		16.2	34	8.19	7.0		18.2	34	8.27	8.6		17.9	34	8.23	7.2		18.2	35
2.0	1	7.72	8.6	4.33	18.5	34	7.64	1.6	2.80	16.4	34	8.22	7.0		18.4	34	—	—	—	—	—	—	—	—	—	—
	2						7.60	0.6		16.3	34	8.16	6.1	2.26	18.3	34	—	—	—	—	—	—	—	—	—	—
	3						7.62	1.6		16.3	34	8.16	6.7		18.3	34	—	—	—	—	—	—	—	—	—	—
	4						7.58	0.4		16.3	34	8.12	6.4		18.3	34	—	—	—	—	—	—	—	—	—	—
	5						7.55	0.4		16.3	34	8.11	6.2		18.2	34	—	—	—	—	—	—	—	—	—	—
Min		7.72	8.6	0.17	18.5	34	7.55	0.4	0.19	16.2	34	8.11	6.1	0.09	18.2	34	8.04	7.9	0.12	17.9	34	8.16	7.2	0.15	18.2	35
Max		8.02	9.0	4.33	18.6	34	8.16	7.8	2.80	16.5	34	8.26	7.4	2.26	18.4	34	8.29	8.6	1.19	18.0	34	8.29	7.8	1.36	18.5	36

Note: — = All animals dead.

APPENDIX TABLE 6

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	1	10	9	9	9	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.06	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.125	1	10	9	9	9	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	9	9	9	9	90	96.0
0.25	1	10	10	*	*	7	70	
	2	10	10	*	*	10	100	
	3	10	10	*	*	8	80	
	4	10	9	*	*	6	60	
	5	10	10	*	*	10	100	82.0
0.5	1	10	*	*	*	5	50	
	2	10	*	*	*	7	70	
	3	10	*	*	*	7	70	
	4	10	*	*	*	10	100	
	5	10	*	*	*	8	80	74.0
1	1	10	*	0	—	—	0	
	2	10	*	*	*	2	20	
	3	10	*	*	*	0	0	
	4	10	*	0	—	—	0	
	5	10	*	*	*	0	0	4.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 6 (Cont'd)

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.06	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	9	9	90	
	5	10	10	9	9	9	90	96.0
0.125	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	9	90	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.25	1	10	*	*	10	10	100	
	2	10	*	*	10	9	90	
	3	10	*	*	10	10	100	
	4	10	*	*	9	9	90	
	5	10	*	*	10	10	100	96.0
0.5	1	10	*	*	*	5	50	
	2	10	*	*	*	6	60	
	3	10	*	*	*	7	70	
	4	10	*	*	*	7	70	
	5	10	*	*	*	6	60	62.0
1	1	10	*	*	*	1	10	
	2	10	*	*	*	0	0	
	3	10	*	*	*	2	20	
	4	10	*	*	*	0	0	
	5	10	*	*	*	2	20	10.0
2	1	10	*	0	—	—	0	
	2	10	*	0	—	—	0	
	3	10	*	0	—	—	0	
	4	10	*	0	—	—	0	
	5	10	*	0	—	—	0	0.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 7

Mysidopsis bahia
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1				Day 2				Day 3				Day 4			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal
0.7	1	8.07	9.0	17.5	34	8.11	7.8	16.5	34	8.09	6.8	18.6	34	7.98	7.8	18.4	34	7.77	6.3	18.7	35
	2					8.10	7.8	16.3	34	8.08	6.8	18.5	34	8.00	8.0	18.2	34	7.82	6.5	18.6	35
	3					8.10	7.7	16.2	34	8.07	6.6	18.4	34	8.00	8.0	18.0	34	7.84	6.4	18.5	35
1.25	1	8.08	9.0	17.6	34	8.07	7.3	16.4	34	8.04	6.4	18.5	34	7.97	8.0	18.2	34	7.84	6.5	18.6	35
	2					8.08	7.3	16.4	34	8.05	6.6	18.5	34	7.98	7.8	18.2	34	7.85	6.4	18.6	35
	3					8.08	7.3	16.2	34	8.06	6.6	18.4	34	7.98	7.8	18.1	34	7.85	6.4	18.6	35
2.5	1	8.08	9.2	17.6	34	8.05	7.0	16.4	34	8.03	6.6	18.5	34	7.96	7.8	18.2	34	7.86	6.2	18.5	35
	2					8.04	6.8	16.3	34	8.03	6.6	18.5	34	7.97	7.8	18.1	34	7.87	6.3	18.5	35
	3					8.04	6.8	16.2	34	8.04	6.6	18.5	34	7.98	7.8	18.1	34	7.87	6.3	18.5	35
5	1	8.08	9.2	17.6	34	7.99	6.0	16.5	34	7.96	6.0	18.5	34	7.89	7.0	18.2	34	7.84	5.8	18.6	35
	2					7.98	5.8	16.4	34	7.96	6.0	18.5	34	7.90	7.1	18.1	34	7.80	5.7	18.5	35
	3					7.98	5.8	16.2	34	7.98	6.2	18.5	34	7.92	7.3	18.1	34	7.81	5.8	18.5	35
10	1	8.08	9.2	17.6	34	7.93	5.0	16.5	34	7.87	5.2	18.6	34	7.87	7.3	18.2	34	7.82	6.0	18.6	35
	2					7.92	5.1	16.3	34	7.83	5.2	18.5	34	7.86	7.3	18.1	34	7.85	6.3	18.5	35
	3					7.92	4.9	16.2	34	7.83	5.1	18.5	34	7.87	7.4	18.1	34	7.86	6.5	18.5	34
20	1	8.09	9.2	17.6	34	7.92	4.9	16.4	34	7.73	4.8	18.6	34	7.75	5.8	18.3	34	7.79	6.1	18.6	34
	2					7.93	4.9	16.4	34	7.69	4.7	18.5	34	7.70	5.3	18.2	34	7.75	6.1	18.6	34
	3					7.93	5.0	16.2	34	7.68	4.8	18.5	34	7.68	5.1	18.2	34	7.74	6.0	18.5	34
Min		8.07	9.0	17.5	34	7.92	4.9	16.2	34	7.68	4.7	18.4	34	7.68	5.1	18.0	34	7.74	5.7	18.5	34
Max		8.09	9.2	17.6	34	8.11	7.8	16.5	34	8.09	6.8	18.6	34	8.00	8.0	18.4	34	7.87	6.5	18.7	35

Note: — = All animals dead.

APPENDIX TABLE 8

Mysidopsis bahia
SURVIVAL DATA FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.7	**1**	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	9	9	90	96.7
1.25	**1**	10	10	10	10	10	100	
	2	10	10	10	9	9	90	
	3	10	10	10	10	10	100	96.7
2.5	**1**	10	10	10	10	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	96.7
5	**1**	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	9	9	9	90	96.7
10	**1**	10	10	10	9	8	80	
	2	10	10	10	10	10	100	
	3	10	10	10	8	8	80	86.7
20	**1**	10	2	1	1	1	10	
	2	10	7	6	6	6	60	
	3	10	8	3	3	3	30	33.3

Note: — = All animals dead.

Appendix 8
FEIS Model Description (Appendix B of 1989 FEIS)

APPENDIX B

MATHEMATICAL MODELING

OF FISH WASTE DISPOSAL IN DEEP WATER

FINAL
ENVIRONMENTAL IMPACT STATEMENT

FOR THE DESIGNATION
OF AN OCEAN DISPOSAL SITE FOR FISH CANNERY WASTES
OFF TUTUILA ISLAND, AMERICAN SAMOA

1. INTRODUCTION

The purpose of this study is to predict the fate of fish processing wastes which are discharged at the present dumpsite off Tutuila Island, American Samoa in the South Pacific. The center point of the 1.5 nautical mile (n mi) diameter dumpsite is located at 170°40.87'W and 14°22.18'S. and is about 3.3 n mi due east of Sail Rock Point on Tutuila Island.

The preferred dumpsite selected in the FEIS is located at 170°38.30'W and 14°24.00'S, southeast of the present site. The model studies in this section were performed using the present site and known oceanographic conditions and waste characteristics, but the results are equally applicable to the preferred site under present waste loadings.

The waste is expected to undergo rapid initial mixing after discharge. Since the gross bulk density of the fish waste is between 0.72 and 0.99 gm/ml, the majority of the plume will remain near the ocean surface immediately after being discharged from the ship. Since the model developed by Koh and Chang (1973) was designed to simulate disposal of wastes that are heavier than the sea water, a new mathematical model has been formulated specifically for this study to predict the fate of the floating plume. This model can simulate the diffusion (lateral and vertical) and settling of the waste particles while the plume is advected in the direction of the ambient current. Most of the data used in the simulations were obtained from the reports published by Soule and Oguri (1983 and 1984) but subsequent monitoring data in 1987 and 1988 (See Appendix A) are consistent with the previously published data. The results of the simulations are presented in terms of dilution as a function of time after discharge, and/or distance and time from the discharge location. The simulations have been performed for two density

profiles (summer and winter), three ambient currents (0.2, 0.4, and 0.8 knots), and three particle settling velocities (1, 0.1, and 0.01 cm/sec). The waste plume is advected downstream by the ambient current. The direction of the ambient current varies with the season and the time of measurement. Some drogue studies by Soule and Oguri (1984) indicate movement toward the southwest direction while some 1987 current meter data indicate movement in the northwest direction. A close examination of the current direction based on the data published in the U.S. Navy Marine Climatic Atlas of the World (1979) for the region under study also indicates a SW direction. The prevailing south equatorial current indicates the direction is from SE toward NW. In order to cover several possible scenarios several current directions are used for simulation.

Since no data were ascertained for the settling velocity of the waste particles of the Samoa plant, velocities of 1, 0.1, and 0.01 cm/sec have been used in the calculations to cover the possible range of settling velocities. It is possible to distinguish the waste particles into three categories according to the density of the particles: (a) particles that are buoyant will form a thin layer floating at the ocean surface; (b) particles that are neutrally buoyant will be mixed and dispersed within the mixed layer (the mixed layer is the surface layer of the ocean extending from the ocean surface to the thermocline); (c) particles that are heavier than sea water will sink as the layer of waste particles is advected by the ambient current.

2. DEVELOPMENT OF MATHEMATICAL MODEL

Based on the data contained in Soule and Oguri (1983), the bulk densities of the fish processing wastes generated by Star-Kist Samoa and Samoa Packing are 0.72 to 0.96 gm/ml and 0.99 gm/ml, respectively. Recent

data on the specific gravity tests of the cannery waste provided to us on November 13, 1987 indicate a range of 0.99 to 1.023 gm/ml have been measured. Thus the possible settling velocity of the particulates in the plume is covered in our range of simulation. The tuna fish waste discharged from the ship is predominantly buoyant in sea water. Immediately after being discharged by the vessel pumps it undergoes rapid, near field, initial mixing similar to mixing in a jet. Because the discharge vessel circles around within the discharge zone, it is reasonable to assume that this nearfield mixing process, in combination with the ship's track and the prevailing current, would (1) establish an initial zone of width L and depth H within which the mean concentration is Co, and (2) the plume would drift downstream emanating from this initial zone. The dimension L would be expected to be approximately the turning diameter of the discharge ship. The concentration Co would correspond to the dilution obtained by the discharge jet as it is propelled downward and then returns towards the surface. The dimension H would be obtained such that where Q is the

$$U\ L\ H\ Co = Q \qquad (2.1)$$

discharge rate of the tuna fish waste and U is the magnitude of the prevailing current. It can be visualized that the initial plume to be advected by the ambient current has a concentration Co with the plume width L and the plume depth extending from the ocean surface downward by a value of H.

Each discharge episode would have a duration T. We shall assume that the prevailing current can be regarded as constant during that time. Then a plume of length UT would be generated as a result of the discharge episode.

Along the length of the plume, the concentration would decrease from

Co due to lateral mixing. Longitudinal diffusion will be probably small.

Diffusion of waste effluent in an ocean current was analyzed by Brooks (1960), taking into account the increase of the eddy diffusivity as the waste field spreads.

The basic differential equation, based on the principle of conservation of mass, for the substance being diffused is:

$$\frac{\partial}{\partial y}\left(-\mathcal{E}\frac{\partial C}{\partial y}\right) + U\frac{\partial C}{\partial x} + KC = 0 \qquad (2.2)$$

where the spatial coordinate x represents longitudinal direction (in the direction of ambient current) and y represents the lateral direction. The three terms in the above equation represents the rates of concentration decay per unit volume due to lateral diffusion, longitudinal advection and apparent dieoff respectively.

Incorporating an exponential decay term to take care of the dieoff term in Equation 2.2 such as

$$C = \phi e^{-Kx/U} \qquad (2.3)$$

would transform the equation into a simpler differential equation

$$\mathcal{E}\frac{\partial^2\phi}{\partial y} = U\frac{\partial\phi}{\partial x} \qquad (2.4)$$

The function ϕ is the concentration without any dieoff effect; it is a function of x and y.

An additional change of variable: $\mathcal{E} = \mathcal{E}_0 f(x)$ and $dx' = f(x)dx$ would allow one to transform Equation 2.4 to the classical heat equation as follows:

$$\mathcal{E}\frac{\partial^2\phi}{\partial y^2} = U\frac{\partial\phi}{\partial x} \qquad (2.5)$$

where $\mathcal{E}_o$ is the eddy diffusivity at x=0.

An exact solution to Equation 2.5, therefore, Equation 2.2 can easily be found as:

$$C(x,y) = \frac{Co\ e^{-Kx/U}}{2\sqrt{\pi \mathcal{E}_o t'}} \int_{-\frac{b}{2}}^{\frac{b}{2}} e^{-\frac{(y-y')^2}{4\mathcal{E}_o t'}}\, dy \qquad (2.6)$$

in which $t' = x'/U$ has been used, Co is the initial waste concentration at $x=0$, for $-b/2 < y < b/2$.

The integral in Equation 2.6 can be arranged to become the well known error function defined as

$$\text{erf } z = (2/\sqrt{\pi}) \int_0^z \exp(-\xi^2)\, d\xi \qquad (2.7)$$

We further introduce the concentration Cmax(x) as the concentration of the waste plume at y=0 and neglect the dieoff effect (i.e. set k=0.), this would yield a conservative estimation. We also assume that the lateral diffusivity can be expressed as

$$\mathcal{E} = A\ L^{4/3} \qquad (2.8)$$

where L is a length parameter proportional to the lateral width of the plume and A is a proportionality constant.

Thus, the maximum concentration at the center line of the plume can be simplified to be

$$\frac{Cmax}{Co} = \text{erf}\left\{ \left[\frac{1.5}{(1 + 8\ A\ t\ /\ L^{2/3})^3 - 1} \right]^{1/2} \right\} \qquad (2.9)$$

The error function in Equation 2.9 has been defined in Equation 2.7, and t is defined as x/U with x denoting the distance downstream from the initial dumping location.

For the waste with settling velocity Ws, it can be readily visualized that the combination of lateral diffusion, downstream advection by current, and settling can be schematised to a very good approximation by taking an x' coordinate inclined to the original downstream x coordinate by an angle $\theta = \tan^{-1}(Ws/U)$, as shown in Figure 2-1.

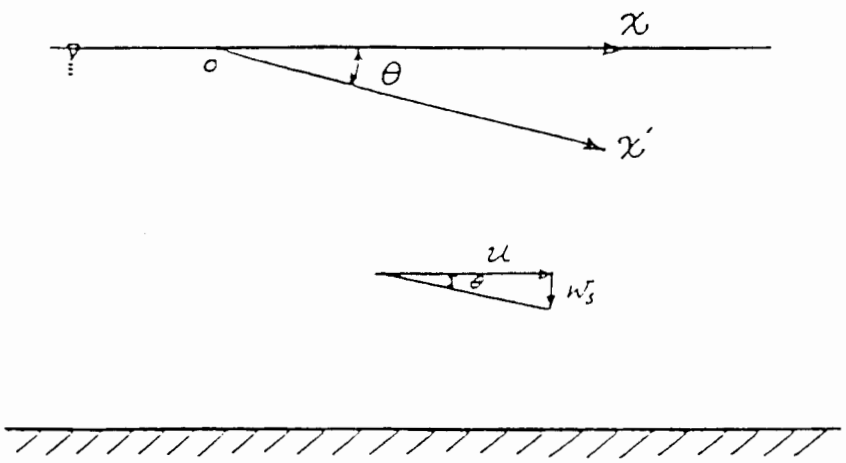


Figure 2-1. Definition sketch of the longitudinal direction with the effects of settling velocity.

Physically we are simply following the particles down with a velocity Ws while they are being advected downstream at speed U. The reduction in concentration still obeys the same formula as in Equation 2.9 except that the velocity along x' should be $U' \approx \sqrt{(U^2 + Ws^2)}$. But $t = x/U = x'/U'$ and hence the evaluation of Equation 2.9 needs only to be performed once for all Ws. Only the vertical location needs to be changed for each of the particle classes with differing fall velocities.

The effect of vertical diffusion can be incorporated approximately by deducing a concentration reduction factor based on vertical diffusion. For this purpose we assume Fickian diffusion with a diffusion coefficient Kv. Then it can be readily deduced that the concentration reduction factor due to vertical diffusion is approximately

$$\frac{H/4}{(2\ Kv\ t + H^2/16)^{1/2}} \qquad (2.10)$$

The quantity in the denominater is simply the characteristic vertical dimension (standard deviation) of the plume whose initial dimension is H/4. Combining this with the reduction due to lateral diffusion gives

$$\frac{Cmax}{Co} = \frac{H/4}{(2Kvt+H^2/16)^{1/2}}\ \mathrm{erf}\left\{ \left[\frac{1.5}{(1 + 8At/L^{2/3})^3} \right]^{1/2} - 1 \right\} \qquad (2.11)$$

where the vertical location of the centroid y is

$$y = Ws\ t = Ws\ x\ /\ U \qquad (2.12)$$

The above formulation retains all the essence of the complicated diffusion process in an ocean current. It is believed that this model provides a good and valid estimate of the mixing, transport, and diffusion of the tuna fish waste.

3. RESULTS OF MATHEMATICAL MODELING

The mathematical model developed in Section 2 was used to simulate the fate of the discharged fish processing wastes with the available data. The data used in the simulations are first presented. Then the results are presented in terms of dilution as a function of time after discharge and distance from the discharge location. According to Fischer et al. (1979), dilution usually is defined as the ratio of the total volume of a sample to the volume of effluent contained in the sample. Thus the volume fraction of effluent in a sample is equal to the reciprocal of dilution.

3.1 Data used for Simulations

The following input data are obtained from Soule and Oguri (1983):

Ambient Current Velocity	0 to 0.8 knots	
Ambient Density Profiles	summer, winter	
Dumpsite Water Depth	1.46 km (800 fathoms)	
Discharge Rate	500 to 1400 gpm	
	(1.89 cu m/min to 5.30 cu m/min)	
Sludge Bulk Density	0.72 to 0.96 gm/ml	Star-kist
	0.99 gm/ml	Van Camp
Sludge Tank Capacity	24000 gal (90.85 cu m)	
Dump Vessel Key Dimensions	Length = 49.0 m Beam = 8.1 m Draft = 3.35 m	

The radius of the dumping circle circumscribed by the dump vessel is 0.2 n mi. Also, the pumping rate of the sludge is 140 gpm per knot of vessel speed which can go up to 10 knots. Thus, for our simulation a range of discharge rates between 500 gpm and 1400 gpm is used. The discharge of the fish waste is completed within a time period during which the current direction does not change. For example, with the sludge tank capacity of 24,000 gallons and the discharge rate of 500 gpm the estimated discharge

period would be 48 minutes. It is reasonable to assume that the direction of the current would not be altered during this period.

Data of the ambient current velocity in the vicinity of the dumpsite are also available from the drogue and waste plume tracking studies conducted by Soule and Oguri (1984) and 1987 permit monitoring data. According to the drogue tracking studies, the speed of the surface current ranges from 0.39 to 0.94 knots. The waste plume was observed to move at an average speed of 0.67 knots. These values of the ambient current speed are in good agreement with the values (0.4 to 0.8 knots) published in the U.S. Navy Marine Climatic Atlas of the World (1979). The prevailing surface current patterns in the South Pacific Ocean for the summer and winter seasons are shown in Figures 3-1 and 3-2, respectively. Therefore, current speeds of 0.2, 0.4, and 0.8 knots have been used in the simulations.

Two ambient density profiles have been used in the simulations to account for the summer and winter seasons. Typical sea water temperature and salinity profiles for the summer and winter seasons are shown in Tables 3-1 and 3-2, respectively. These profiles were obtained from Soule and Oguri (1983) who conducted cruise studies in the vicinity of the dumpsite. As shown in Table 3-1, the temperature data were obtained to a water depth of 24.5 m. However, a thermocline would be present in the summer season. Hence, a thermocline is assumed to be present at a water depth of about 100 - 200 m based on the data available for the Southern Pacific Ocean. The sea water temperature profile for the summer season looks like this:

0 to 100 m	same as shown in Table 3-1
100 to 200 m	a temperature gradient of $8^{o}C$ / 50 m
below 200 m	a temperature gradient of $1.2^{o}C$ / 50 m

FIG. 3-1 PREVAILING SURFACE CURRENTS SUMMER, (DEC., JAN., FEB.)

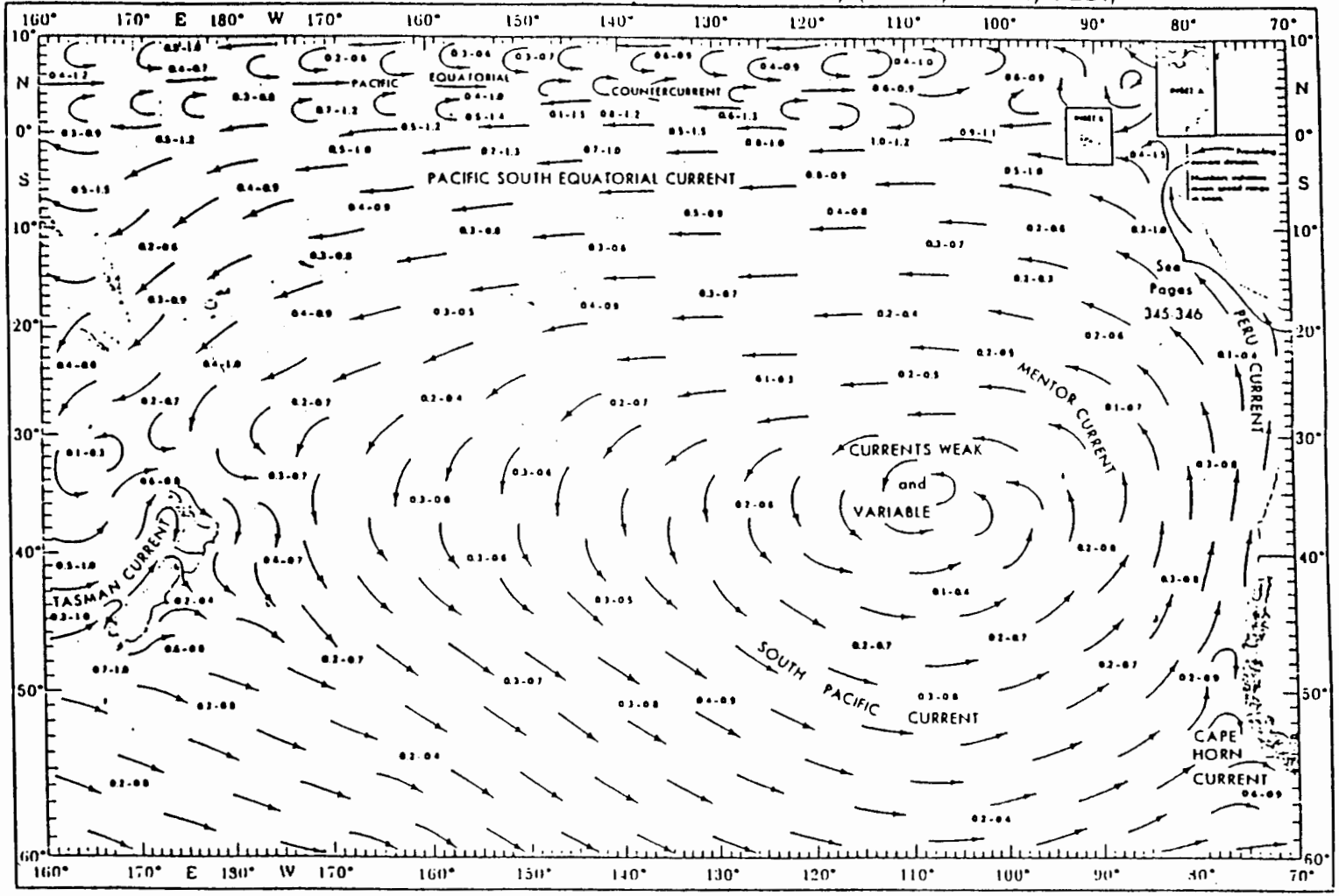


FIG. 3-2 PREVAILING SURFACE CURRENTS WINTER, (JUN., JUL., AUG.)

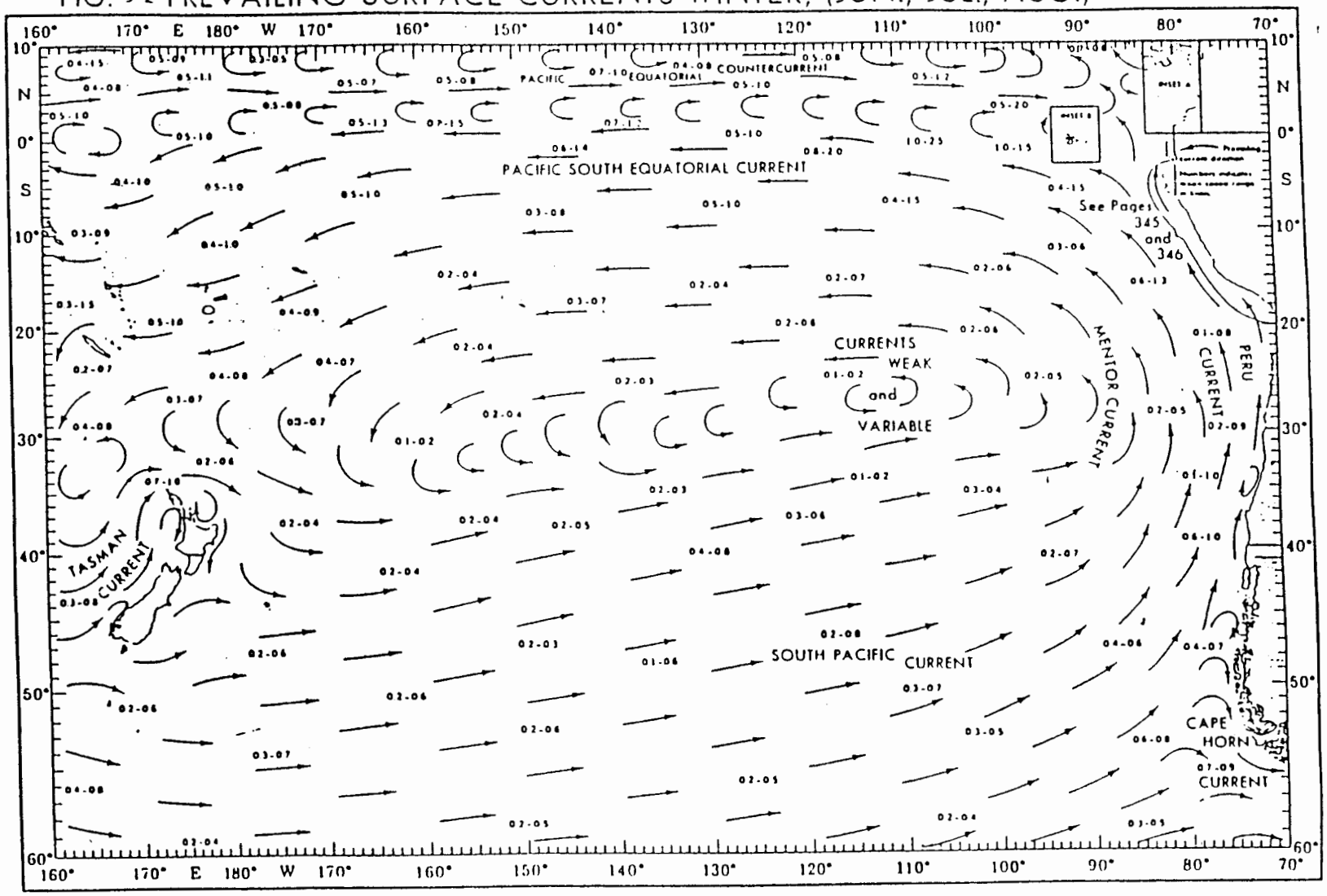


Table 3-1

CRUISE: Star-Kist - Van Camp NOAA-OMPA-AMERICAN SAMOA

VESSEL: AUTELE

DATE: 21 Jan. 1982

WEATHER: See Cruise Report

SEA STATE: See Cruise Report

TIDE: High; 1710, 2.6ft.

Station	Depth m	Time	Temp °C	Sal ‰	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l	DO Winkler
TP05	0	1045	29.8	36.3	5.9	8.4	55	3	6		4.5		5.4
	3		29.9	36.8	6.1	8.4	85				3.5		5.4
	6		29.5	37.0	6.1	8.4	90						5.6
	10		29.4	37.0	6.1	8.4	96				3		5.5
	15		29.4		6.0	8.5	98						
TS06	0	1115	29.5	36.1	5.7	8.4	87	4	4				5.4
	3		29.5	36.5	5.5	8.4	86						5.7
	6		29.4	36.5	5.8	8.4	91						5.8
	10		29.4	36.8	6.0	8.5	95						5.6
	15		29.4		5.8	8.5	96						
TS07	0	1135	29.4	36.6	5.7	8.4	90	7	3		7.5		5.6
	3		29.5	36.6	6.0	8.4	88				5		5.4
	6		29.5	36.7	5.7	8.4	91				6		5.6
	10		29.5	36.9	5.8	8.4	92				5.5		5.7
	15		29.5		5.8	8.5	94						
	20		29.4		5.8	8.5	93						
	24.5		29.4		5.8	8.5	93						

Table 3-2

CRUISE: NOAA-OMPA-Star-Kist Samoa VESSEL: Autele DATE: 23 July 1982

WEATHER: Hot, calm with gusts, 2-6k SEA STATE: Long swells, 8-10ft TIDE: Low 1530, -0.5ft

Station (Map/Site)	Depth m	Time	Temp °C	Sal o/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS E (6)	0	1141	28.37	34.28	6.68	8.27		3	6			
	3		28.33	34.30	6.64	8.26						
	6		28.25	34.32	6.68	8.26						
	10		28.24	34.32	6.65	8.26						
	15		28.24	34.33	6.66	8.27						
	20		28.23	34.35	6.63	8.27						
* (7)												
TS F (8)	0	1157	28.59	34.25	6.62	8.25		4	4			
	3		28.29	34.31	6.66	8.26						
	6		28.26	34.31	6.41	8.26						
	10		28.25	34.32	6.41	8.27						
	15		28.25	34.32	6.51	8.27						
	20		28.25	34.32	6.41	8.27						
TS G (9)	0	1206	28.44	34.27	6.62	8.25		14	3			
	3		28.31	34.30	6.65	8.26						
	6		28.26	34.30	6.66	8.27						
	10		28.24	34.31	6.53	8.27						
	15		28.24	24.32	6.42	8.27						
	20		28.24	34.31	6.41	8.27						

*7 1151 drogues only

For water depths below 100 m, the temperature gradients have been estimated from the data shown in Figure III.11, of this volume. A temperature profile as shown in Table 3-2 has been assumed for the winter season. The temperature gradient is about 0.5^{o}C per 30.5m.

3.2 Results of Simulations

Before the simulations were performed, parameters such as A, Co, Kv, and L in Equation 2.11 need to be calculated or chosen. The parameter A is a constant called the dissipation parameter. The constant A relates the lateral diffusivity to the plume width parameter as defined in Equation 2.8. The empirical value of A in the ocean environment is generally from 0.1 to 0.0001 $ft^{2/3}$ /sec. (See Koh & Fan 1970, page 129 for presentation of such data). For the study site the exact value of A is not known. Therefore, a median value in the range just cited can be assumed. The value of A chosen for this simulation is 0.001 $ft^{2/3}$ /sec Since the exact value varies from day to day and it also depends on the currents in the study site, this chosen value is believed to be reasonable. More precise value may be obtained by field experiments.

The initial mean concentration Co of the fish wastes discharged into the ocean water through the disposal ship must be estimated based on the discharge rate. This value corresponds to the dilution obtained at the wake of the discharge ship and it can be estimated by the formula developed by Koh and Chang (1973). In their analysis they first assumed that the pumping rate of the waste material is such that the waste material is completely mixed into the wake by the turbulence without altering the wake flow pattern. Secondly, the effect of surface waves can be disregarded so that the flow pattern can be approximated from the analysis of the jet and wake flows. Thirdly, they assumed that the flow

pattern approaches a similarity form at a certain distance from the discharge point. Based on the given information of the discharge vessel and the assumptions involved in deriving the Koh and Chang formula, the initial mean concentration, Co, can be estimated by the following formula:

$$Co = \frac{Q}{1.814\,\pi\,R^2\,V} \qquad (3.1)$$

where Q is the discharge rate of the fish waste from the discharge pipe.

R is a characteristic length of the body which is chosen as the geometric mean of the half beam and the draft of the discharge vessel (i.e. $[(\text{ship draft})\ (\text{half beam})]^{1/2}$.

V is the relative velocity between ship and ambient current.

It should be noted that based on Equation 3.1 the scale of the mixing zone in the wake is proportional to the characteristic dimension of the discharge vessel which is reasonable.

The vertical diffusion coefficient Kv can be evaluated by the formulation of Koh and Fan (1970)

$$Kv = 10^{-4} / E \qquad (\text{sq cm/sec}) \qquad (3.2)$$

and

$$E = \left| \frac{1}{\rho} \frac{d}{dy} \right| \qquad (3.3)$$

where E = sea water density gradient

ρ = sea water density

y = water depth (meters)

From the temperature profiles developed in Section 3.1, the values of Kv, as shown in Table 3-3, are calculated as a function of water depth for the summer and winter seasons.

The width L of the initial plume is expected to be approximately twice the turning radius of the discharge ship. Since the turning radius

Table 3-3. Vertical Diffusion Coefficient.

Depth (m)	Kv (sq cm/sec) Summer	Winter
0 - 100	7.8	17.3
100 - 200	1.2	17.3
> 200	7.3	17.3

of the disposal vessel is 0.2 n mi (370.5 m), L is taken to be 741 m.

The results of the simulations are presented in terms of dilution of the fish wastes as a function of time after discharge and distance from the discharge location. Dilution is reciprocal of the product of Co and Cmax/Co. This value gives an indication of the volume fraction of fish waste in the water sample after the waste plume has traveled for a certain distance from the discharge location. Since no data have been obtained for the settling velocity of the Samoa waste particles, velocities of 1, 0.1, and 0.01 cm/sec have been used in the calculations to cover the possible range of settling velocities which is a function of the density of the waste material relative to the sea water density. The group of results with settling velocities of 0.01, 0.1, and 1.0 cm/sec would correspond to the particles that are floating on the ocean surface, neutrally buoyant in sea water and heavier than sea water respectively. The behavior of the particles with a settling velocity of 0.1 cm/sec is similar to that of neutrally buoyant particles and thus they are advected by the ambient surface and near surface currents.

The settling tank experiments reported by Soule and Oguri (1983) indicate that 30% of the fish waste being studied had a fall velocity greater than zero, 7% of the wastes had a fall velocity greater than 0.059 cm/sec and only 0.5% of the waste had a fall velocity greater than 0.24 cm/sec. Therefore the range of fall velocity used for the present study is reasonable. In fact, the fall velocity of 0.01 cm/sec would be the most representative value; thus, when discussing the simulated results, attention is directed toward the fall velocity of 0.01 cm/sec.

The computer model results are presented in tabular form in Tables 3-4 to 3-7 using the dimensions given for the dump vessel. Tables 3-4 and

Table 3-4. Results of Summer Waste Dilution, Q = 500 gpm.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
				Vfall = 1 cm/s			Vfall = 0.1 cm/s			Vfall = 0.01 cm/s		
T(hr)	X(n mi)	U(kt)	Co	Y1(m)	Cmax/Co	Ratio	Y2(m)	Cmax/Co	Ratio	Y3(m)	Cmax/Co	Ratio
5.0	1.0	.2	.000222	180.0	.05423	.33	18.0	.04999	.36	1.8	.04999	.36
7.5	1.5	.2	.000222	270.0	.03242	.56	27.0	.03038	.59	2.7	.03038	.59
10.0	2.0	.2	.000222	360.0	.02172	.83	36.0	.02052	.88	3.6	.02052	.88
12.5	2.5	.2	.000222	450.0	.01562	1.15	45.0	.01482	1.22	4.5	.01482	1.22
15.0	3.0	.2	.000222	540.0	.01179	1.53	54.0	.01133	1.59	5.4	.01122	1.61
17.5	3.5	.2	.000222	630.0	.00922	1.95	63.0	.00947	1.90	6.3	.00880	2.05
20.0	4.0	.2	.000222	720.0	.00741	2.43	72.0	.00805	2.24	7.2	.00769	2.54
2.5	1.0	.4	.000222	90.0	.05794	.31	9.0	.05035	.36	.9	.05035	.36
3.7	1.5	.4	.000222	135.0	.03798	.47	13.5	.03430	.53	1.3	.03430	.53
5.0	2.0	.4	.000222	180.0	.02726	.66	18.0	.02507	.72	1.8	.02507	.72
6.3	2.5	.4	.000222	225.0	.02067	.87	22.5	.01920	.94	2.2	.01920	.94
7.5	3.0	.4	.000222	270.0	.01627	1.11	27.0	.01522	1.18	2.7	.01522	1.18
8.8	3.5	.4	.000222	315.0	.01317	1.37	31.5	.01238	1.46	3.1	.01238	1.46
10.0	4.0	.4	.000222	360.0	.01089	1.65	36.0	.01028	1.75	3.6	.01028	1.75
1.2	1.0	.8	.000222	45.0	.04207	.43	4.5	.04207	.43	.5	.04207	.43
1.9	1.5	.8	.000222	67.5	.03532	.51	6.8	.03183	.57	.7	.03183	.57
2.5	2.0	.8	.000222	90.0	.02859	.63	9.0	.02521	.71	.9	.02521	.71
3.1	2.5	.8	.000222	112.5	.02287	.79	11.3	.02058	.88	1.1	.02058	.88
3.7	3.0	.8	.000222	135.0	.01883	.96	13.5	.01717	1.05	1.3	.01717	1.05
4.4	3.5	.8	.000222	157.5	.01585	1.14	15.8	.01457	1.24	1.6	.01457	1.24
5.0	4.0	.8	.000222	180.0	.01355	1.33	18.0	.01254	1.44	1.8	.01254	1.44

Table 3-5. Results of Summer Waste Dilution, Q = 1400 gpm.

				Vfall = 1 cm/s			Vfall = 0.1 cm/s			Vfall = 0.01 cm/s		
T(hr)	X(n mi)	U(kt)	Co	Y1(m)	Cmax/Co	Ratio	Y2(m)	Cmax/Co	Ratio	Y3(m)	Cmax/Co	Ratio
5.0	1.0	.2	.000621	180.0	.05423	.12	18.0	.05060	.13	1.8	.05000	.13
7.5	1.5	.2	.000621	270.0	.03242	.20	27.0	.03039	.21	2.7	.03039	.21
10.0	2.0	.2	.000621	360.0	.02172	.30	36.0	.02052	.31	3.6	.02052	.31
12.5	2.5	.2	.000621	450.0	.01562	.41	45.0	.01483	.43	4.5	.01483	.43
15.0	3.0	.2	.000621	540.0	.01179	.55	54.0	.01133	.57	5.4	.01123	.57
17.5	3.5	.2	.000621	630.0	.00922	.70	63.0	.00947	.68	6.3	.00880	.73
20.0	4.0	.2	.000621	720.0	.00741	.87	72.0	.00805	.80	7.2	.00789	.91
2.5	1.0	.4	.000621	90.0	.05795	.11	9.0	.05036	.13	.9	.05036	.13
3.7	1.5	.4	.000621	135.0	.03799	.17	13.5	.03430	.19	1.3	.03430	.19
5.0	2.0	.4	.000621	180.0	.02727	.24	18.0	.02507	.26	1.8	.02507	.26
6.3	2.5	.4	.000621	225.0	.02067	.31	22.5	.01921	.34	2.2	.01921	.34
7.5	3.0	.4	.000621	270.0	.01627	.40	27.0	.01522	.42	2.7	.01522	.42
8.8	3.5	.4	.000621	315.0	.01317	.49	31.5	.01238	.52	3.1	.01238	.52
10.0	4.0	.4	.000621	360.0	.01089	.59	36.0	.01028	.63	3.6	.01028	.63
1.2	1.0	.8	.000621	45.0	.04208	.15	4.5	.04208	.15	.5	.04209	.15
1.9	1.5	.8	.000621	67.5	.03533	.18	6.8	.03184	.20	.7	.03184	.20
2.5	2.0	.8	.000621	90.0	.02859	.23	9.0	.02522	.26	.9	.02522	.26
3.1	2.5	.8	.000621	112.5	.02287	.28	11.3	.02058	.31	1.1	.02058	.31
3.7	3.0	.8	.000621	135.0	.01884	.34	13.5	.01717	.37	1.3	.01717	.37
4.4	3.5	.8	.000621	157.5	.01585	.41	15.8	.01457	.44	1.6	.01457	.44
5.0	4.0	.8	.000621	180.0	.01355	.47	18.0	.01254	.51	1.8	.01254	.51

Table 3-6. Results of Winter Waste Dilution, Q = 500 gpm.

				Vfall = 1 cm/s			Vfall = 0.1 cm/s			Vfall = 0.01 cm/s		
T(hr)	X(n mi)	U(kt)	Co	Y1(m)	Cmax/Co	Ratio	Y2(m)	Cmax/Co	Ratio	Y3(m)	Cmax/Co	Ratio
5.0	1.0	.2	.000222	180.0	.03364	.54	18.0	.03364	.54	1.8	.03364	.54
7.5	1.5	.2	.000222	270.0	.02043	.88	27.0	.02043	.88	2.7	.02043	.88
10.0	2.0	.2	.000222	360.0	.01379	1.31	36.0	.01379	1.31	3.6	.01379	1.31
12.5	2.5	.2	.000222	450.0	.00996	1.81	45.0	.00996	1.81	4.5	.00996	1.81
15.0	3.0	.2	.000222	540.0	.00754	2.39	54.0	.00754	2.39	5.4	.00754	2.39
17.5	3.5	.2	.000222	630.0	.00591	3.05	63.0	.00591	3.05	6.3	.00591	3.05
20.0	4.0	.2	.000222	720.0	.00476	3.78	72.0	.00476	3.78	7.2	.00476	3.78
2.5	1.0	.4	.000222	90.0	.03385	.53	9.0	.03385	.53	.9	.03385	.53
3.7	1.5	.4	.000222	135.0	.02385	.78	13.5	.02385	.78	1.3	.02385	.78
5.0	2.0	.4	.000222	180.0	.01684	1.07	18.0	.01684	1.07	1.8	.01684	1.07
6.3	2.5	.4	.000222	225.0	.01290	1.40	22.5	.01290	1.40	2.2	.01290	1.40
7.5	3.0	.4	.000222	270.0	.01022	1.76	27.0	.01022	1.76	2.7	.01022	1.76
8.8	3.5	.4	.000222	315.0	.00831	2.17	31.5	.00831	2.17	3.1	.00831	2.17
10.0	4.0	.4	.000222	360.0	.00690	2.61	36.0	.00690	2.61	3.6	.00690	2.61
1.2	1.0	.8	.000222	45.0	.02827	.64	4.5	.02827	.64	.5	.02827	.64
1.9	1.5	.8	.000222	67.5	.02138	.84	6.8	.02138	.84	.7	.02138	.84
2.5	2.0	.8	.000222	90.0	.01693	1.06	9.0	.01693	1.06	.9	.01693	1.06
3.1	2.5	.8	.000222	112.5	.01382	1.30	11.3	.01382	1.30	1.1	.01382	1.30
3.7	3.0	.8	.000222	135.0	.01153	1.56	13.5	.01153	1.56	1.3	.01153	1.56
4.4	3.5	.8	.000222	157.5	.00979	1.84	15.8	.00979	1.84	1.6	.00979	1.84
5.0	4.0	.8	.000222	180.0	.00842	2.14	18.0	.00842	2.14	1.8	.00842	2.14

Table 3-7. Results of Winter Waste Dilution, Q = 1400 gpm.

				Vfall = 1 cm/s			Vfall = 0.1 cm/s			Vfall = 0.01 cm/s		
T(hr)	X(n mi)	U(kt)	Co	Y1(m)	Cmax/Co	Ratio	Y2(m)	Cmax/Co	Ratio	Y3(m)	Cmax/Co	Ratio
5.0	1.0	.2	.000621	180.0	.03364	.19	18.0	.03364	.19	1.8	.03364	.19
7.5	1.5	.2	.000621	270.0	.02043	.32	27.0	.02043	.32	2.7	.02043	.32
10.0	2.0	.2	.000621	360.0	.01380	.47	36.0	.01380	.47	3.6	.01380	.47
12.5	2.5	.2	.000621	450.0	.00996	.65	45.0	.00996	.65	4.5	.00996	.65
15.0	3.0	.2	.000621	540.0	.00754	.85	54.0	.00754	.85	5.4	.00754	.85
17.5	3.5	.2	.000621	630.0	.00591	1.09	63.0	.00591	1.09	6.3	.00591	1.09
20.0	4.0	.2	.000621	720.0	.00476	1.35	72.0	.00476	1.35	7.2	.00476	1.35
2.5	1.0	.4	.000621	90.0	.03385	.19	9.0	.03385	.19	.9	.03385	.19
3.7	1.5	.4	.000621	135.0	.02305	.28	13.5	.02305	.28	1.3	.02305	.28
5.0	2.0	.4	.000621	180.0	.01684	.38	18.0	.01684	.38	1.8	.01684	.38
6.3	2.5	.4	.000621	225.0	.01290	.50	22.5	.01290	.50	2.2	.01290	.50
7.5	3.0	.4	.000621	270.0	.01022	.63	27.0	.01022	.63	2.7	.01022	.63
8.8	3.5	.4	.000621	315.0	.00832	.77	31.5	.00832	.77	3.1	.00832	.77
10.0	4.0	.4	.000621	360.0	.00690	.93	36.0	.00690	.93	3.6	.00690	.93
1.2	1.0	.8	.000621	45.0	.02027	.23	4.5	.02027	.23	.5	.02027	.23
1.9	1.5	.8	.000621	67.5	.02138	.30	6.8	.02138	.30	.7	.02138	.30
2.5	2.0	.8	.000621	90.0	.01694	.38	9.0	.01694	.38	.9	.01694	.38
3.1	2.5	.8	.000621	112.5	.01382	.47	11.3	.01382	.47	1.1	.01382	.47
3.7	3.0	.8	.000621	135.0	.01153	.56	13.5	.01153	.56	1.3	.01153	.56
4.4	3.5	.8	.000621	157.5	.00979	.66	15.8	.00979	.66	1.6	.00979	.66
5.0	4.0	.8	.000621	180.0	.00842	.76	18.0	.00842	.76	1.8	.00842	.76

3-5 show the results for the summer months, with discharge rates Q = 500 gpm and Q = 1400 gpm, respectively. To interpret the results, it is fruitful to note the various items shown in each of the tables. The first column in Table 3-4 is the time after the initial release of the waste material. The second column converts the time into distance from the discharge point. In the third column, three different current speeds, namely 0.2 knots, 0.4 knots, and 0.8 knots are included. Based on Equation (3.1) the initial mean concentration, Co, is computed. For a discharge rate of 500 gpm Co is computed to be 0.000222. The vertical location of the centerline of the plume at different times for a fall velocity of 1 cm/sec is shown in the fifth column. The concentration at the centerline of the plume Cmax normalized with respect to Co is shown in column 6. The dilution, which can be obtained as the reciprocal of (Co) (Cmax/Co), can easily be obtained by the inverse of the value in column 4 multiplied by that in column 6. According to Soule and Oguri (1983) and Section III.A.2.C.1 of this report, the limiting permissible concentration (LPC) of the waste being discharged is 0.0004 % concentration of the fish waste. This value of concentration corresponds to a dilution of 250,000. Therefore, for convenience the dilution ratio has been normalized with respect to 250,000 and such ratio is presented in column 7. For the fall velocity of 0.1 cm/sec the corresponding results are presented in columns 8 to 10. Similarly the results for 0.01 cm/sec fall velocity are shown in columns 11 to 13. Thus, when one reads the value at columns 7, 10, and 13, a value of 1.00 implies the dilution of 250,000. A value greater than 1.0 implies a dilution greater than 250,000.

The major difference between the summer months and winter months is for the value of vertical diffusion. For the winter months, larger

vertical diffusions were used causing more mixing and thus a larger dilution. It can be seen that a greater mixing, therefore larger dilution, is achieved in the winter months (Tables 3-6 and 3-7) in comparison with the corresponding results for that in the summer months (Tables 3-4 and 3-5).

The results presented in Tables 3-4 to 3-7 can be plotted to provide a better picture of the extent of the waste plume following a prescribed current direction. Based on the available data the two observed directions at the discharge site are SW and NW. The waste plume is therefore advected along these directions while experiencing a lateral mixing along the way.

3.3 Extent of the Plume at the Present Site

To show the extent of the plume. at the present site, curves containing a series of equi-dilution lines are presented in Figures 3-3 and 3-4 (based on the results presented in Tables 3-4 and 3-6 respectively). The dilution ratios shown are the dilutions normalized with respect to 250,000 (LPC) for both the summer and winter months and for current speeds of 0.2 knots, 0.4 knots. and 0.8 knots. The discharge rate for these figures is 500 gpm and the fall velocity is set at 0.01 cm/sec.

Figure 3-5 shows the equi-dilution lines in the summer months plotted on the map for a waste discharge of 500 gpm in a current of 0.2 knots towards the SW direction. Two different equi-dilution lines are drawn: the line for 0.5 represents a dilution of 125,000, while the line for 1.0 represents a dilution of 250,000. Such a favorable current direction would continue to carry the plume away in the SW direction. Thus, the plume would not reach the shore region while undergoing a significant mixing and diffusion.

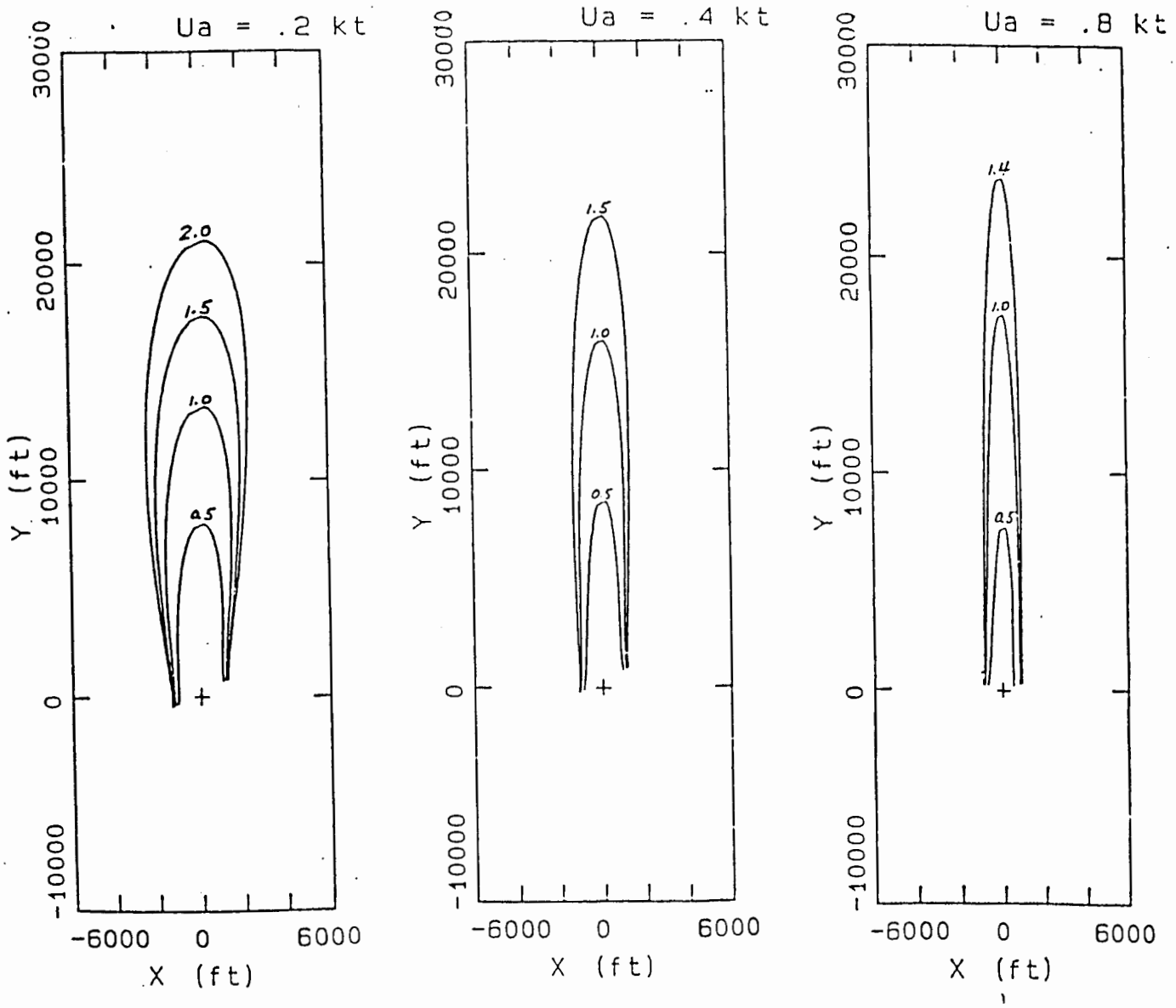


Figure 3-3. Equi-dilution lines of discharge waste plume, summer months. (Q = 500 gpm, Vfall = 0.01 cm/s, Ua = 0.2, 0.4, 0.8 kt).

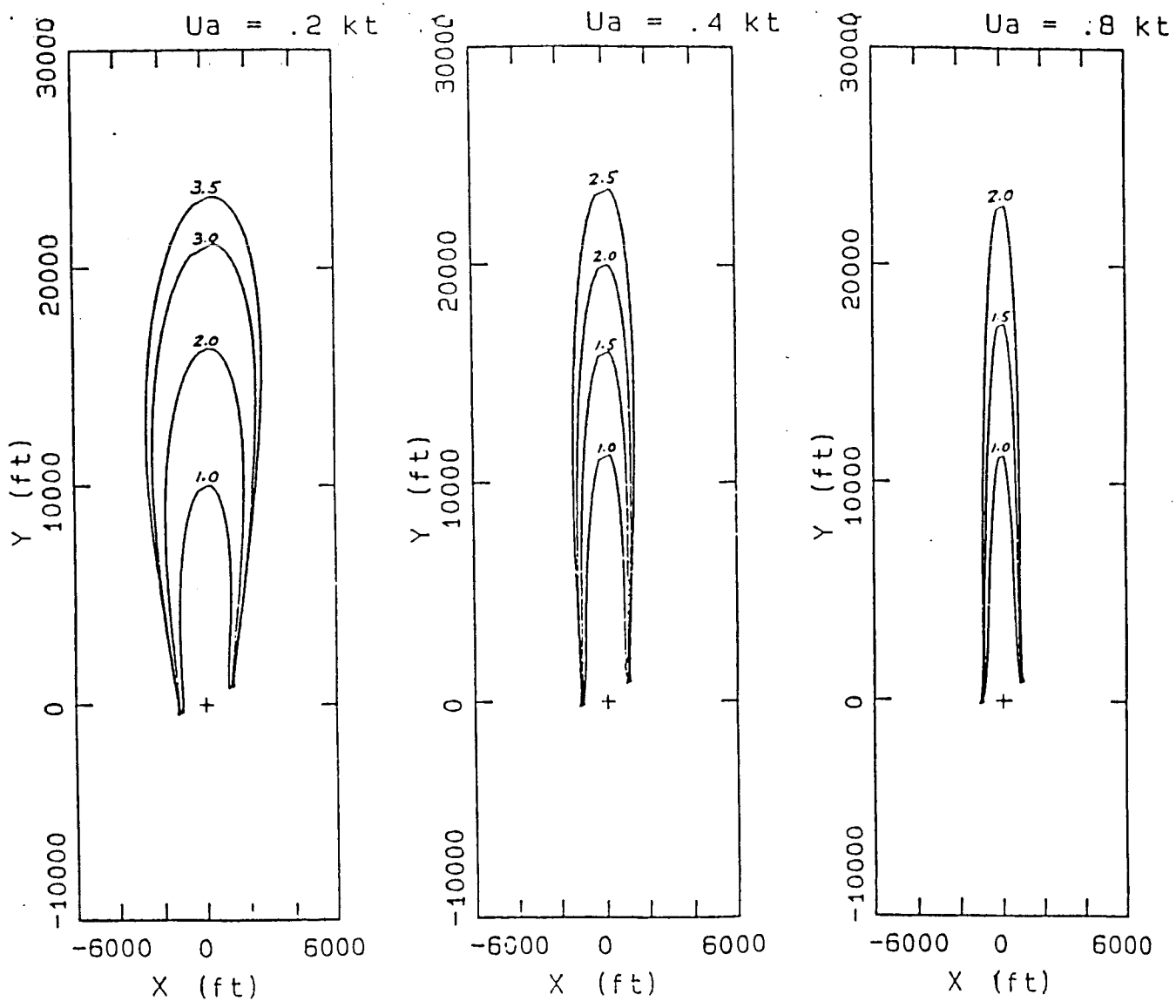


Figure 3-4. Equi-dilution lines of discharge waste plume, winter months. (Q = 500 gpm, Vfall = 0.01 cm/s, Ua = 0.2, 0.4, 0.8 kt).

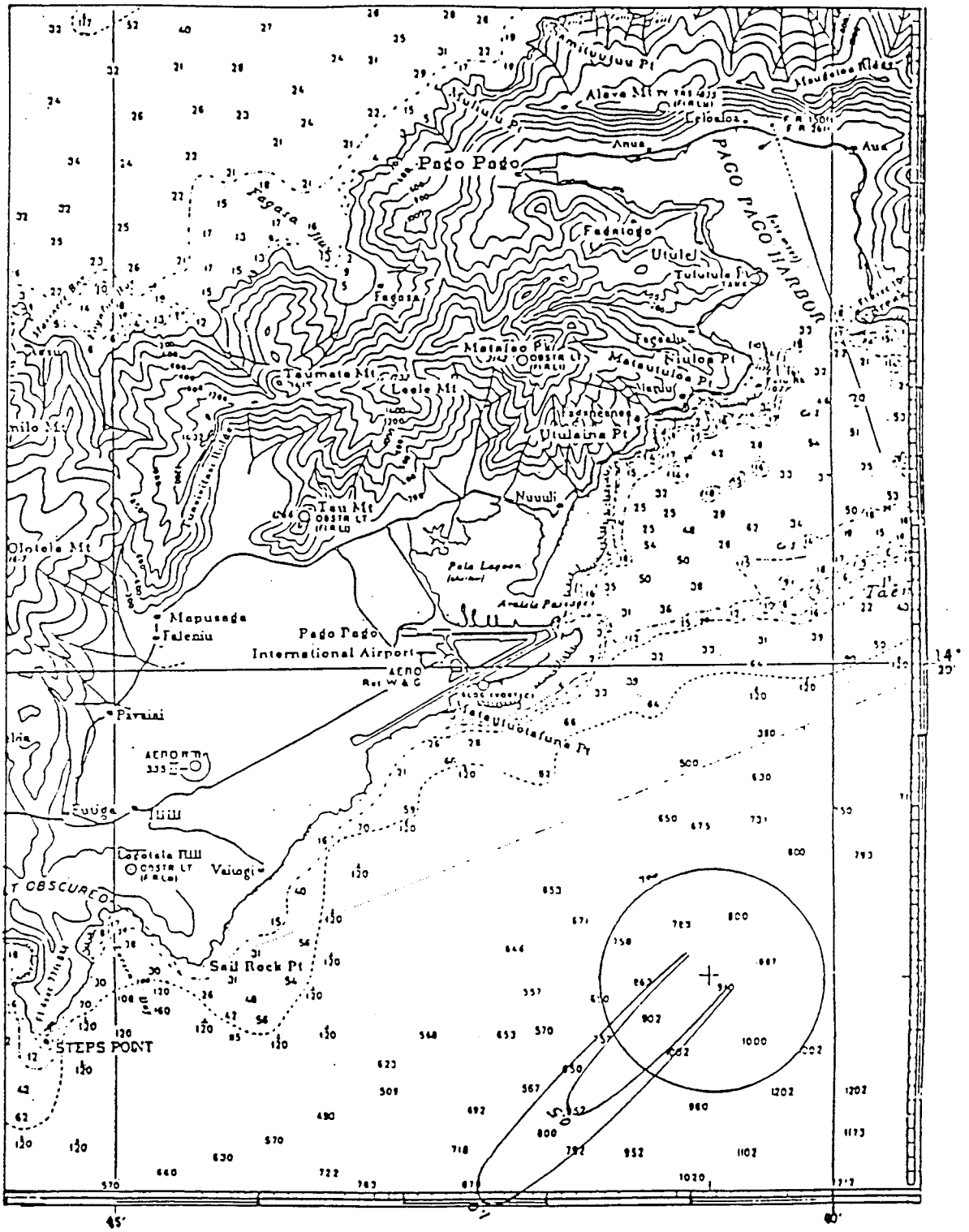


Figure 3-5. Equi-dilution lines of discharge waste plume, summer months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.2 kt).

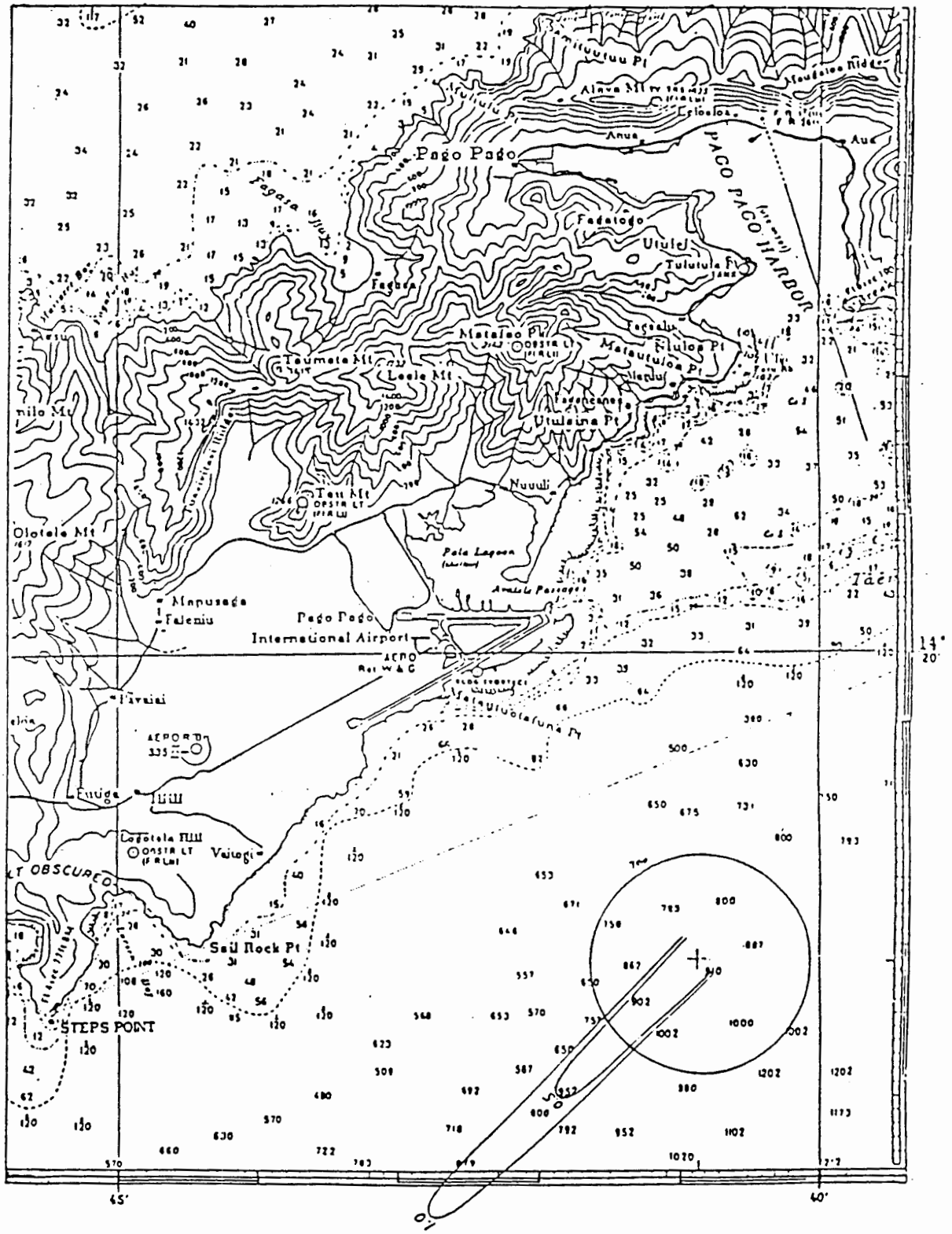


Figure 3-6. Equi-dilution lines of discharge waste plume, summer months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.4 kt).

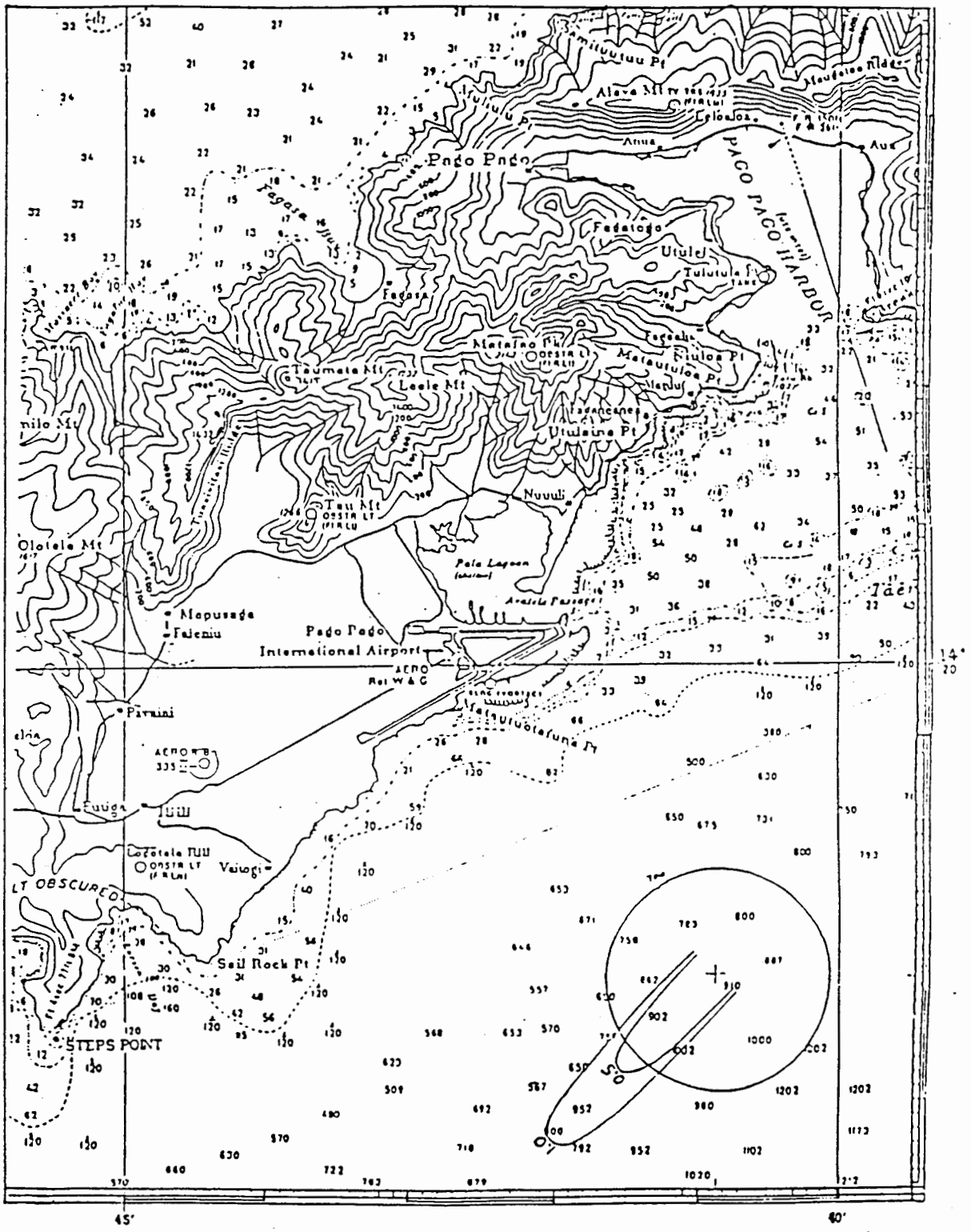


Figure 3-7. Equi-dilution lines of discharge waste plume, winter months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.2 kt).

Figure 3-6 shows the extent of the waste plume with a SW current of 0.4 kt. Comparing the results in Figure 3-6 with those in Figure 3-5, one observes that the effect of a stronger current is to advect the plume swiftly downstream in the current direction. Therefore, the extent of lateral diffusion is much narrower.

Figures 3-7 and 3-8 show the corresponding pictures for the winter months. By comparing these results with those presented in Figures 3-5 and 3-6, one can observe that a greater dilution is achieved in the winter months due to increased vertical diffusion.

The drogue studies conducted by Soule and Oguri (1984) indicate a current toward the southwest (SW) direction and that the data on the surface current presented in Figure III.8 also show predominant southwest surface current. However, some 1987 current meter data detect current in the northwest (NW) direction. Some current data indicated that a current in the southwest direction with a magnitude of 0.25 knots outside of the 120-fathom depth contour (CH2M Hill, 1976). A sketch confirming the direction of drogue movement (along the SW direction) after CH2M Hill is shown in Figure 3-9. Since the coastal current normally follows the depth contour, it is reasonable to expect a worst case illustration having a NW current (0.2 knots) at the dumpsite would at first carry the plume initially in the NW direction; however, as the plume propagates toward the shore the current will gradually bend the plume in a pattern such as shown in Figure 3-10. In fact, the simulated plume trajectory for this worst case scenario is illustrated in Figure 3-11. In Figure 3-11 the equi-dilution lines are drawn for the summer months with a waste discharge of 500 gpm in a current of 0.2 knots toward the NW direction at the dumpsite. It is seen that the dilution ratio of 1.0 (corresponds to 250,000

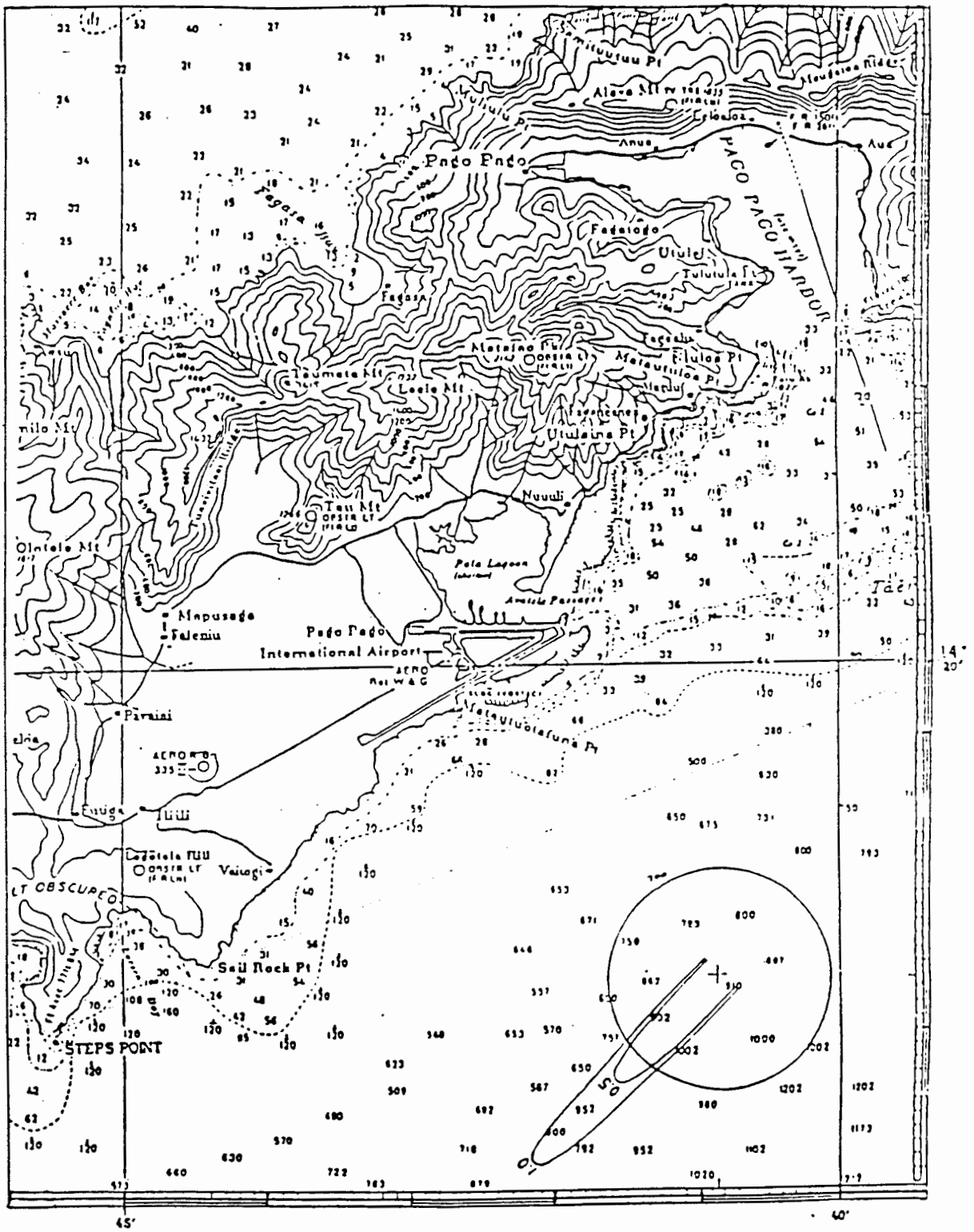


Figure 3-8. Equi-dilution lines of discharge waste plume, winter months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.4 kt).

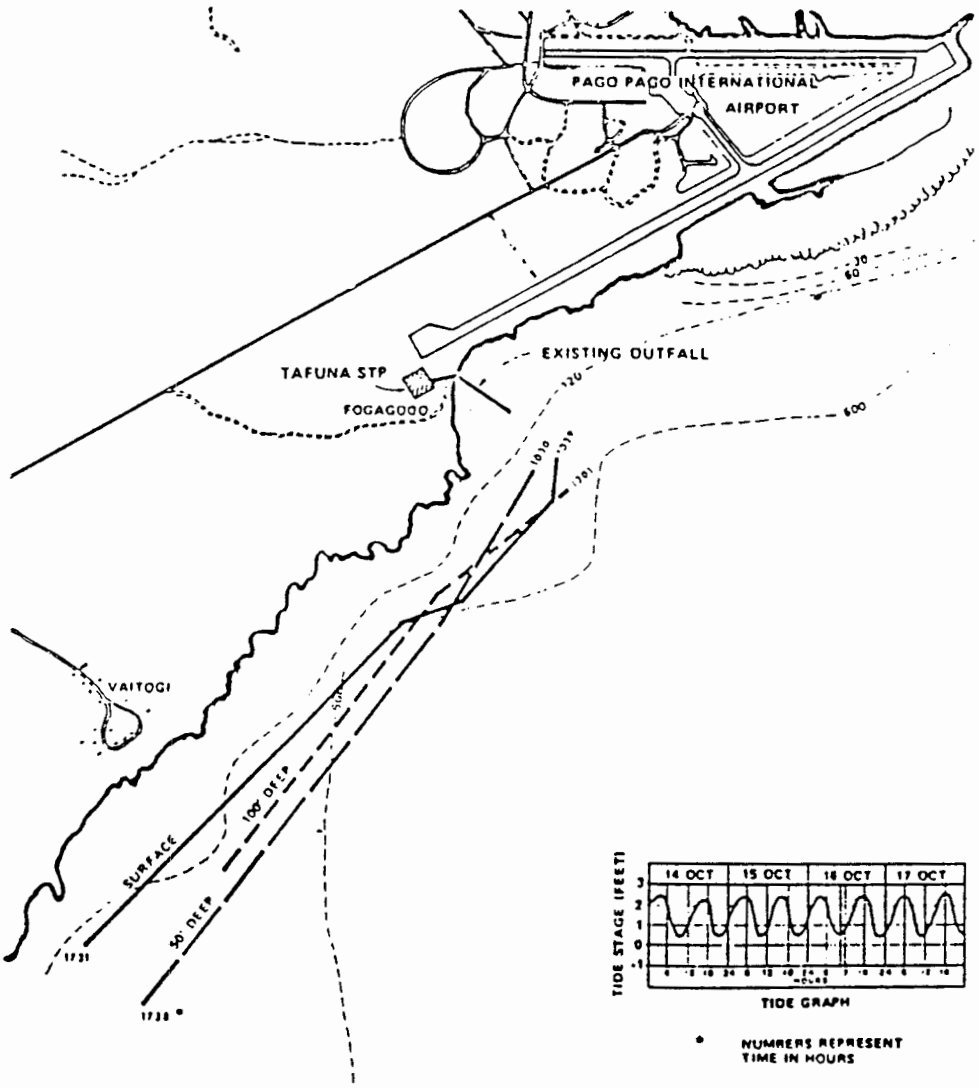


Figure 3-9. Drogue movement along shore (after CH_2M Hill, 1976).

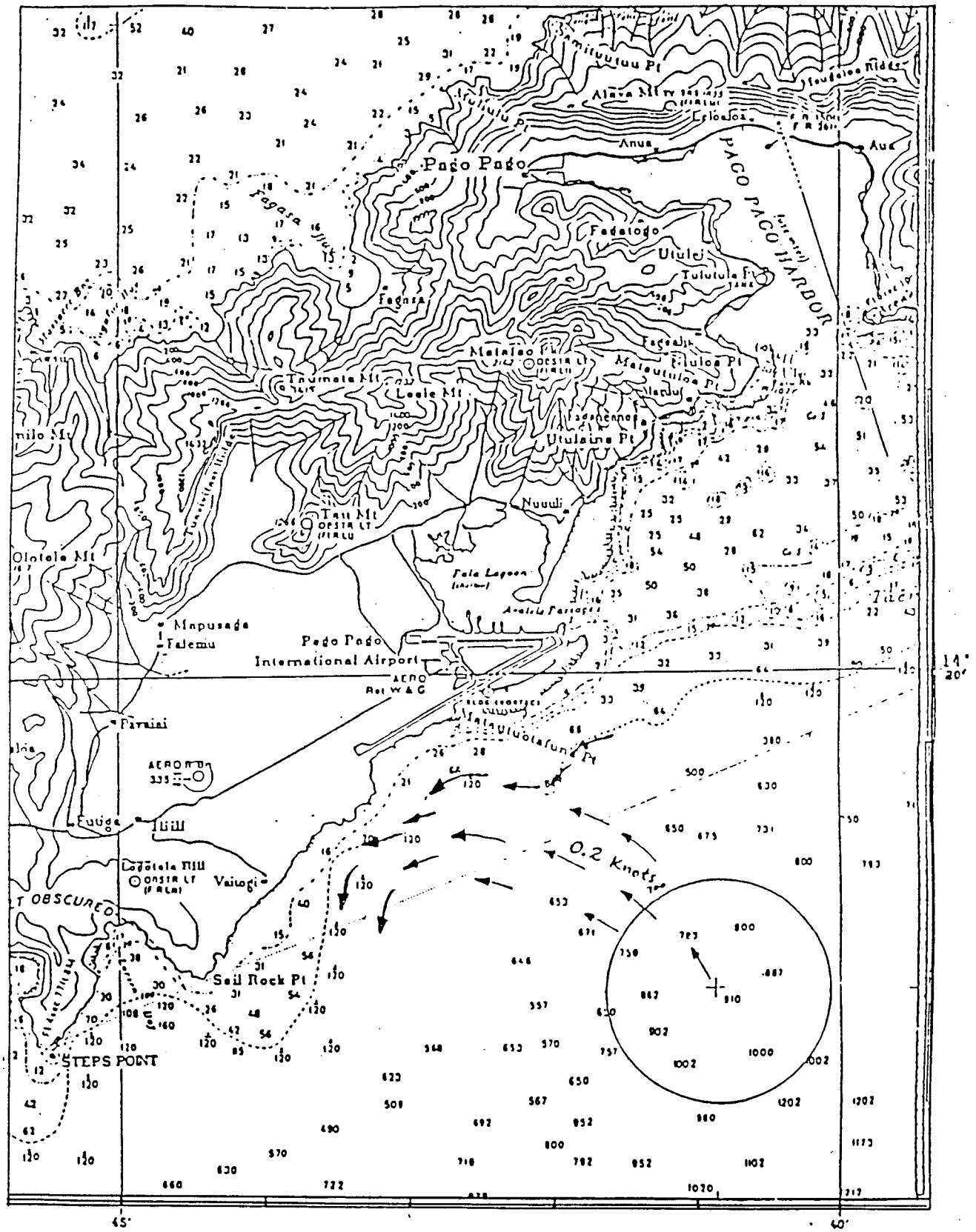


Figure 3.10. The expected near shore current pattern assuming the worst case scenario of NW current at the dumpsite.

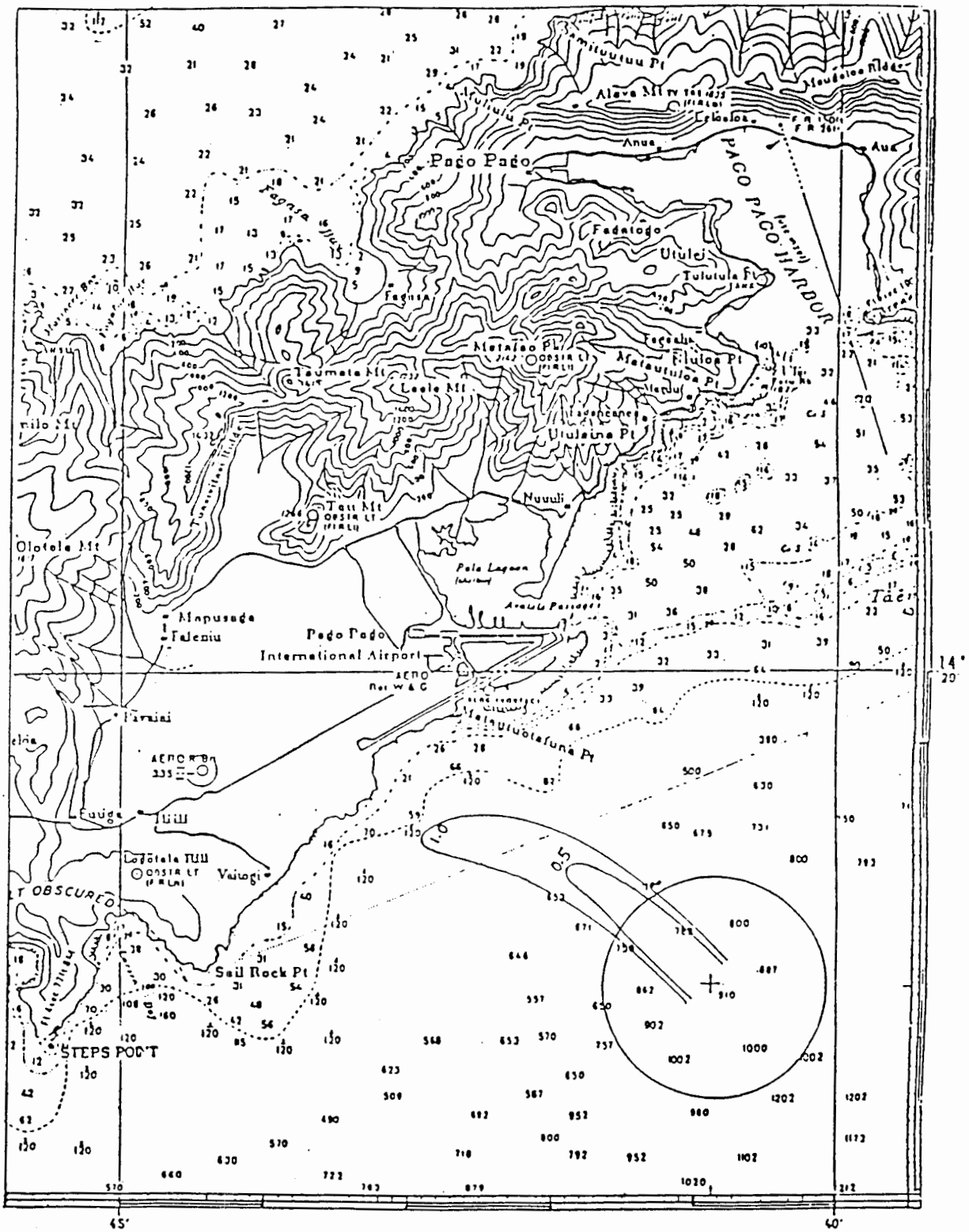


Figure 3-11. The worst-case illustration of the direction of the plume without the SW longshore current. the 250,000 dilution is reached before the plume reaches the 120 fm depth contour. Equi-dilution lones of discharge waste plume, summer months NW current (Q = 500 gpm, Vfall = 0.01 cm/s, Ua = 0.2 kt).

dilution) does not even reach a region at the 120-fathom contour, where significant change in water depth occurs. The longshore current in the SW direction would carry the plume in that direction, preventing the plume from reaching the shore region.

The longshore current to the SW is described in Section III.B.2.b. Therefore, the plume is expected to gradually bend toward the SW direction following the depth contour line (a direction along island shoreline) carrying the plume with it. In order to make a further, detailed prediction of the direction and the extent of the plume in this shallower water region, more definitive information on the seaward extent of the longshore current and its magnitude is needed. It should be emphasized that the results in Figure 3-9 are for the summer months. Results for the winter months would indicate more mixing, therefore greater dilution within the region shown.

3.4 Extent of Plume at Deeper Water Preferred Site.

With the selection of the deeper water site as the preferred site, the curves containing the equi-dilution lines were plotted for the same conditions shown in Figures 3-5 through 3-8 and 3-11 and discussed in Sectin 33. The results are shown in Figures 3-12 through 3-16.

Although the plumes are plotted from the center of the site, it has been recommended to EPA that the dump protocol be changed. The dump vessel would make observations of the surface current direction before dumping begins and dump at the upstream periphery, circling within the dumpsite during discharge. This would result in the plumes being dissipated to the LPC concentration of 1:250,000 within the dumpsite under most conditions.

The plume would not move inshore sufficiently to reach the longshore

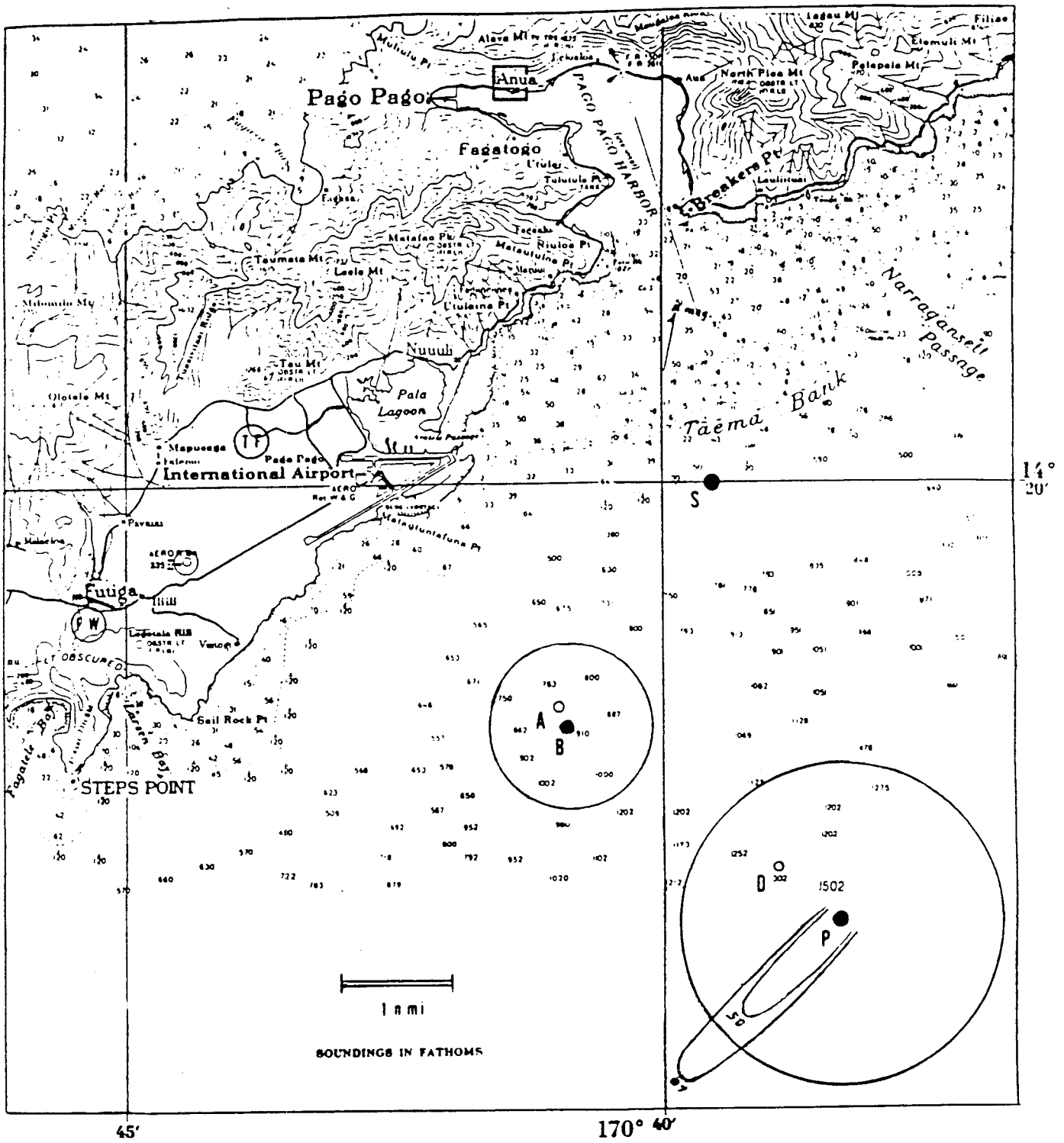


Figure 3-12. Equi-dilution lines of discharge waste plume, summer months SW current (Q= 500 gpm, Vfall = 0.01 cm/s Ua = 0.2 kt). If dumping were to take place at the NE periphery under these conditions, the plume would be fully dissipated, reaching background levels, within the dumpsite circle.

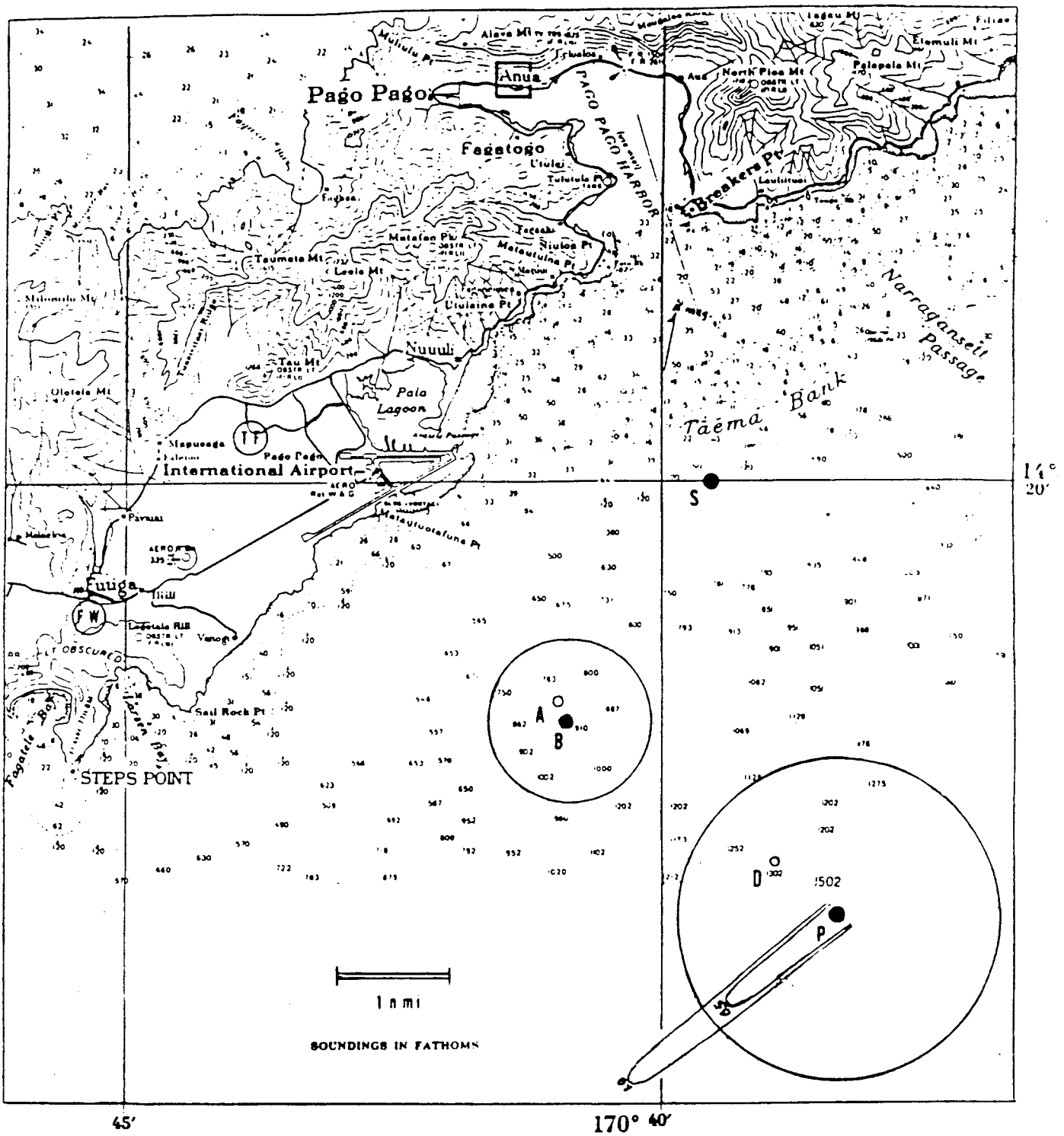


Figure 3-13. Equi-dilution lines of discharge waste plume, summer months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.4 kt). If dumping were to take place at the NE periphery under these conditions, the plume would be mostly dissipated within the dump circle.

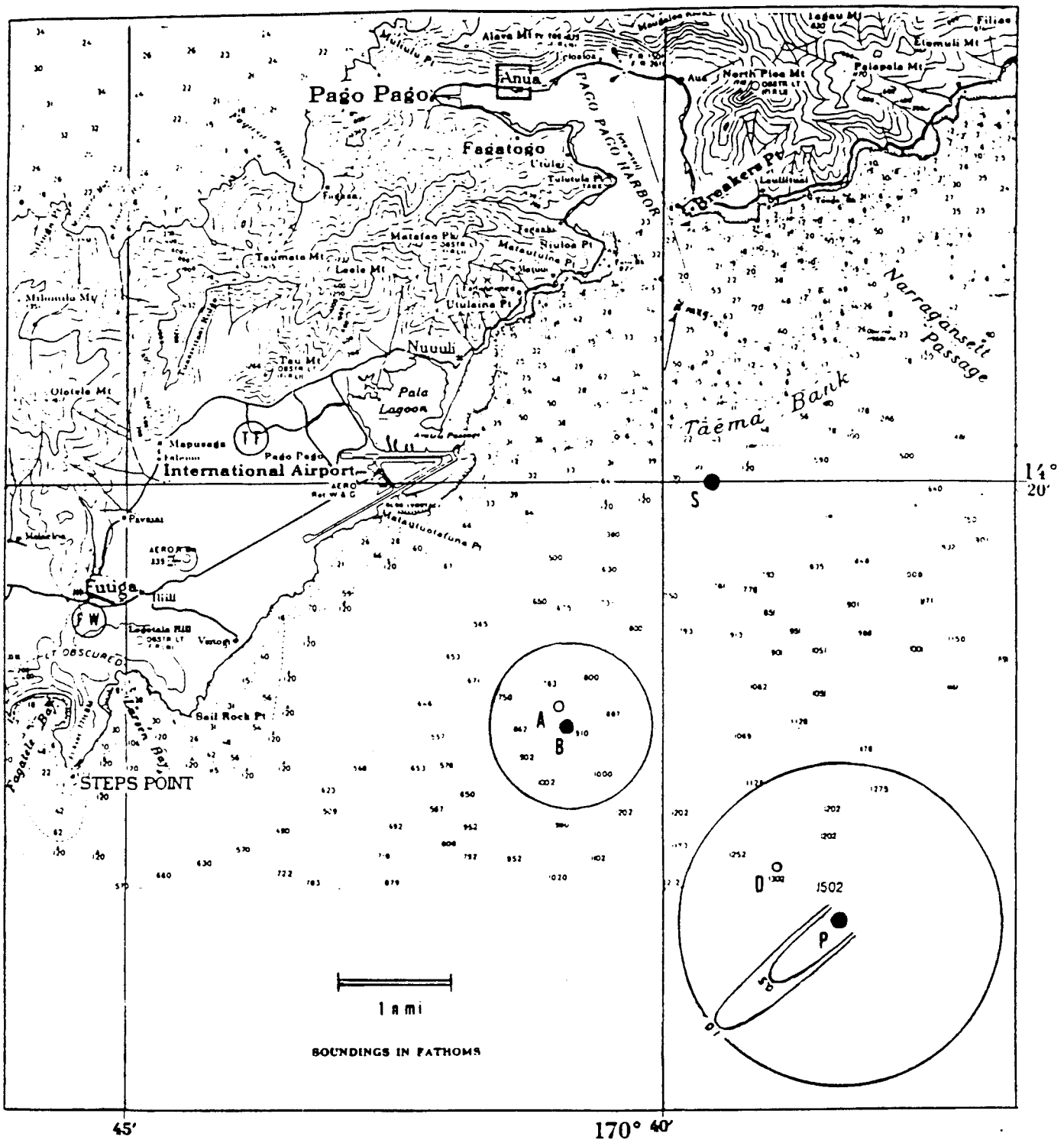


Figure 3-14. Equi-dilution lines of discharge waste plume, winter months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.2 kt). If dumping were to take place at the NE periphery under these conditions, the plume would be dissipated within the dumpsite circle.

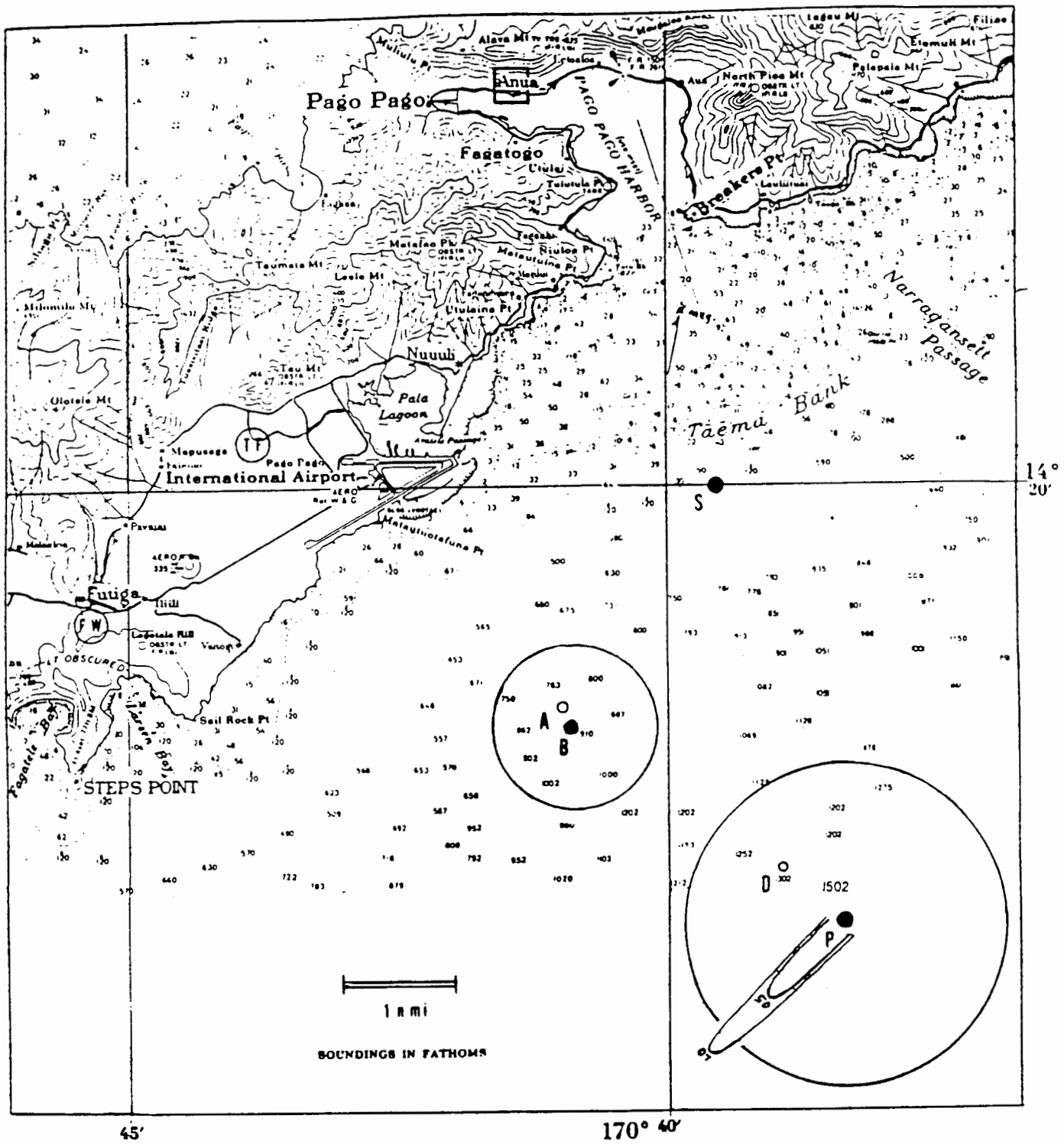


Figure 3-15. Equi-dilution lines of discharge waste plume, winter months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = o.4 kt). If dumping were to take place at the NE periphery under these conditions the plume would be dissipated within the dumpsite circle.

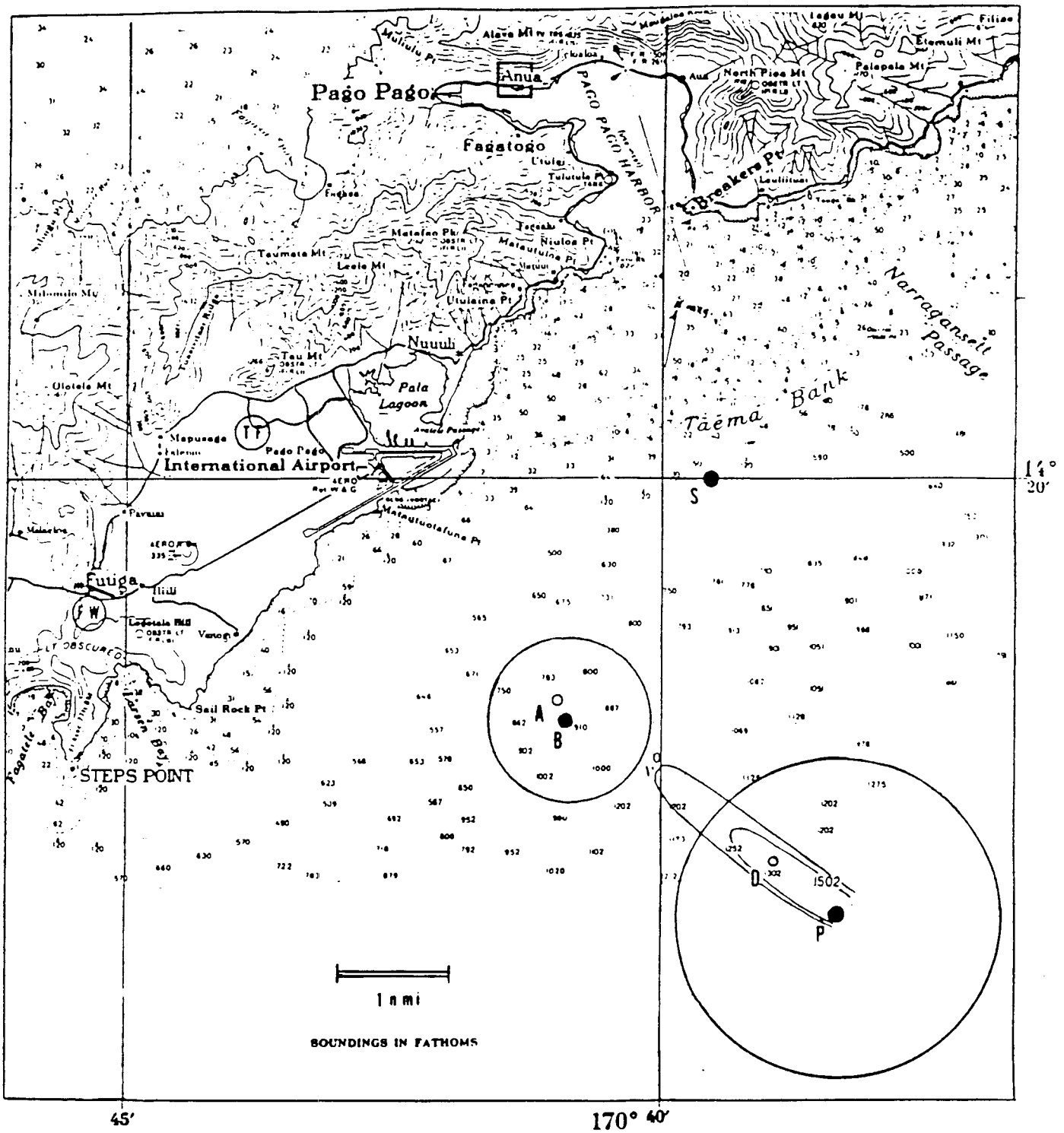


Figure 3-16. The worst-case illustration of the direction of the plume without the SW current. The 250, 000 dilution is reached before the plume reaches territorial waters. Equi-dilution lines of discharge waste plume, summer months NW current (Q = gpm, Vfall = 0.01 cm/s, Ua = 0.2 kt). If dumping were to begin at the SE periphery of the circle, the plume would be dissipated within the dumpsite circle.

current that generally flows southwest between the 120 fm and 600 fm contours. Even if a slick persisted on the surface it would generally be carried farther out to sea to the southwest and could not approach shallow waters.

4. CONCLUSION AND RECOMMENDATION

The results presented in this study are computed by a mathematical model of which the accuracy is dependent on the available data. Whenever the required data are not available, assumptions have been made for the parameters. We have used our best judgment in the estimation of the parameters. We believe that the results obtained by this mathematical model are at least as good as those obtained by any model using the present state of the knowledge.

The present mathematical model predicts the dilution as a function of distance and time from the point of release if the current direction is specified. The extent of the plume has also been shown under various conditions. A key factor in the determination of the plume trajectory is the direction of the ocean current. Field measurements indicate two persistent current directions, SW direction and NW direction. For current going towards the SW direction, it is shown that the plume at the present site will be advected in that direction at a distance at least 2 n mi south of Sail Rock Point. For current in the NW direction, significant dilution has been achieved when the plume reaches the region of shallower depth. Therefore, the longshore current is expected to carry such diluted plume again in SW direction (along the island shoreline direction). More definitive current, information especially on the incidence of reversal of the longshore current in the shallower depth region would be needed in order to predict the extent of the plume in the shallow depth region if

the present site were to continue to be used.

By using the preferred deepwater site, and by dumping upstream of the direction of flow, the plume would be fully dissipated within the dumpsite circle in most cases. The plume would not reach territorial waters, the longshore current, or the reefs.

If there is significant change in vessel size or in quantities dumped, the model should be run again to determine the nature of the plume trajectory and extent. A small change in vessel beam is not considered significant.

REFERENCES

Brooks, N.H. 1960. "Diffusion of Sewage Effluent in an Ocean Current." Proc. Int. Conf. Waste Disposal Mar. Environ., 1st. pp. 246-267. Pergamon, Oxford.

CH2M Hill. 1976. Wastewater Facilities Plan, American Samoa. Vol 2, Appendices. Government of American Samoa.

Fischer, H.B., List, E.J., Koh, R.C.Y., Imberger, J., and Brooks, N.H. 1979. Mixing in Inland and Coastal Waters. Academic Press. 483 pp.

Koh, R.C.Y. and Chang, Y.C. 1973. "Mathematical Model for Barged Ocean Disposal of Wastes." Prepared for Office of Research and Development, U.S. Environmental Protection Agency. EPA-660/2-73-029. 178 pp.

Koh, R.C.Y. and Fan, L.N. 1970. "Mathematical Models for the Prediction of Temperature Distributions Resulting from the Discharge of Heated Water into Large Bodies of Water." Water Quality Office, Environmental Protection Agency. Report Number 16130DWO10/70. Also a Tetra Tech, Inc. Report. 219 pp.

Soule, D.F. and Oguri, M. 1983. "A Report on Ocean Disposal of Fish Processing Wastes off Pago Pago, American Samoa." Prepared for the U.S. Environmental Protection Agency, Region IX, San Francisco, California and NOAA, Department of Commerce on behalf of Star-Kist Foods, Inc., and Van Camp Seafood Division, Ralston Purina Co.

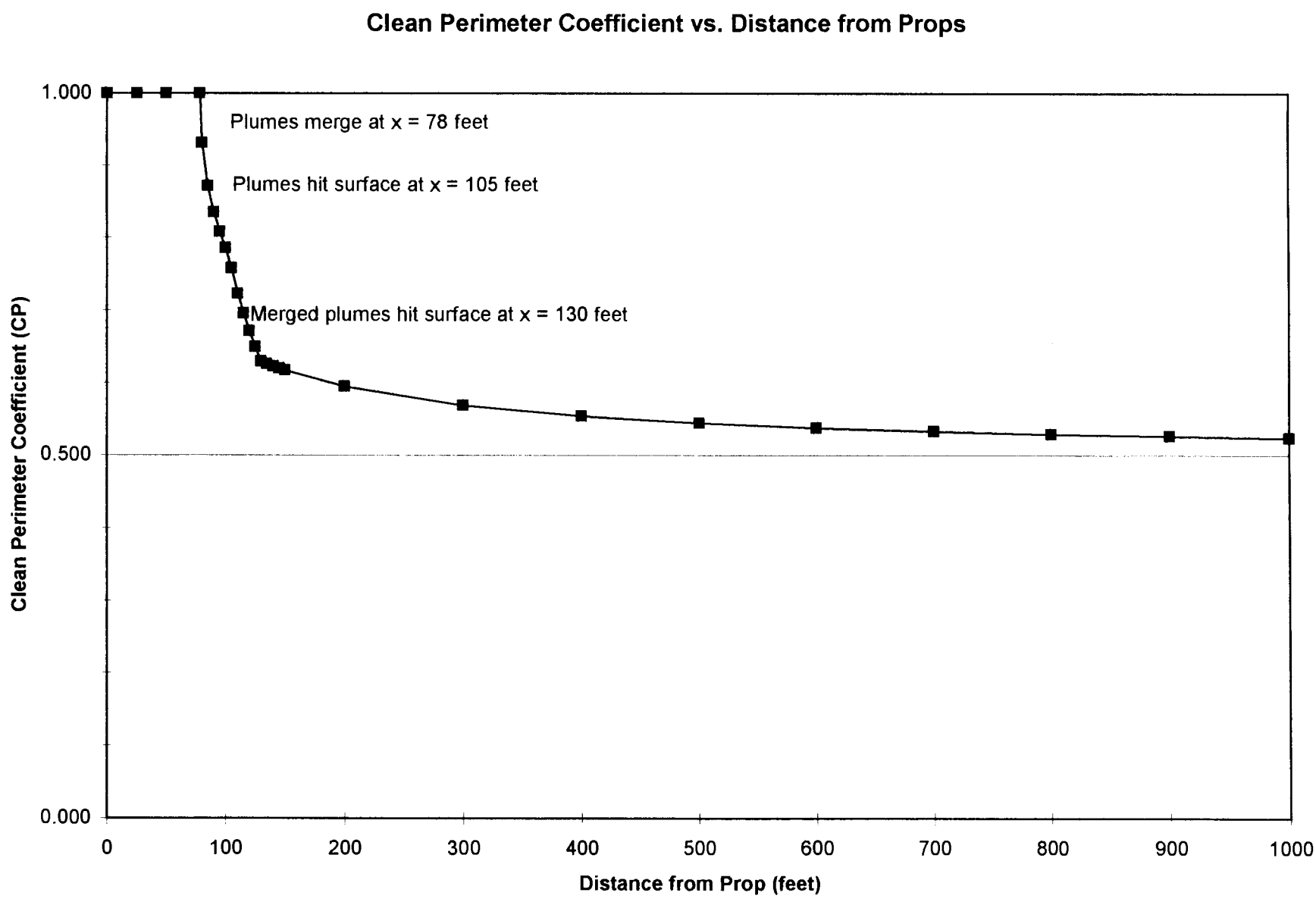
Soule, D.F. and Oguri, M. 1984. "Assessment of the Ocean Disposal Alternative for Management of Fish Processing Wastes." Final Report to NOAA - Grant # NA81RAD00009. Harbors Environmental Projects, Institute for Marine and Coastal Studies, University of Southern California.

U.S. Navy Marine Climatic Atlas of the World 1979. Volume V, South Pacific Ocean. Produced by the Naval Weather Service Detachment, Asheville, N.C. for the Commander, Naval Oceanography Command.

Appendix 9
Calculation of Entrainment Adjustment

Contents of Appendix 9:

- Plot of Clean Perimeter Coefficient vs Distance From Props
- Figure showing Plumes From Adjacent Propellers with Surface Boundary
- Table showing Calculation of Clean Perimeter Ratio


Clean Perimeter Coefficient vs. Distance from Props
Plumes merge at x = 78 feet
Plumes hit surface at x = 105 feet
Merged plumes hit surface at x = 130 feet
1.000
0.500
0.000
Clean Perimeter Coefficient (CP)
0
100
200
300
400
500
600
700
800
900
1000
Distance from Prop (feet)

Plumes from Adjacent Propellers - with Surface Boundary

caled by the ratio of the perimeter inside the adjacent plume to the total perimeter available for entrainment.

hereby defined as the clean perimeter coefficient (CP).

rainment is uniform over the perimeter of the plume. Propellers located 15 feet apart and 10 feet below water surface.

s calculated as r = 0.096X, where X is the distance downstream of the props.

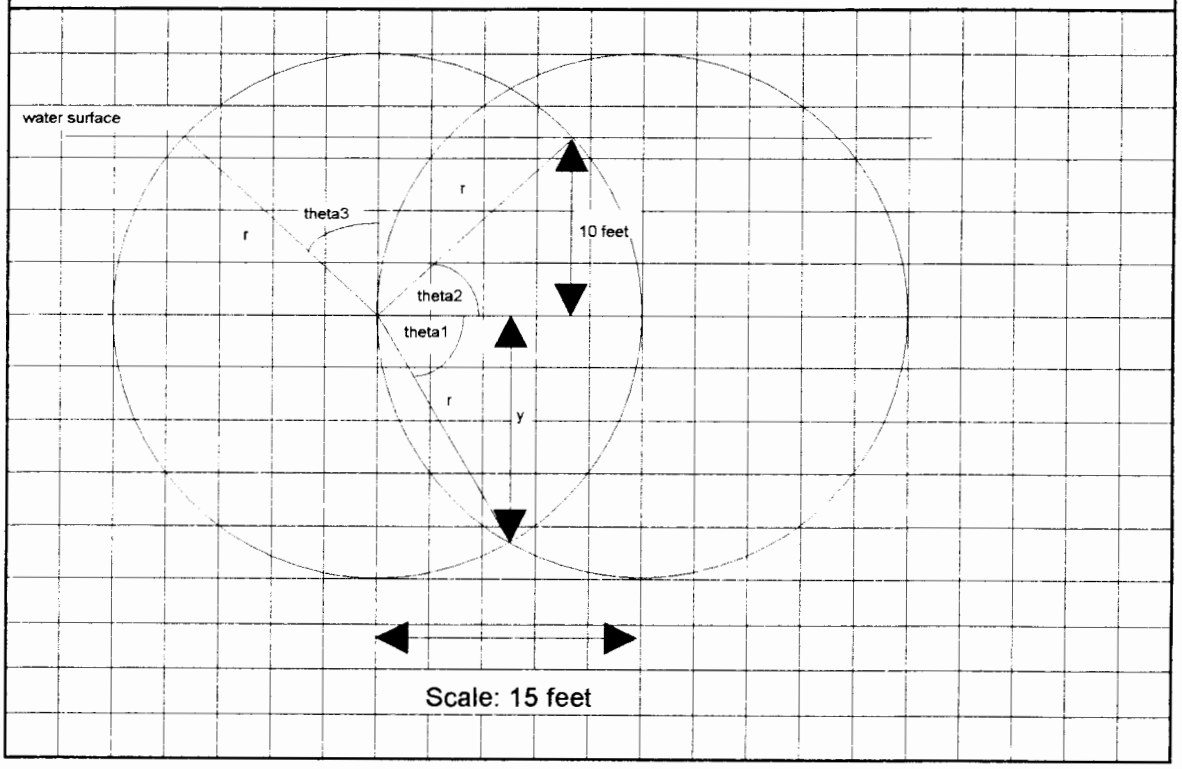
eter coefficient develops in four distinct steps based on plume radius r.

umes merge, CP = 1.0, as the plumes have not interferred with each other. [X<78.125 feet]

plumes merge but before the tops of theindividual plumes hit the surface. [78.125<X<105 feet]

individual plumes hit the surface, but before the merged area hits the surface. [105<X<130 feet]

merged area hits the surface. [130<X]



Calculation of the Clean Perimeter Ratio

Assumptions and Basis for Calculation:
plume half-width b = 0.096*X from Sobey, 1994
X ranges from 25 to 1000 feet
plumes merge at X = 78.125 feet
at 78.125 feet clean perimeter ratio = 1.0
individual plume encounters surface at X = 105 feet
merged plume reaches surface at X = 130 feet

X	b	y	theta1		theta2		theta3		Perimeter (in)	Perimeter (out)	clean ratio
(feet)	(feet)	(feet)	(rad)	(deg)	(rad)	(deg)	(rad)	(deg)	(feet)	(feet)	
0	0.0										1.000
25	2.4										1.000
50	4.8										1.000
78.125	7.5	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.0	47.1	1.000
80	7.7	1.7	0.22	12.4	0.22	12.4	0.00	0.0	3.3	44.9	0.931
85	8.2	3.2	0.40	23.2	0.40	23.2	0.00	0.0	6.6	44.7	0.871
90	8.6	4.3	0.52	29.8	0.52	29.8	0.00	0.0	9.0	45.3	0.835
95	9.1	5.2	0.61	34.7	0.61	34.7	0.00	0.0	11.0	46.3	0.807
100	9.6	6.0	0.67	38.6	0.67	38.6	0.00	0.0	12.9	47.4	0.785
105	10.1	6.7	0.73	41.9	0.73	41.9	0.13	7.2	14.8	46.0	0.757
110	10.6	7.4	0.78	44.7	0.78	44.7	0.33	18.7	16.5	42.9	0.723
115	11.0	8.1	0.82	47.2	0.82	47.2	0.44	25.1	18.2	41.5	0.695
120	11.5	8.7	0.86	49.4	0.86	49.4	0.52	29.8	19.9	40.6	0.671
125	12.0	9.4	0.90	51.3	0.90	51.3	0.59	33.6	21.5	39.8	0.650
130	12.5	10.0	0.93	53.1	0.93	53.1	0.64	36.7	23.1	39.3	0.630
135	13.0	10.6	0.95	54.6	0.88	50.5	0.69	39.5	23.8	39.8	0.626
140	13.4	11.2	0.98	56.1	0.84	48.1	0.73	41.9	24.4	40.3	0.623
145	13.9	11.7	1.00	57.4	0.80	45.9	0.77	44.1	25.1	40.9	0.620
150	14.4	12.3	1.02	58.6	0.77	44.0	0.80	46.0	25.8	41.6	0.617
200	19.2	17.7	1.17	67.0	0.55	31.4	1.02	58.6	33.0	48.4	0.595
300	28.8	27.8	1.31	74.9	0.35	20.3	1.22	69.7	47.9	63.0	0.568
400	38.4	37.7	1.37	78.7	0.26	15.1	1.31	74.9	62.9	78.0	0.554
500	48.0	47.4	1.41	81.0	0.21	12.0	1.36	78.0	77.9	93.0	0.544
600	57.6	57.1	1.44	82.5	0.17	10.0	1.40	80.0	93.0	108.1	0.537
700	67.2	66.8	1.46	83.6	0.15	8.6	1.42	81.4	108.1	123.1	0.533
800	76.8	76.4	1.47	84.4	0.13	7.5	1.44	82.5	123.2	138.2	0.529
900	86.4	86.1	1.48	85.0	0.12	6.6	1.45	83.4	138.2	153.2	0.526
1000	96.0	95.7	1.49	85.5	0.10	6.0	1.47	84.0	153.3	168.3	0.523

The inside perimeter is equal to (theta 1 + theta 2) times the radius of the plume:

$$p(in) = (\Theta_1 + \Theta_2)r$$

The outside perimeter is equal to (2 pi - 2 theta 3 - theta 1 - theta 2) times the radius of the plume:

$$p(out) = (2\pi - 2\Theta_3 - \Theta_1 - \Theta_2)r$$

The clean perimeter coefficient (CP) is equal to 1 minus the inside perimeter divided by the sum of the inside and the outside perimeters:

$$CP = 1 - \frac{p(in)}{p(in) + p(out)}$$

Appendix 10
Farfield Model Output

Contents of Appendix 10:

Farfield Dilution Model Output

- Winter Conditions, Ocean Current 0.2 knots, Vessel Speed 10 knots
- Winter Conditions, Ocean Current 0.4 knots, Vessel Speed 10 knots
- Winter Conditions, Ocean Current 0.6 knots, Vessel Speed 10 knots
- Winter Conditions, Ocean Current 0.8 knots, Vessel Speed 10 knots
- Winter Conditions, Ocean Current 1.0 knots, Vessel Speed 10 knots

- Winter Conditions, Ocean Current 0.2 knots, Vessel Speed 6 knots
- Winter Conditions, Ocean Current 0.4 knots, Vessel Speed 6 knots
- Winter Conditions, Ocean Current 0.6 knots, Vessel Speed 6 knots
- Winter Conditions, Ocean Current 0.8 knots, Vessel Speed 6 knots
- Winter Conditions, Ocean Current 1.0 knots, Vessel Speed 6 knots

- Summer Surface Conditions, Ocean Current 0.2 knots, Vessel Speed 10 knots
- Summer Surface Conditions, Ocean Current 0.4 knots, Vessel Speed 10 knots
- Summer Surface Conditions, Ocean Current 0.6 knots, Vessel Speed 10 knots
- Summer Surface Conditions, Ocean Current 0.8 knots, Vessel Speed 10 knots
- Summer Surface Conditions, Ocean Current 1.0 knots, Vessel Speed 10 knots

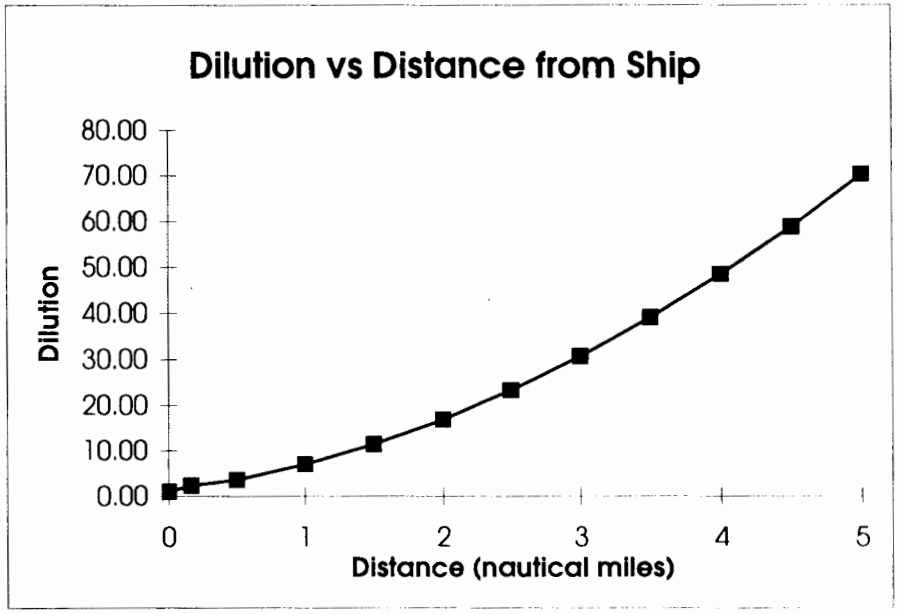
- Summer Surface Conditions, Ocean Current 0.2 knots, Vessel Speed 6 knots
- Summer Surface Conditions, Ocean Current 0.4 knots, Vessel Speed 6 knots
- Summer Surface Conditions, Ocean Current 0.6 knots, Vessel Speed 6 knots
- Summer Surface Conditions, Ocean Current 0.8 knots, Vessel Speed 6 knots
- Summer Surface Conditions, Ocean Current 1.0 knots, Vessel Speed 6 knots

Farfield Dilution Model

Winter Conditions - Ocean Current 0.2 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
1400 (gpm)	17.3 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
0.2 (knots)	0.001	50 (m)	10 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	1.4	0.42	0.42	2.41
3040	0.5	2.5	0.28	0.28	3.59
6080	1	5.0	0.14	0.14	7.01
9120	1.5	7.5	0.09	0.09	11.43
12160	2	10.0	0.06	0.06	16.85
15200	2.5	12.5	0.04	0.04	23.26
18240	3	15.0	0.03	0.03	30.66
21280	3.5	17.5	0.03	0.03	39.06
24320	4	20.0	0.02	0.02	48.46
27360	4.5	22.5	0.02	0.02	58.86
30400	5	25.0	0.01	0.01	70.25



Farfield Dilution Model

Winter Conditions - Ocean Current 0.4 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.4 (knots)

Dissipation Parameter (A)
0.001

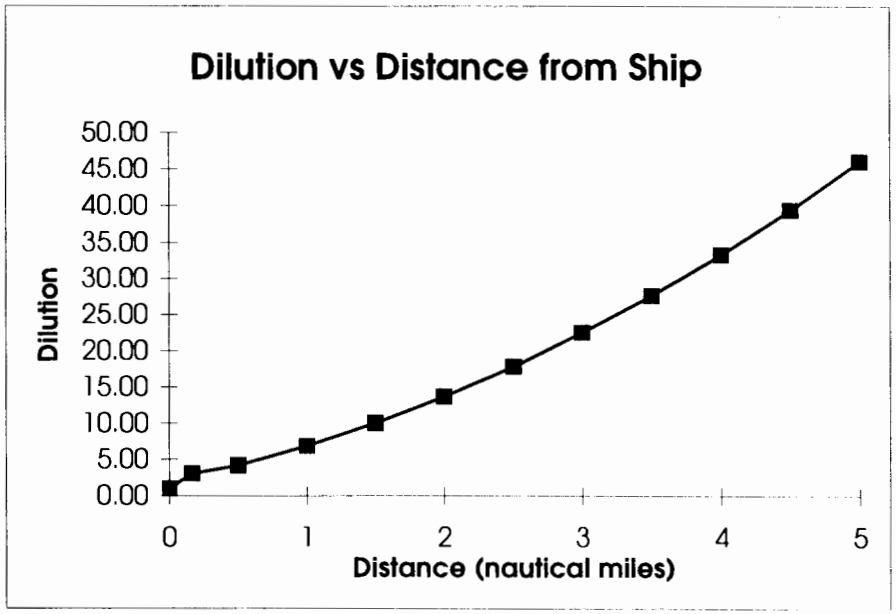
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.7	0.33	0.33	3.07
3040	0.5	1.3	0.24	0.24	4.18
6080	1	2.5	0.15	0.15	6.86
9120	1.5	3.8	0.10	0.10	10.03
12160	2	5.0	0.07	0.07	13.69
15200	2.5	6.3	0.06	0.06	17.85
18240	3	7.5	0.04	0.04	22.50
21280	3.5	8.8	0.04	0.04	27.65
24320	4	10.0	0.03	0.03	33.29
27360	4.5	11.3	0.03	0.03	39.43
30400	5	12.5	0.02	0.02	46.06

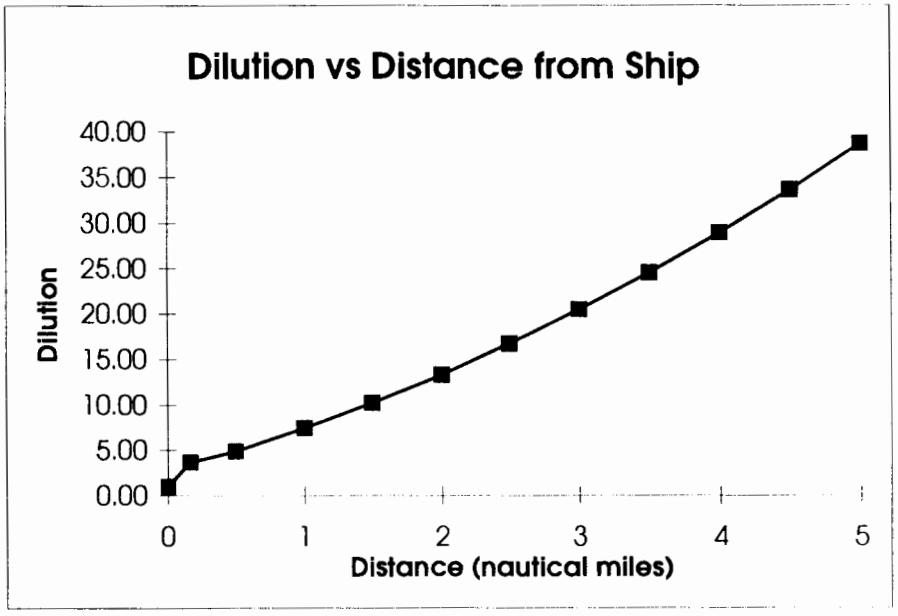


Farfield Dilution Model

Winter Conditions - Ocean Current 0.6 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
1400 (gpm)	17.3 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
0.6 (knots)	0.001	50 (m)	10 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.5	0.27	0.27	3.68
3040	0.5	0.8	0.20	0.20	4.90
6080	1	1.7	0.13	0.13	7.44
9120	1.5	2.5	0.10	0.10	10.20
12160	2	3.3	0.08	0.08	13.29
15200	2.5	4.2	0.06	0.06	16.70
18240	3	5.0	0.05	0.05	20.45
21280	3.5	5.8	0.04	0.04	24.52
24320	4	6.7	0.03	0.03	28.92
27360	4.5	7.5	0.03	0.03	33.65
30400	5	8.3	0.03	0.03	38.71

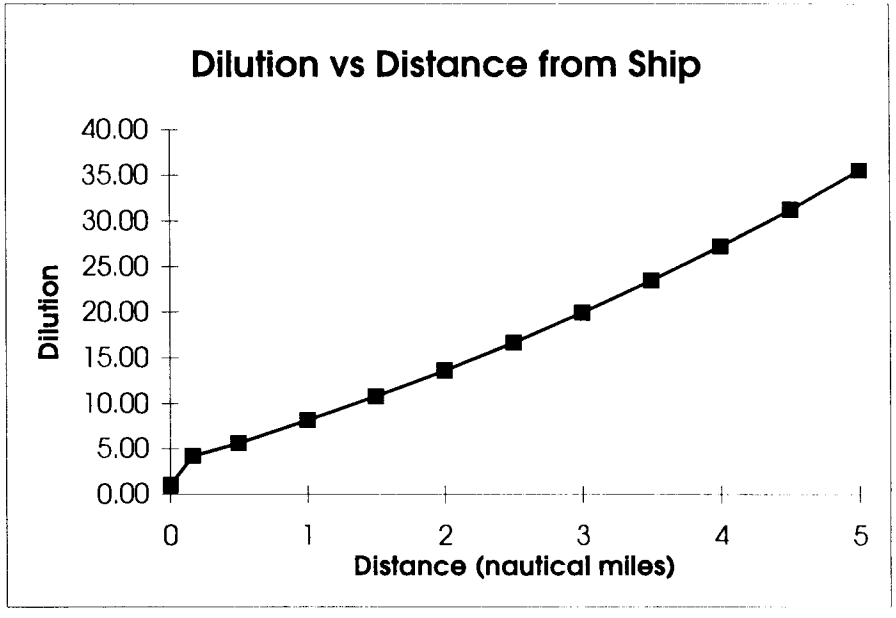


Farfield Dilution Model

Winter Conditions - Ocean Current 0.8 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
1400 (gpm)	17.3 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
0.8 (knots)	0.001	50 (m)	10 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.24	0.24	4.20
3040	0.5	0.6	0.18	0.18	5.58
6080	1	1.3	0.12	0.12	8.16
9120	1.5	1.9	0.09	0.09	10.75
12160	2	2.5	0.07	0.07	13.56
15200	2.5	3.1	0.06	0.06	16.61
18240	3	3.8	0.05	0.05	19.90
21280	3.5	4.4	0.04	0.04	23.44
24320	4	5.0	0.04	0.04	27.22
27360	4.5	5.6	0.03	0.03	31.25
30400	5	6.3	0.03	0.03	35.52



Farfield Dilution Model

Winter Conditions - Ocean Current 1.0 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
1 (knots)

Dissipation Parameter (A)
0.001

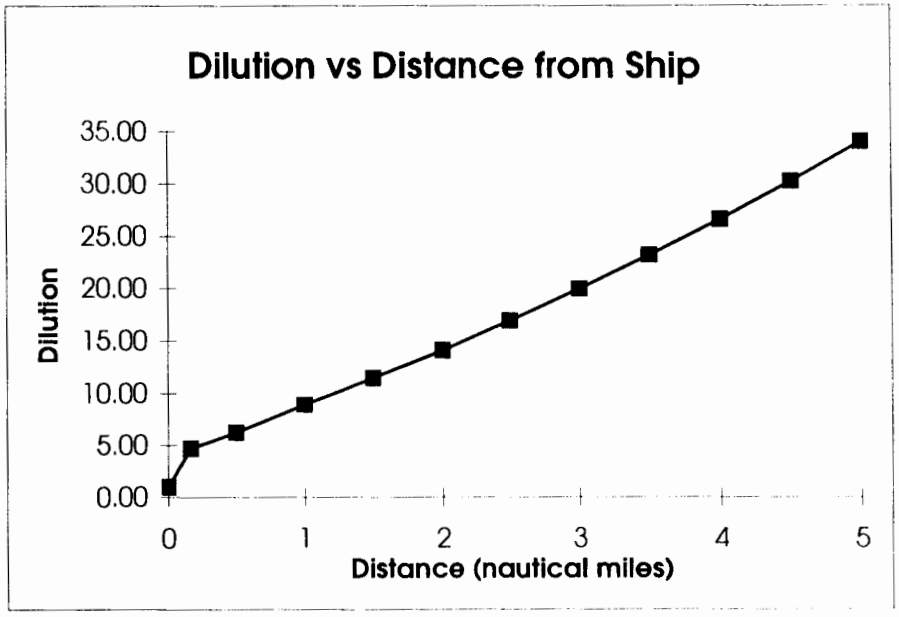
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.21	0.21	4.67
3040	0.5	0.5	0.16	0.16	6.21
6080	1	1.0	0.11	0.11	8.90
9120	1.5	1.5	0.09	0.09	11.44
12160	2	2.0	0.07	0.07	14.10
15200	2.5	2.5	0.06	0.06	16.93
18240	3	3.0	0.05	0.05	19.95
21280	3.5	3.5	0.04	0.04	23.17
24320	4	4.0	0.04	0.04	26.58
27360	4.5	4.5	0.03	0.03	30.19
30400	5	5.0	0.03	0.03	34.00



Farfield Dilution Model

Winter Conditions - Ocean Current 0.2 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.2 (knots)

Dissipation Parameter (A)
0.001

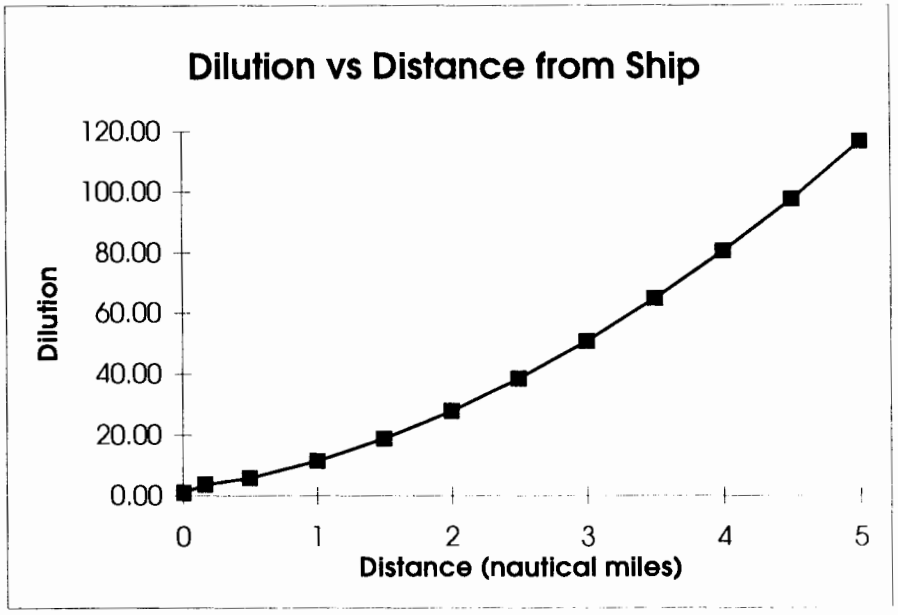
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	1.4	0.27	0.27	3.76
3040	0.5	2.5	0.17	0.17	5.76
6080	1	5.0	0.09	0.09	11.45
9120	1.5	7.5	0.05	0.05	18.80
12160	2	10.0	0.04	0.04	27.79
15200	2.5	12.5	0.03	0.03	38.44
18240	3	15.0	0.02	0.02	50.75
21280	3.5	17.5	0.02	0.02	64.72
24320	4	20.0	0.01	0.01	80.35
27360	4.5	22.5	0.01	0.01	97.63
30400	5	25.0	0.01	0.01	116.58



Farfield Dilution Model

Winter Conditions - Ocean Current 0.4 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.4 (knots)

Dissipation Parameter (A)
0.001

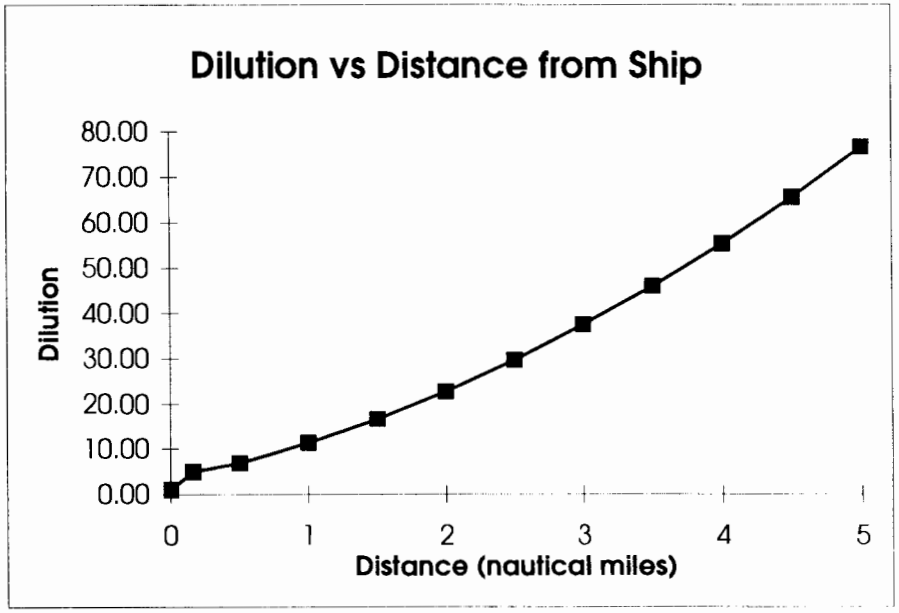
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.7	0.20	0.20	4.94
3040	0.5	1.3	0.15	0.15	6.82
6080	1	2.5	0.09	0.09	11.32
9120	1.5	3.8	0.06	0.06	16.60
12160	2	5.0	0.04	0.04	22.70
15200	2.5	6.3	0.03	0.03	29.62
18240	3	7.5	0.03	0.03	37.37
21280	3.5	8.8	0.02	0.02	45.94
24320	4	10.0	0.02	0.02	55.33
27360	4.5	11.3	0.02	0.02	65.56
30400	5	12.5	0.01	0.01	76.61



Farfield Dilution Model

Winter Conditions - Ocean Current 0.6 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.6 (knots)

Dissipation Parameter (A)
0.001

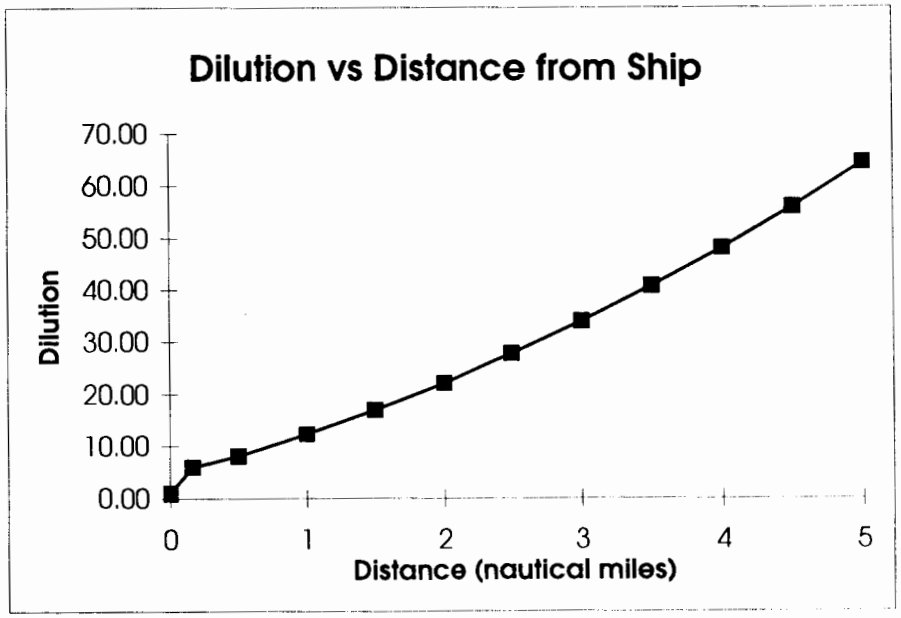
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.5	0.17	0.17	5.98
3040	0.5	0.8	0.12	0.12	8.05
6080	1	1.7	0.08	0.08	12.31
9120	1.5	2.5	0.06	0.06	16.93
12160	2	3.3	0.05	0.05	22.07
15200	2.5	4.2	0.04	0.04	27.76
18240	3	5.0	0.03	0.03	34.00
21280	3.5	5.8	0.02	0.02	40.78
24320	4	6.7	0.02	0.02	48.11
27360	4.5	7.5	0.02	0.02	55.99
30400	5	8.3	0.02	0.02	64.42



Farfield Dilution Model

Winter Conditions - Ocean Current 0.8 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
840 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.8 (knots)

Dissipation Parameter (A)
0.001

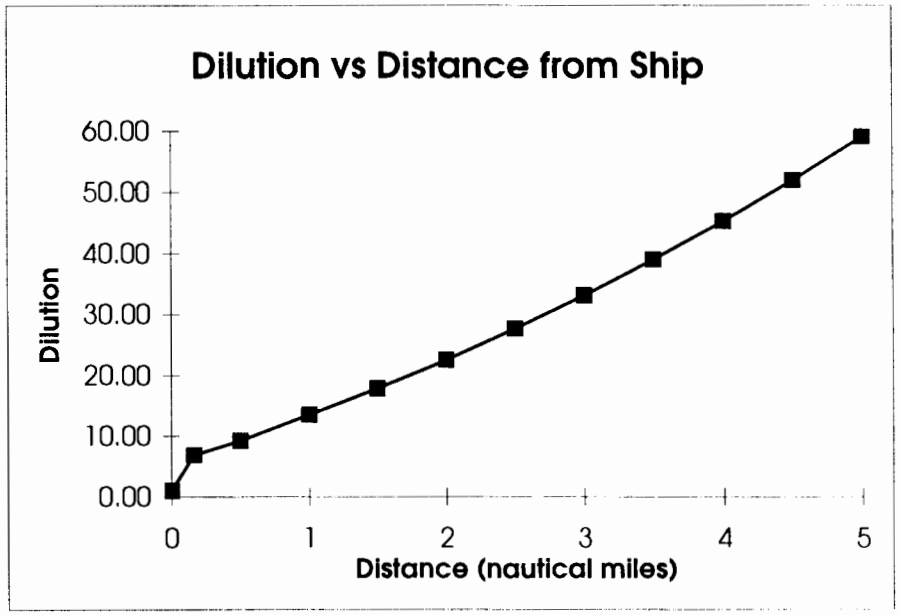
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.15	0.15	6.88
3040	0.5	0.6	0.11	0.11	9.21
6080	1	1.3	0.07	0.07	13.52
9120	1.5	1.9	0.06	0.06	17.86
12160	2	2.5	0.04	0.04	22.55
15200	2.5	3.1	0.04	0.04	27.62
18240	3	3.8	0.03	0.03	33.11
21280	3.5	4.4	0.03	0.03	39.00
24320	4	5.0	0.02	0.02	45.30
27360	4.5	5.6	0.02	0.02	52.02
30400	5	6.3	0.02	0.02	59.14

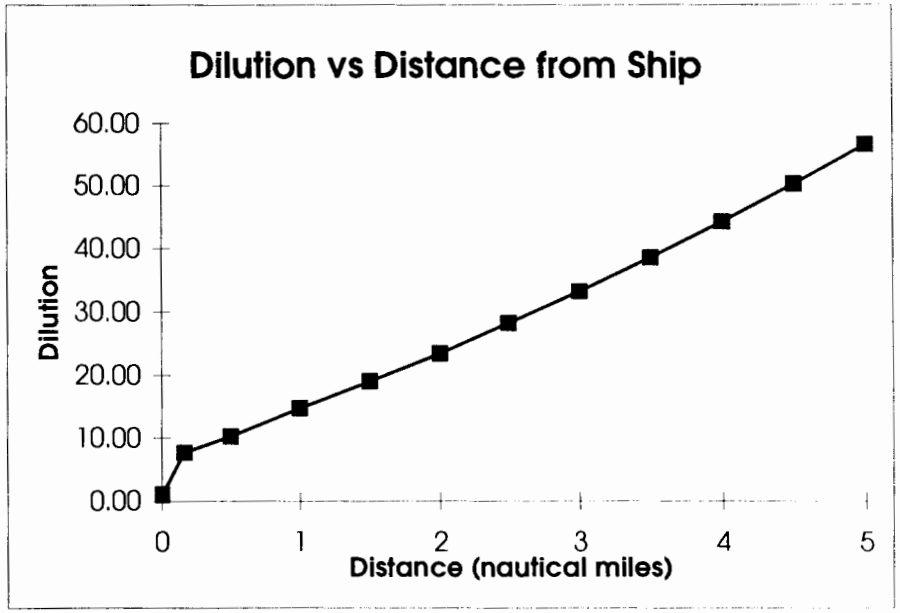


Farfield Dilution Model

Winter Conditions - Ocean Current 1.0 knots - Vessel Speed 6knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
840 (gpm)	17.3 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
1 (knots)	0.001	50 (m)	6 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.13	0.13	7.67
3040	0.5	0.5	0.10	0.10	10.27
6080	1	1.0	0.07	0.07	14.78
9120	1.5	1.5	0.05	0.05	19.01
12160	2	2.0	0.04	0.04	23.44
15200	2.5	2.5	0.04	0.04	28.17
18240	3	3.0	0.03	0.03	33.20
21280	3.5	3.5	0.03	0.03	38.57
24320	4	4.0	0.02	0.02	44.25
27360	4.5	4.5	0.02	0.02	50.27
30400	5	5.0	0.02	0.02	56.61



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.2 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1200 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.2 (knots)

Dissipation Parameter (A)
0.001

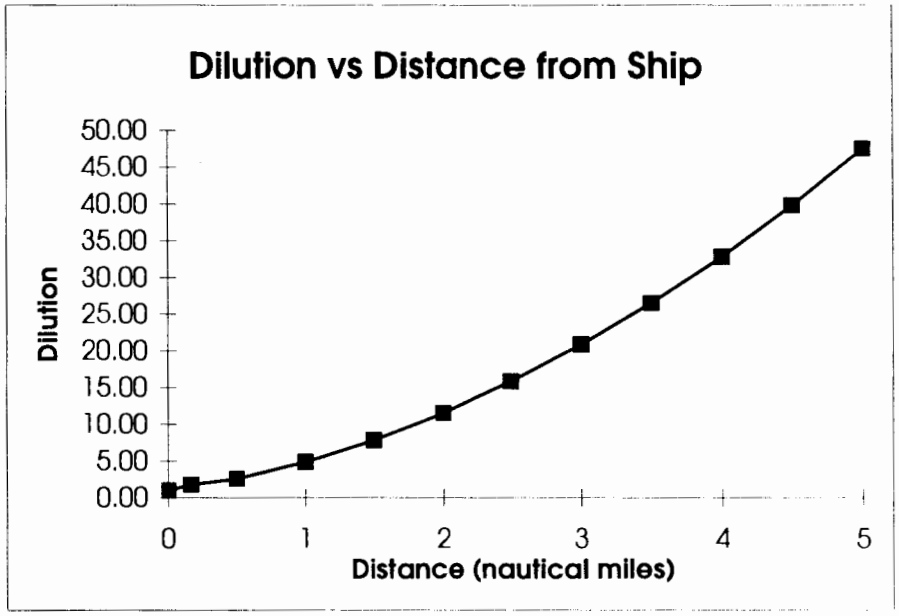
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	1.4	0.56	0.56	1.80
3040	0.5	2.5	0.39	0.39	2.58
6080	1	5.0	0.20	0.20	4.88
9120	1.5	7.5	0.13	0.13	7.87
12160	2	10.0	0.09	0.09	11.53
15200	2.5	12.5	0.06	0.06	15.86
18240	3	15.0	0.05	0.05	20.86
21280	3.5	17.5	0.04	0.04	26.53
24320	4	20.0	0.03	0.03	32.86
27360	4.5	22.5	0.03	0.03	39.87
30400	5	25.0	0.02	0.02	47.54

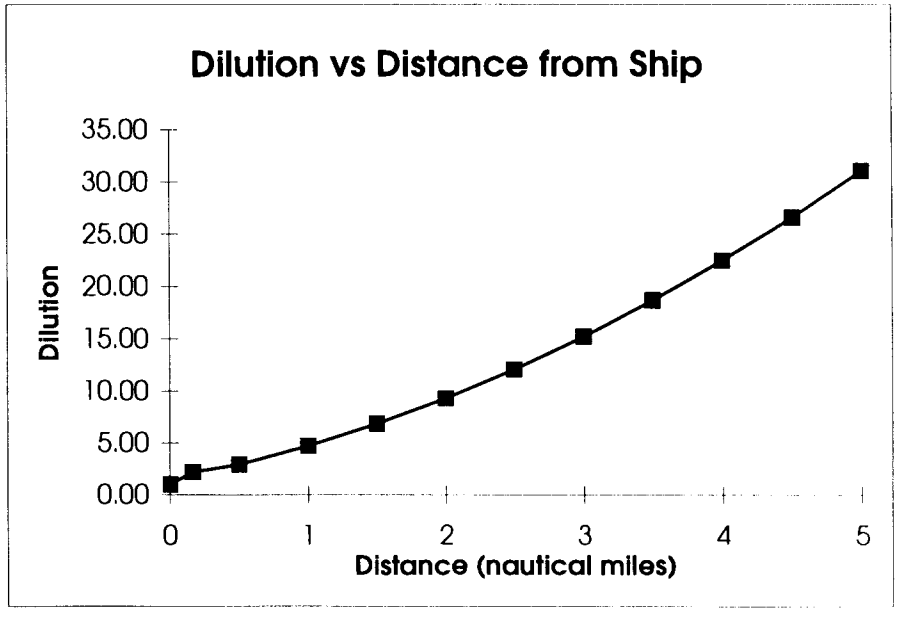


Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.4 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
1200 (gpm)	7.8 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
0.4 (knots)	0.001	50 (m)	10 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.7	0.46	0.46	2.19
3040	0.5	1.3	0.34	0.34	2.91
6080	1	2.5	0.21	0.21	4.70
9120	1.5	3.8	0.15	0.15	6.82
12160	2	5.0	0.11	0.11	9.29
15200	2.5	6.3	0.08	0.08	12.08
18240	3	7.5	0.07	0.07	15.21
21280	3.5	8.8	0.05	0.05	18.67
24320	4	10.0	0.04	0.04	22.46
27360	4.5	11.3	0.04	0.04	26.59
30400	5	12.5	0.03	0.03	31.05

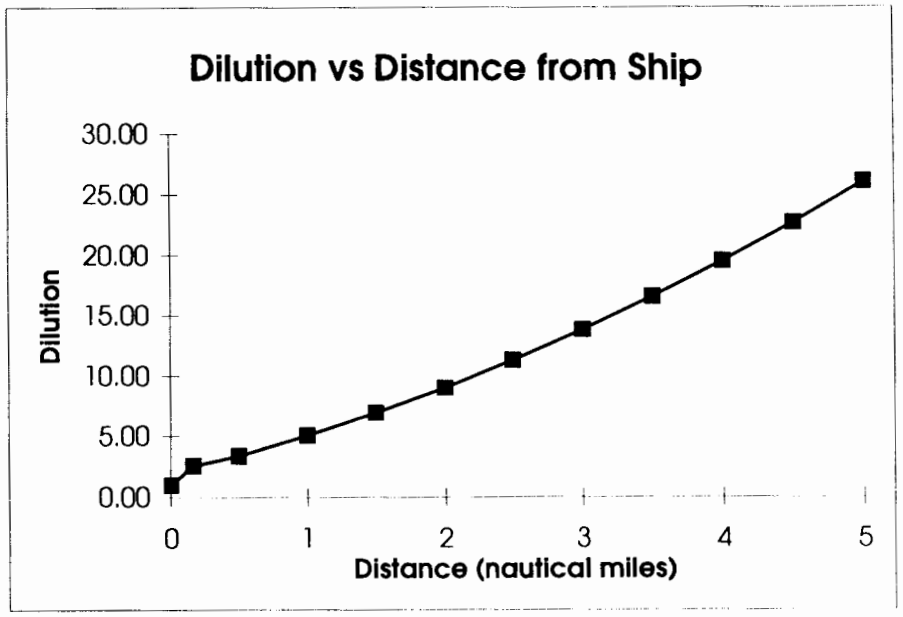


Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.6 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
1200 (gpm)	7.8 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
0.6 (knots)	0.001	50 (m)	10 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.5	0.39	0.39	2.58
3040	0.5	0.8	0.30	0.30	3.37
6080	1	1.7	0.20	0.20	5.06
9120	1.5	2.5	0.14	0.14	6.91
12160	2	3.3	0.11	0.11	8.98
15200	2.5	4.2	0.09	0.09	11.28
18240	3	5.0	0.07	0.07	13.79
21280	3.5	5.8	0.06	0.06	16.53
24320	4	6.7	0.05	0.05	19.48
27360	4.5	7.5	0.04	0.04	22.66
30400	5	8.3	0.04	0.04	26.06



Farfield Dilution Model

Summer Surface - Ocean Current 0.8 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1200 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.8 (knots)

Dissipation Parameter (A)
0.001

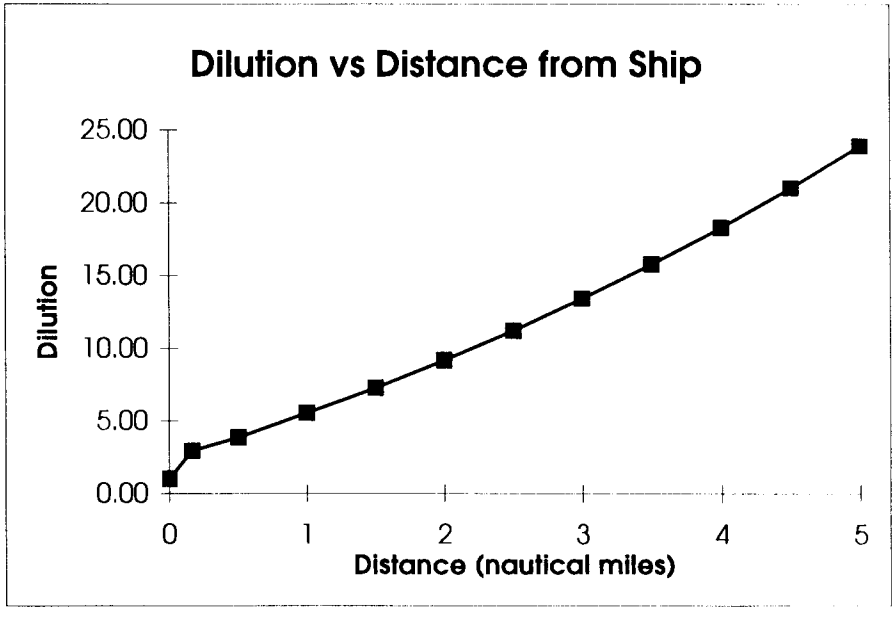
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.34	0.34	2.92
3040	0.5	0.6	0.26	0.26	3.82
6080	1	1.3	0.18	0.18	5.53
9120	1.5	1.9	0.14	0.14	7.27
12160	2	2.5	0.11	0.11	9.15
15200	2.5	3.1	0.09	0.09	11.20
18240	3	3.8	0.07	0.07	13.41
21280	3.5	4.4	0.06	0.06	15.78
24320	4	5.0	0.05	0.05	18.32
27360	4.5	5.6	0.05	0.05	21.03
30400	5	6.3	0.04	0.04	23.90



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 1.0 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1200 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
1 (knots)

Dissipation Parameter (A)
0.001

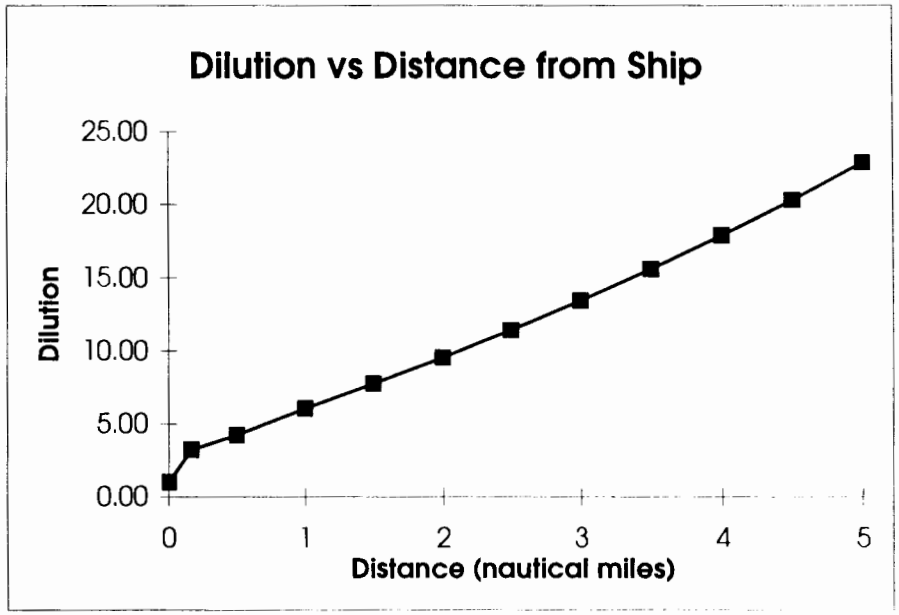
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.31	0.31	3.22
3040	0.5	0.5	0.24	0.24	4.24
6080	1	1.0	0.17	0.17	6.03
9120	1.5	1.5	0.13	0.13	7.72
12160	2	2.0	0.11	0.11	9.50
15200	2.5	2.5	0.09	0.09	11.40
18240	3	3.0	0.07	0.07	13.43
21280	3.5	3.5	0.06	0.06	15.59
24320	4	4.0	0.06	0.06	17.88
27360	4.5	4.5	0.05	0.05	20.31
30400	5	5.0	0.04	0.04	22.86

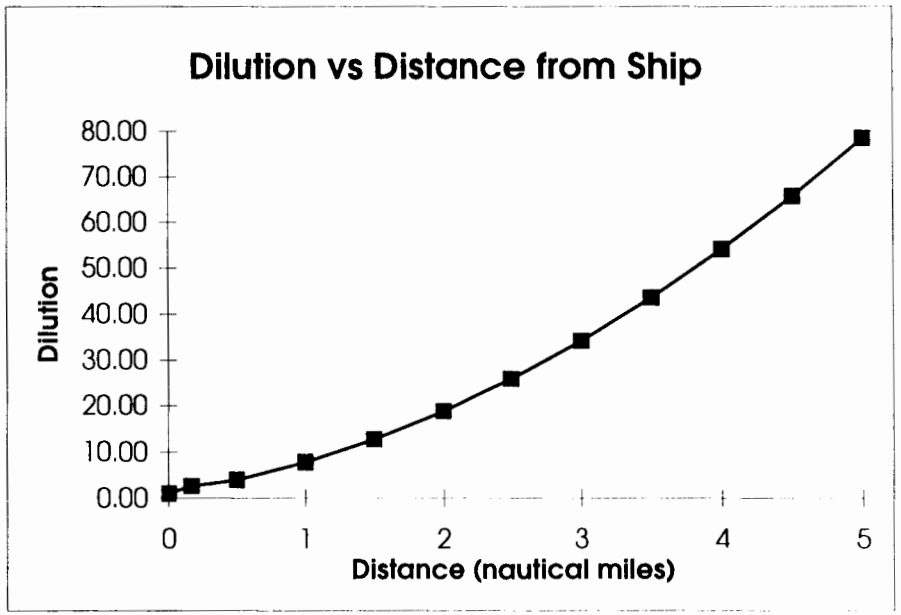


Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.2 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
720 (gpm)	7.8 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
0.2 (knots)	0.001	50 (m)	6 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	1.4	0.38	0.38	2.64
3040	0.5	2.5	0.25	0.25	3.97
6080	1	5.0	0.13	0.13	7.80
9120	1.5	7.5	0.08	0.08	12.74
12160	2	10.0	0.05	0.05	18.79
15200	2.5	12.5	0.04	0.04	25.96
18240	3	15.0	0.03	0.03	34.24
21280	3.5	17.5	0.02	0.02	43.64
24320	4	20.0	0.02	0.02	54.14
27360	4.5	22.5	0.02	0.02	65.77
30400	5	25.0	0.01	0.01	78.51



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.4 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
720 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.4 (knots)

Dissipation Parameter (A)
0.001

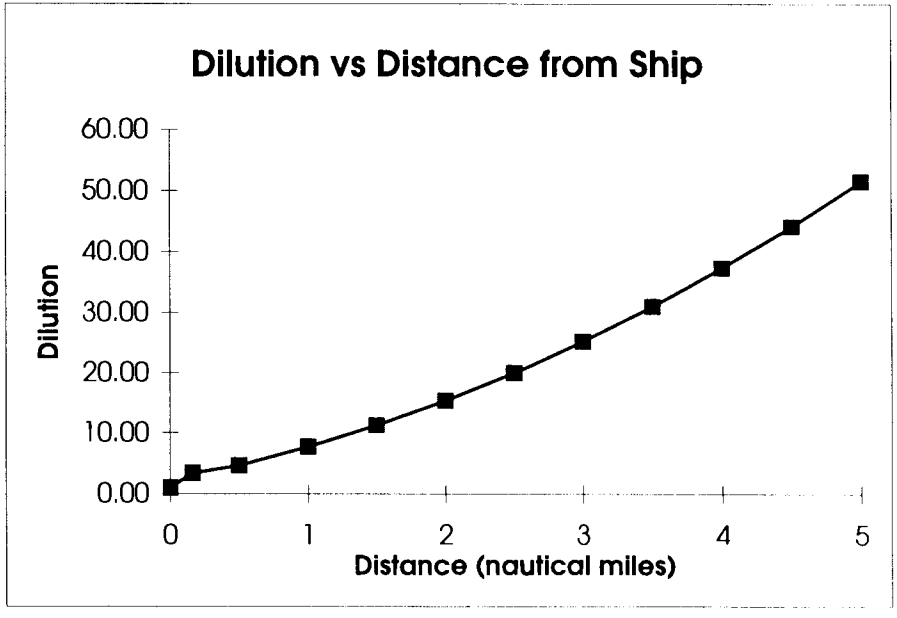
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.7	0.29	0.29	3.40
3040	0.5	1.3	0.22	0.22	4.65
6080	1	2.5	0.13	0.13	7.66
9120	1.5	3.8	0.09	0.09	11.20
12160	2	5.0	0.07	0.07	15.30
15200	2.5	6.3	0.05	0.05	19.95
18240	3	7.5	0.04	0.04	25.15
21280	3.5	8.8	0.03	0.03	30.91
24320	4	10.0	0.03	0.03	37.22
27360	4.5	11.3	0.02	0.02	44.09
30400	5	12.5	0.02	0.02	51.52



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.6 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
720 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.6 (knots)

Dissipation Parameter (A)
0.001

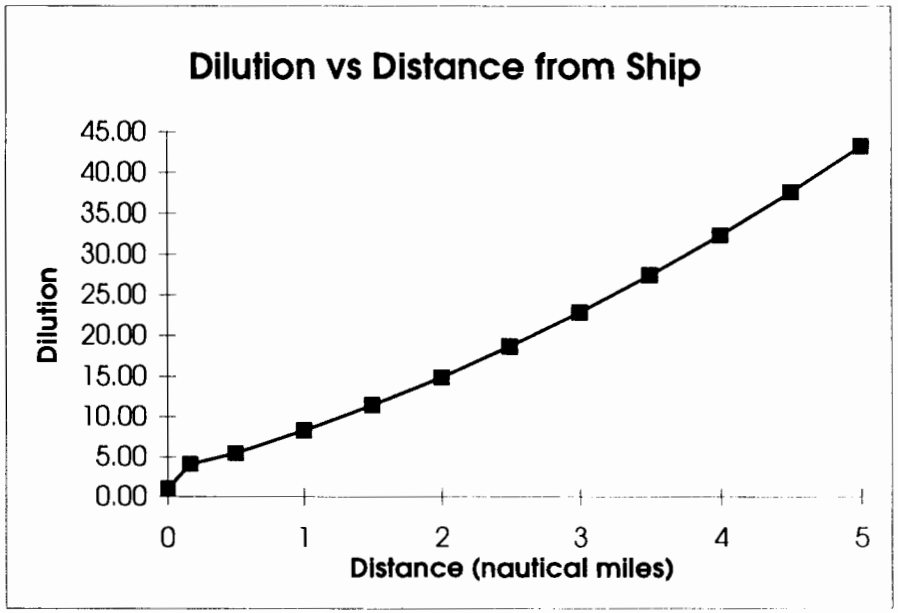
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.5	0.24	0.24	4.08
3040	0.5	0.8	0.18	0.18	5.46
6080	1	1.7	0.12	0.12	8.30
9120	1.5	2.5	0.09	0.09	11.40
12160	2	3.3	0.07	0.07	14.86
15200	2.5	4.2	0.05	0.05	18.68
18240	3	5.0	0.04	0.04	22.86
21280	3.5	5.8	0.04	0.04	27.42
24320	4	6.7	0.03	0.03	32.34
27360	4.5	7.5	0.03	0.03	37.64
30400	5	8.3	0.02	0.02	43.30

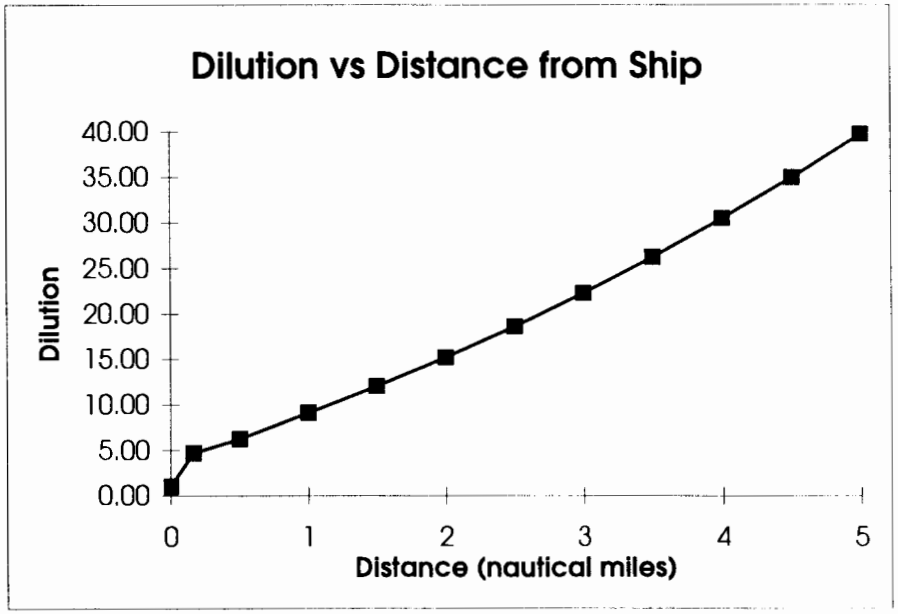


Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.8 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
720 (gpm)	7.8 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
0.8 (knots)	0.001	50 (m)	6 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.21	0.21	4.68
3040	0.5	0.6	0.16	0.16	6.23
6080	1	1.3	0.11	0.11	9.11
9120	1.5	1.9	0.08	0.08	12.02
12160	2	2.5	0.07	0.07	15.17
15200	2.5	3.1	0.05	0.05	18.58
18240	3	3.8	0.04	0.04	22.26
21280	3.5	4.4	0.04	0.04	26.21
24320	4	5.0	0.03	0.03	30.45
27360	4.5	5.6	0.03	0.03	34.95
30400	5	6.3	0.03	0.03	39.74



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 1.0 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
720 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
1 (knots)

Dissipation Parameter (A)
0.001

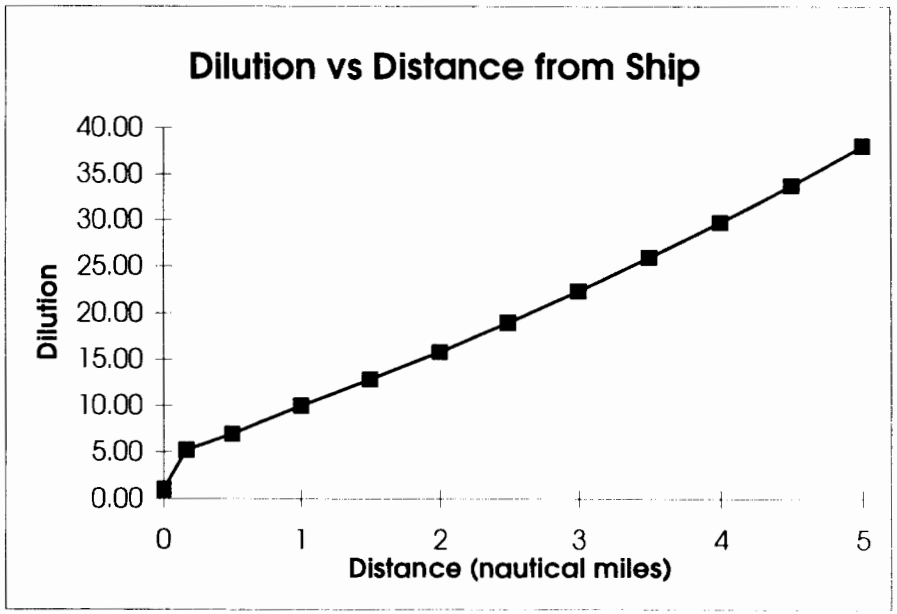
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.19	0.19	5.21
3040	0.5	0.5	0.14	0.14	6.93
6080	1	1.0	0.10	0.10	9.95
9120	1.5	1.5	0.08	0.08	12.79
12160	2	2.0	0.06	0.06	15.76
15200	2.5	2.5	0.05	0.05	18.93
18240	3	3.0	0.04	0.04	22.32
21280	3.5	3.5	0.04	0.04	25.92
24320	4	4.0	0.03	0.03	29.74
27360	4.5	4.5	0.03	0.03	33.78
30400	5	5.0	0.03	0.03	38.04



Appendix 11
Summary of Monitoring Data

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Average Daily Volumes Ocean Disposed

(not including zero disposal days)

September 1993 - September 1996

MONTH/YR	AVERAGE DAILY TOTAL			VOLUME FRACTION	
	Samoa Packing (gallons)	StarKist Samoa (gallons)	COMBINED (gallons)	Samoa Packing	StarKist Samoa
Sep-93	83,200	121,094	204,294	0.41	0.59
Oct-93	104,540	106,368	210,909	0.50	0.50
Nov-93	92,208	115,474	207,682	0.44	0.56
Dec-93	92,048	90,682	182,729	0.50	0.50
Jan-94	88,818	97,200	186,018	0.48	0.52
Feb-94	86,760	112,280	199,040	0.44	0.56
Mar-94	105,393	100,792	206,185	0.51	0.49
Apr-94	105,640	99,647	205,287	0.51	0.49
May-94	107,609	100,500	208,109	0.52	0.48
Jun-94	111,650	97,692	209,342	0.53	0.47
Jul-94	89,150	98,913	188,063	0.47	0.53
Aug-94	84,550	95,154	179,704	0.47	0.53
Sep-94	92,600	108,600	201,200	0.46	0.54
Oct-94	104,692	91,409	196,101	0.53	0.47
Nov-94	95,000	105,208	200,208	0.47	0.53
Dec-94	91,964	104,000	195,964	0.47	0.53
Jan-95	102,654	88,864	191,517	0.54	0.46
Feb-95	99,174	102,904	202,078	0.49	0.51
Mar-95	105,000	130,385	235,385	0.45	0.55
Apr-95	97,625	80,333	177,958	0.55	0.45
May-95	93,115	101,670	194,785	0.48	0.52
Jun-95	117,864	105,962	223,825	0.53	0.47
Jul-95	91,542	85,208	176,750	0.52	0.48
Aug-95	93,962	124,826	218,787	0.43	0.57
Sep-95	88,500	117,459	205,959	0.43	0.57
Oct-95	110720	101,250	211,970	0.52	0.48
Nov-95	100,292	100,343	200,634	0.50	0.50
Dec-95	101,952	124,578	226,530	0.45	0.55
Jan-96	101,174	118,285	219,459	0.46	0.54
Feb-96	97,318	112,275	209,593	0.46	0.54
Mar-96	96,231	120,508	216,739	0.44	0.56
Apr-96	118,789	99,917	218,706	0.54	0.46
May-96	78,204	88,331	166,535	0.47	0.53
Jun-96	73,394	89,606	163,000	0.45	0.55
Jul-96	109,337	89,120	198,458	0.55	0.45
Aug-96	123,359	101,266	224,626	0.55	0.45
Sep-96	119,184	85,219	204,403	0.58	0.42
Minimum	73,394	80,333	163,000	0.41	0.42
Maximum	123,359	130,385	235,385	0.58	0.59
Mean	98,790	103,063	201,852	0.49	0.51
Median	97,625	101,250	204,294	0.48	0.52
St. Deviation	11,515	12,427	16,478	0.04	0.04

Samoa Packing Onshore Monitoring
Results of Composite (Storage Tank) Samples
September 1993 - September 1996

DATE	TSS (MG/L)	TVSS (MG/L)	BOD5 (MG/L)	0&G (MG/L)	TP (MG/L)	TN (MG/L)	Ammonia (MG/L)	pH (SU)	Density (G/ML)
8-Sep-93	17300	9920	425000	20588	3500	19040	8400	6.65	0.98
6-Oct-93	6790	897	33500	33370	750	2940	560	7.06	1.02
14-Oct-93	8480	3390	255000	5680	1400	3080	840	6.61	1.01
3-Nov-93	19200	9270	30700	16700	2400	5880	3450	7.39	1.03
9-Nov-93	27500	13900	32000	8520	2100	6160	3480	6.73	1.03
16-Nov-93	17600	8890	27100	14580	2200	7840	6580	6.87	1.00
6-Dec-93	12100	6270	13800	4006	600	4480	1880	6.43	1.02
13-Dec-93	33200	25000	21000	5240	1200	8120	1180	6.28	1.02
4-Jan-94	15600	7170	24400	2460	1000	5880	2650	6.86	1.01
10-Jan-94	7730	2440	13200	10240	1200	5880	1850	6.74	1.02
1-Feb-94	16300	8430	24100	7240	1000	5880	2390	6.93	0.98
7-Feb-94	14500	7050	18000	3700	1000	4760	2000	6.96	1.00
1-Mar-94	11900	5090	19900	1958	600	7280	2290	6.94	1.00
7-Mar-94	9900	2870	20100	17440	800	6160	2500	6.68	0.99
4-Apr-94	12000	5820	18900	19040	1900	5880	2050	7.00	0.98
11-Apr-94	12700	5980	19300	16200	2000	7280	2300	6.72	1.01
2-May-94	5390	1430	11300	9780	1200	1960	1960	7.36	1.01
10-May-94	9350	5940	14400	8880	1200	4760	1590	6.32	0.98
7-Jun-94	33500	27000	350000	28120	1000	4480	2030	6.02	0.99
14-Jun-94	45900	38400	480000	37900	1000	7560	2250	6.16	1.00
5-Jul-94	22000	16400	22500	7212	1000	2800	1220	6.25	1.00
12-Jul-94	64800	55300	54500	28840	700	4480	1440	6.20	1.00
1-Aug-94	72400	59200	73200	5788	1200	3080	2800	6.00	0.99
8-Aug-94	18700	10700	26400	57260	1000	7560	2240	6.02	1.00
6-Sep-94	45300	35300	57800	37660	2400	3920	3370	6.50	1.00
12-Sep-94	86300	72800	99800	19460	1200	4480	3530	6.03	1.00
3-Oct-94	16200	8300	21600	15940	1200	8960	2960	6.00	1.01
25-Oct-94	26000	20000	23300	160000	1200	6160	2170	5.90	0.99
1-Nov-94	22600	10300	24200	919	1700	7280	3340	5.30	1.00
6-Nov-94	24600	15400	20700	1789	1200	7560	3240	5.60	0.99
5-Dec-94	20700	11000	16000	13360	2000	5320	3530	5.40	1.00
12-Dec-94	18400	8850	15600	1161	1500	7560	3930	5.00	1.00

Samoa Packing Onshore Monitoring
Results of Composite (Storage Tank) Samples
September 1993 - September 1996

DATE	TSS (MG/L)	TVSS (MG/L)	BOD5 (MG/L)	0&G (MG/L)	TP (MG/L)	TN (MG/L)	Ammonia (MG/L)	pH (SU)	Density (G/ML)
3-Jan-95	22600	13000	32400	62820	2000	4480	3310	6.70	1.00
13-Jan-95	10000	3190	16500	62000	1000	5320	2800	5.00	1.01
1-Feb-95	12300	3420	20300	68020	1300	7280	3320	6.80	0.99
16-Feb-95	13700	5730	18600	49140	1700	7560	2870	6.70	0.99
1-Mar-95	12600	2170	21000	10460	1200	6160	3720	6.50	1.00
9-Mar-95	16900	7200	39100	7600	1200	4480	2710	6.00	1.01
3-Apr-95	16700	7490	21500	9360	2000	5264	2550	6.80	0.99
13-Apr-95	19300	12200	26600	7600	1200	6348	2690		1.00
1-May-95	24000	16100	36200	11440	1800	5040	2730	6.60	1.00
12-May-95	15700	9500	22900	2240	1300	7840	2420		1.00
1-Jun-95	16100	8690	29100	14780	1000	7840	2340	6.80	0.99
16-Jun-95	15700	7460	27400	15580	700	4760	2050	6.60	0.99
5-Jul-95	15700	7280	19400	404200	1200	6160	2170	6.90	1.00
18-Jul-95	15600	7260	18000	78640	287	7560	2210	7.10	1.00
2-Aug-95	17000	7510	20500	259880	310	7560	2400	6.60	1.00
17-Aug-95	14700	6640	18700	10120	333	8400	2290	6.80	0.99
6-Sep-95	10600	3860	18900		507	8960	2300	6.60	1.00
12-Sep-95	37000	27900	43500	23800	780	17640	2760	6.70	1.00
3-Oct-95	35400	25200	32000	20500	793	8120	2900	7.00	1.00
6-Nov-95	14700	7540	29200	24600	368	5880	2870	6.20	1.00
6-Dec-95	18700	9760	24600	59920	1059	8400	2670	6.60	1.00
3-Jan-96	16600	7860	23900	115060	655	7280	2790	6.50	1.00
1-Feb-96	74300	69400	41300	178560	616	6720	1260	6.70	1.00
4-Mar-96	18200	11900	23100	12468	1287	8960	2150	6.50	1.00
2-Apr-96	22500	13400	27000	97560	984	5880	3080	6.70	1.01
6-May-96	13200	6130	14200	5590	818	5320	1930	7.00	1.01
3-Jun-96	9740	4530	12500	62200	371	5320	1730	6.90	1.00
2-Jul-96	21600	10400	21700	3760	736	5600	2440	6.80	1.00
5-Aug-96	35100	23900	29500	5200	404	3080	2440	7.30	1.00
3-Sep-96	16280	10400	18400	3860	2156	11760	1840	7.00	0.99
No. Samples	62	62	62	61	62	62	62	60	62
Maximum	86300	72800	480000	404200	3500	19040	8400	7.39	1.03
Minimum	5390	897	11300	919	287	1960	560	5.00	0.98
Mean	22217	14125	49279	37836	1200	6539	2609	6.52	1.00
Median	16800	8770	23200	14780	1200	6160	2430	6.67	1.00
St. Dev.	16346	15464	90696	66742	616	2839	1149	0.52	0.01

StarKist Samoa Onshore Monitoring
Results of Composite (Storage Tank) Samples
September 1993 - September 1996

DATE	TSS (mg/L)	TVSS (mg/L)	BOD5 (mg/L)	0&G (mg/L)	TP (mg/L)	TN (mg/L)	Ammonia (mg/L)	pH (SU)	Density (g/ml)
10-Sep-93	20,400	13,500		3,920	252	3,790	1,960	6.89	1.01
28-Oct-93	34,400	19,500	37,800	6,280	87	6,570	8,220	6.95	1.02
3-Nov-93	70,200	51,000	55,400	6,940	115	9,810	10,800	6.70	1.03
17-Nov-93	68,600	45,600	83,900	29,300	670	9,120	7,965	6.54	0.94
19-Nov-93	52,100	33,100	44,900	25,500	552	6,210	9,105	6.80	1.01
10-Dec-93	58,300	45,300	73,527	4,950	651	7,000	4,190	6.86	0.95
17-Dec-93	35,800	20,800	67,247	10,100	502	5,110	3,040	6.50	1.00
21-Jan-94	35,400	17,400	57,425	8,110	526	6,380	4,930	6.93	1.03
28-Jan-94	70,140	52,600	60,958	19,700	1,040	7,850	4,230	6.88	0.99
9-Feb-94	109,000	89,300	73,236	29,800	1,250	7,290	3,690	6.50	0.98
17-Feb-94	50,600	34,300	54,610	14,600	915	7,480	4,140	6.73	1.01
9-Mar-94	50,200	29,200	65,167	4,500	897	1,750	283	6.98	0.97
24-Mar-94	69,900	46,800	112,261	20,100	3,210	14,300	9,700	7.13	0.96
23-May-94	42,100	25,700	58,327	13,669	655	5,120	3,510	6.84	1.02
30-May-94	73,600	58,100	125,375	22,352	1,072	6,900	4,410	6.18	0.97
15-Jun-94	30,600	12,800	67,282	6,535	608	4,940	3,420	6.46	1.02
22-Jun-94	39,100	28,900	38,781	23,013	734	4,600	2,290	6.23	1.00
20-Jul-94	46,600	2,700	103,767	26,415	1,740	7,090	5,200	6.73	0.99
27-Jul-94	36,700	19,600	131,250	14,979	674	5,390	4,470	6.68	1.01
16-Aug-97	150,000	131,000	96,833	51,903	2,530	5,330	1,910	6.52	0.94
25-Aug-94	48,600	35,800	103,072	76,256	1,040	3,180	282	5.47	0.97
20-Sep-94	55,100	38,500	95,483	32,696	1,270	5,190	4,580	6.96	0.98
27-Sep-94	37,100	24,200	102,428	13,433	618	5,120	3,990	6.62	0.99
1-Oct-94	54,200	35,300	95,567	15,008	620	5,540	3,060	6.35	1.00
7-Oct-94	48,200	26,400	96,644	14,123	512	5,040	3,900	6.52	0.99
17-Nov-94	49,700	33,300	66,709	187,779	950	8,290	4,300	6.71	1.01
23-Nov-94	36,700	21,200	66,366	16,179	662	6,150	4,220	6.63	1.01
14-Dec-94	88,900	63,200	99,026	30,084	1,180	5,060	3,390	6.10	1.03
21-Dec-94	137,000	113,000	100,911	61,901	1,110	2,370	295	5.40	1.00

StarKist Samoa Onshore Monitoring
Results of Composite (Storage Tank) Samples
September 1993 - September 1996

DATE	TSS (mg/L)	TVSS (mg/L)	BOD5 (mg/L)	0&G (mg/L)	TP (mg/L)	TN (mg/L)	Ammonia (mg/L)	pH (SU)	Density (g/ml)
27-Jan-95	60,800	44,000	74,889	25,340	789	4,100	4,800	6.40	1.01
31-Jan-95	64,000	4,470	82,339	22,721	1,110	6,660	5,160	6.90	1.01
25-Feb-95	64,300	49,400	95,139	56,793	997	6,660	5,170	6.80	0.99
2-Mar-95	56,300	40,700	101,978	50,204	612	3,940	3,330	6.44	1.01
3-Mar-95	53,600	38,600	106,856	39,360	933	4,500	3,650	6.30	1.00
11-Mar-95	117,000	84,100	94,628	36,286	3,830	4,370	3,720	6.20	1.01
7-Apr-95	61,100	39,300	93,505	40,968	3,100	2,820	2,290	6.40	1.00
13-Apr-95	27,300	20,700	50,893	17,648	361	1,790	1,560	6.60	0.99
3-May-95	79,300	60,300	136,750	31,841	1,400	6,390	434	6.30	1.00
10-May-95	46,400	33,600	111,611	16,791	666	4,820	4,050	6.60	1.00
28-Jun-95	41,500	29,300	63,726	18,098	502	2,807	2,310	6.49	1.01
5-Jul-95	53,200	38,800	113,300	13,526	791	5,570	3,870	6.75	1.01
6-Jul-95	62,600	46,900	95,850	35,005	940	9,640	5,230	6.76	1.00
26-Jul-95	65,700	45,000	67,268	18,619	1,100	5,920	4,470	6.73	1.00
1-Aug-95	60,000	36,800	77,311	13,579	817	6,350	3,990	6.71	1.00
9-Aug-95	32,500	18,600	64,220	9,103	525	3,490	2,990	6.56	0.99
14-Sep-95	46,200	30,800	51,950	5,134	652	3,250	2,910	6.00	1.00
28-Sep-95	42,500	25,000	93,550	10,898	667	4,980	3,060	6.40	1.00
19-Oct-95	86,800	58,000	122,500	14,635	2,200	6,490	3,850	6.50	1.01
27-Oct-95	42,700	27,100	72,289	13,504	626	5,820	4,210	6.50	1.00
15-Nov-95	48,500	26,800	74,089	33,710	691	4,220	3,410	6.60	1.02
28-Nov-95	22,400	10,300	70,686	5,038	609	5,430	3,880	6.70	1.00
19-Dec-95	80,700	61,600	95,661	22,771	1,070	8,120	4,610	6.70	1.04
15-Jan-96	35,200	22,900	60,901	11,239	846	5,010	3,870	6.70	1.00
24-Jan-96	50,300	35,700	62,132	21,240	975	4,330	3,740	6.46	1.00
7-Feb-96	39,900	24,400	63,229	40,929	639	5,020	3,260	6.50	1.00
21-Feb-96	51,800	36,900	64,295	34,066	935	6,720	3,840	6.50	1.01
13-Mar-96	46,900	31,200	75,369	18,090	654	5,550	2,910	6.40	1.00
22-Mar-96	34,100	18,200	68,610	8,526	546	4,930	3,310	6.70	1.01
23-Apr-96	43,700	27,100	79,633	28,399	353	3,400	1,430	6.40	1.00
30-Apr-96	61,500	44,600	73,890	39,266	951	6,360	5,270	6.70	1.00
2-May-96	60,000	40,200	62,077	42,754	866	6,070	4,720	6.60	1.01
15-May-96	64,000	47,400	65,833	21,046	742	7,200	2,980	6.50	1.00
19-Jun-96	109,400	94,200	68,756	49,715	1,290	1,190	5,810	6.70	1.00
27-Jun-96	62,100	43,400	66,239	23,065	1,040	8,250	4,950	6.70	1.00
10-Jul-96	77,200	70,300	69,327	24,258	1,450	8,930	5,070	6.40	1.00
30-Jul-96	81,900	57,800	66,493	31,960	1,430	7,020	1,770	6.70	1.02
7-Aug-96	74,300	47,600	55,259	16,153	906	9,160	4,390	6.60	1.01
28-Aug-96	59,400	44,200	58,049	22,319	811	6,170	3,140	7.00	1.00
5-Sep-96	79,600	63,400	57,818	25,354	981	8,290	4,550	6.80	1.00
19-Sep-96	92,600	70,500	55,617	27,124	902	6,850	4,970	6.60	1.02
No. Samples	70	70	69	70	70	70	70	70	70
Maximum	150000	131000	136750	187779	3830	14300	10800	7.13	1.04
Minimum	20400	2700	37800	3920	87	1190	282	5.40	0.94
Mean	59122	40832	78533	26103	971	5808	3977	6.57	1.00
Median	53900	36850	72289	21780	832	5560	3875	6.60	1.00
St. Dev.	24702	23284	22434	24512	654	2148	1926	0.30	0.02

OCEAN MONITORING DATA FOR TSS (mg/L)

September 1993 - September 1996

DATE	VOLUME DISPOSED (gallons)	STATION AND DEPTH																	
		CONTROL			STATION 1			STATION 2			STATION 3			STATION 4			STATION 5		
		1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)
10-Sep-93	310750	1.0	0.9	1.2	1.0	1.1	1.4	1.7	1.1	1.4	0.6	1.5	1.0	1.6	1.4	2.1	1.6	1.1	1.6
27-Oct-93	185000	1.2	1.0	1.9	1.6	2.4	2.2	2.6	2.4	1.4	1.6	1.3	1.2	1.6	1.6	1.8	1.2	1.0	1.0
17-Nov-93	301000	1.7	2.2	2.5	1.0	1.2	2.3	1.3	1.8	2.4	1.1	1.0	1.2	2.2	1.0	2.2	1.1	1.0	2.3
10-Dec-93	158000	6.3	18.0	8.7	7.4	14.9	8.7	9.6	9.5	8.1	7.9	8.3	8.3	9.2	7.0	9.4	6.7	9.4	6.8
21-Jan-94	259000	1.8	0.6	0.7	1.2	0.6	2.8	1.7	1.0	1.1	1.0	2.4	1.1	1.0	1.0	1.3	1.0	1.4	0.8
9-Feb-94	147000	1.4	1.4	1.8	1.1	1.6	1.8	1.0	1.5	1.0	2.0	1.5	2.2	1.8	1.8	1.2	0.8	1.0	0.7
9-Mar-94	292000	2.0	1.4	1.3	3.2	2.2	1.6	1.2	1.0	2.2	2.0	1.0	1.5	2.0	2.0	1.8	1.6	0.9	1.9
26-Apr-94	288000	1.5	1.0	2.3	1.0	1.6	1.4	1.8	1.0	1.3	0.6	0.9	0.8	0.7	1.5	0.9	0.5	0.7	1.6
23-May-94	157000	1.1	1.0	1.0	0.9	1.0	0.9	1.2	1.2	1.6	1.1	0.6		1.0	1.0	1.4	1.0	0.9	1.0
15-Jun-94	265000	1.1	1.0	1.4	1.0	3.2	2.0	1.1	1.2	1.5	1.0	1.2	0.7	0.9	0.8	2.0	1.6	1.0	0.7
21-Jul-94	259000	1.8	0.9	0.8	0.8	0.9	1.7	0.8	1.8	1.0	1.2	1.0	1.0	2.0	2.7	2.0	1.5	0.9	1.6
16-Aug-94	113300	0.4	0.8	0.8	0.8	0.9	0.7	0.9	0.7	0.5	0.6	0.6	1.0	0.4	0.4	0.7	1.4	0.6	0.4
20-Sep-94	282000	0.8	1.0	1.7	3.7	0.8	0.8	1.4	2.0	1.8	1.4	1.9	(28)	0.7	1.6	0.7	1.3	0.9	1.6
1-Oct-94	162000	1.6	0.9	0.9	1.2	1.6	1.0	1.1	2.5	1.0	1.4	1.2	1.0	0.9	1.9	2.0	1.1	1.8	0.8
17-Nov-94	268000	0.6	1.0	2.0	0.5	1.8	0.9	0.8	0.7	0.6	1.0	1.6	1.3	3.7	(121.8)	1.8	0.6	0.6	3.4
14-Dec-94	149000	1.8	0.9	0.8	1.3	1.4	1.0	0.8	1.6	0.5	1.0	1.2	0.9	3.3	0.7	0.8	0.9	0.8	1.1
27-Jan-95	284000	0.9	2.8	1.3	1.0	1.8	1.0	2.0	1.6	1.3	1.8	1.4	1.6	3.6	2.4	2.1	0.7	0.9	1.4
25-Feb-95	142000	1.2	1.2	5.4	3.6	1.8	1.6	1.0	3.5	3.6	0.8	1.0	3.2	3.4	1.0	0.8	1.0	0.9	1.0
3-Mar-95	241000	3.0	3.0	3.7	4.2	1.6	(49)	1.4	4.9	2.2	(19)	2.1	3.0	1.3	6.5	3.6	1.4	2.1	1.5
8-Apr-95	164000	2.8	2.8	2.0	1.3	1.0	1.6	1.8	2.0	0.8	2.2	1.8	3.0	14.5	1.2	2.4	2.4	1.6	2.4
3-May-95	195000	2.8	1.0	3.8	1.2	2.7	4.0	3.9	1.0	0.6	1.4	1.1	1.8	2.6	2.4	2.0	1.4	2.3	1.3
28-Jun-95	154000	0.9	1.8	1.2	2.0	1.2	1.5	1.4	1.4	1.1	1.2	0.8	1.0	1.4	1.2	1.2	0.9	1.2	1.4
7-Jul-95	244000	1.3	1.3	0.8	1.1	1.0	1.2	1.2	1.2	1.4	1.1	1.0	1.2	1.3	1.4	1.1	1.2	1.7	1.2
1-Aug-95	199000	1.0	1.6	2.8	1.6	3.0	6.4	6.2	3.4	6.8	3.8	1.0	2.8	3.2	1.6	1.0	1.4	1.8	1.2
14-Sep-95	224875	1.6	1.2	1.0	1.1	1.4	1.0	2.1	1.0	2.2	2.2	0.9	1.2	2.2	2.1	2.0	2.0	2.0	1.9
19-Oct-95	207867	1.4	1.1	3.0	1.5	4.8	1.4	4.0	3.9	6.0	4.0	5.2	3.4	3.1	4.0	5.7	3.2	1.2	3.8
15-Nov-95	175002	3.4	3.0	3.8	5.2	4.2	3.4	2.0	2.2	5.4	3.8	0.6	3.0	1.1	3.1	2.6	0.6	3.1	3.5
19-Dec-95	329500	1.0	1.0	1.4	1.1	1.2	1.4	2.2	2.2	1.6	1.0	1.0	0.9	1.4	1.2	1.0	0.8	0.9	0.8
15-Jan-96	154500	0.7	0.8	1.2	1.6	3.4	2.0	1.2	1.2	1.2	0.8	1.0	1.0	1.0	2.6	2.1	1.0	1.1	1.8
7-Feb-96	305875	1.6	1.2	2.1	1.6	1.2	1.3	1.2	0.8	1.2	0.8	0.8	2.0	1.4	1.2	1.0	0.8	1.9	0.8
13-Mar-96	310375	2.0	0.8	2.0	1.0	1.0	1.1	1.4	1.2	2.1	1.8	0.9	1.0	1.1	1.5	1.0	1.1	2.0	1.4
23-Apr-96	261375	1.4	2.4	1.3	1.8	2.2	1.2	1.6	2.2	2.0	1.8	1.5	1.2	1.6	1.6	1.4	1.4	1.7	1.2
2-May-96	278750	0.6	0.8	0.9	2.0	1.0	0.8	0.6	0.5	0.7	1.2	0.4	0.6	0.6	1.3	0.6	0.8	0.8	1.4
19-Jun-96	114725	1.4	2.2	1.8	1.0	1.6	1.6	1.0	1.6	2.0	1.6	1.2	1.5	2.2	1.1	1.0	1.8	2.2	2.6
10-Jul-96	163325	0.8	0.6	0.6	0.6	0.7	1.2	0.6	0.8	0.8	0.6	0.7	1.8	1.4	1.0	0.6	0.6	0.8	1.5
7-Aug-96	180100	1.0	2.2	1.8	1.7	1.6	1.8	2.2	1.8	1.0	1.0	1.2	3.6	1.7	1.2	1.0	2.4	1.6	3.1
5-Sep-96	325325	1.4	0.8	1.8	4.3	1.0	2.8	1.2	1.5	1.0	0.8	0.8	1.0	1.1	1.0	1.0	3.5	1.4	1.8

OCEAN MONITORING DATA FOR TVSS (mg/L)

September 1993 - September 1996

DATE	VOLUME DISPOSED (gallons)	STATION AND DEPTH																	
		CONTROL			STATION 1			STATION 2			STATION 3			STATION 4			STATION 5		
		1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)
10-Sep-93	310750	0.4	0.2	0.3	0.2	0.6	0.4	0.5	0.2	0.4	0.2	0.3	0.2	0.3	0.6	0.4	0.4	0.3	0.4
27-Oct-93	185000	0.4	0.2	0.6	0.9	0.1	1.0	1.2	0.8	0.6	0.9	0.5	0.7	0.5	0.4	0.6	0.2	0.4	0.2
17-Nov-93	301000	0.3	0.8	1.4	0.4	0.4	1.1	0.4	0.7	0.6	0.5	0.3	0.6	0.8	0.4	0.6	0.4	0.3	0.8
10-Dec-93	158000	0.7	(5.2)	1.2	1.3	2.4	1.5	1.7	1.9	1.3	1.3	1.4	1.2	1.9	1.3	1.5	1.4	0.9	1.3
21-Jan-94	259000	0.3	0.1	0.1	0.4	0.3	1.0	0.6	0.2	0.4	0.3	0.4	0.2	0.4	0.3	0.4	0.1	0.4	0.2
9-Feb-94	147000	0.5	0.6	0.4	0.6	0.8	1.3	0.6	0.6	0.5	0.5	0.6	0.7	0.6	0.6	0.4	0.2	0.4	0.6
9-Mar-94	292000	0.6	0.4	0.4	1.1	1.5	0.6	0.6	0.6	0.9	0.6	0.6	1.1	0.5	0.8	0.5	0.4	0.2	0.6
26-Apr-94	288000	0.4	0.4	1.0	0.4	0.5	0.6	0.4	0.4	0.6	0.3	0.4	0.4	0.3	0.4	0.3	0.3	0.2	0.4
23-May-94	157000	0.4	0.4	0.4	0.3	0.2	0.4	0.4	0.6	0.6	0.4	0.4		0.2	0.6	0.6	0.2	0.4	0.4
15-Jun-94	265000	0.2	0.2	1.0	0.4	1.7	1.9	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.1	0.4	0.8	0.8	0.2
21-Jul-94	259000	0.9	0.4	0.2	0.3	0.4	0.8	0.4	0.6	0.3	0.4	0.4	0.5	0.6	1.2	0.6	0.4	0.4	0.4
16-Aug-94	113300	0.2	0.2	0.2	0.4	0.2	0.3	0.4	0.2	0.2	0.2	0.1	0.3	0.2	0.1	0.2	0.4	0.2	0.2
20-Sep-94	282000	0.3	0.5	0.4	0.7	0.2	0.3	0.7	1.0	1.4	0.8	0.6	(23.9)	0.2	0.2	0.2	0.4	0.4	0.1
1-Oct-94	162000	0.4	0.2	0.2	0.2	0.4	0.2	0.3	0.4	0.2	0.2	0.3	0.2	0.1	0.4	0.4	0.2	0.3	0.3
17-Nov-94	268000	0.1	0.4	0.6	0.1	0.6	0.5	0.3	0.2	0.2	0.2	0.4	0.2	2.7	(102.2)	0.6	0.2	0.2	2.5
14-Dec-94	149000	1.0	0.4	0.8	0.7	1.2	0.6	0.6	1.2	0.3	0.6	0.8	0.8	1.0	0.4	0.6	0.6	0.4	0.8
27-Jan-95	284000	0.1	0.4	0.2	0.3	0.6	0.1	0.9	0.6	0.7	0.8	0.6	0.4	1.4	1.0	0.8	0.1	0.3	0.4
25-Feb-95	142000	0.5	0.4	1.8	1.2	0.9	1.0	0.6	1.0	1.4	0.5	0.8	0.9	0.9	0.5	0.5	0.3	0.4	0.3
3-Mar-95	241000	0.9	0.8	0.8	1.1	0.4	(13.0)	0.4	1.2	0.9	(4.2)	0.6	1.8	0.6	2.6	1.0	0.6	0.8	0.6
8-Apr-95	164000	1.1	1.3	1.0	0.5	0.4	0.8	0.8	0.6	0.4	0.8	0.9	0.4	(10.6)	0.6	0.6	1.4	0.6	0.6
3-May-95	195000	1.4	0.7	2.9	0.8	0.9	1.2	3.5	0.4	0.6	0.4	0.4	0.5	1.0	0.6	0.5	0.7	1.2	0.8
28-Jun-95	154000	0.4	0.4	0.3	0.8	0.5	0.6	0.4	0.4	0.6	0.4	0.4	0.2	0.7	0.4	0.4	0.4	0.6	0.5
7-Jul-95	244000	0.4	0.4	0.3	0.4	0.2	0.4	0.3	0.2	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4
1-Aug-95	199000	0.5	0.4	0.6	0.6	0.6	1.4	1.5	0.6	1.6	0.8	0.3	0.8	1.0	0.2	0.2	0.3	0.6	0.3
14-Sep-95	224875	1.0	0.5	0.4	0.4	0.4	0.2	0.5	0.4	0.6	0.6	0.4	0.6	0.4	0.4	0.6	0.4	0.6	0.7
19-Oct-95	207867	0.6	0.4	1.0	0.6	1.3	0.6	1.0	1.1	1.3	1.0	1.1	1.0	0.7	1.0	1.2	0.8	0.4	1.0
15-Nov-95	175002	0.6	0.6	0.8	1.2	0.8	0.7	0.6	0.8	1.4	0.7	0.1	0.5	0.3	0.5	0.3	0.2	0.6	0.6
19-Dec-95	329500									0.8									
15-Jan-96	154500	0.3	0.2	0.6	1.0	1.2	1.0	0.6	0.6	0.5	0.4	0.5	0.6	0.6	0.8	0.6	0.4	0.4	0.6
7-Feb-96	305875	0.4	0.4	0.6	0.3	0.4	0.4	0.3	0.3	0.3	0.2	0.1	0.4	0.6	0.6	0.4	0.2	0.4	0.2
13-Mar-96	310375	0.4	0.1	0.8	0.2	0.2	0.3	0.4	0.4	0.6	0.4	0.2	0.2	0.2	0.4	0.3	0.2	0.6	0.4
23-Apr-96	261375	0.4	0.7	0.3	0.4	0.6	0.4	0.5	0.6	0.5	0.6	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4
2-May-96	278750	0.3	0.2	0.3	1.2	0.5	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3
19-Jun-96	114725	0.6	0.7	0.8	0.4	0.5	0.5	0.5	0.5	0.6	0.4	0.6	0.6	0.6	0.3	0.3	0.5	0.6	1.0
10-Jul-96	163325	0.3	0.3	0.4	0.2	0.4	0.3	0.4	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.2	0.3	0.4	0.4
7-Aug-96	180100	0.4	0.4	0.4	0.6	0.8	0.8	0.8	0.7	0.4	0.2	0.6	1.1	1.0	0.4	0.4	0.8	0.7	0.7
5-Sep-96	325325	0.6	0.4	0.7	1.2	0.3	0.7	0.2	0.4	0.2	0.1	0.3	0.3	0.5	0.4	0.4	0.7	0.4	0.4

OCEAN MONITORING DATA FOR O&G (mg/L)

September 1993 - September 1996

DATE	VOLUME DISPOSED (gallons)	STATION AND DEPTH																	
		CONTROL			STATION 1			STATION 2			STATION 3			STATION 4			STATION 5		
		1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)
10-Sep-93	310750	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
27-Oct-93	185000	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
17-Nov-93	301000	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
10-Dec-93	158000	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
21-Jan-94	259000	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
9-Feb-94	147000	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
9-Mar-94	292000	0.61	0.61	0.61	0.90	1.60	0.80	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
26-Apr-94	288000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
23-May-94	157000	0.61	0.61	0.61	0.61	0.61		0.61	0.61	0.61	0.61	0.61	0.61		0.61	0.61	0.61	0.61	0.61
15-Jun-94	265000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
21-Jul-94	259000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
16-Aug-94	113300	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
20-Sep-94	282000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.50	1.00	1.00	(12.40)	1.00	1.00	1.00	1.00	1.00	1.00
1-Oct-94	162000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17-Nov-94	268000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	(40.00)	(31.60)	3.20	0.61	0.61	0.61
14-Dec-94	149000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
27-Jan-95	284000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
25-Feb-95	142000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
3-Mar-95	241000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
8-Apr-95	164000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	(47.60)	0.61	0.61	0.61	0.61	0.61
3-May-95	195000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
28-Jun-95	154000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	1.08	0.61	0.61
7-Jul-95	244000	0.78	0.61	1.12	0.61	0.61	1.28	1.28	0.78	1.79	0.61	0.61	0.61	0.61	0.61	0.61	0.95	0.61	0.61
1-Aug-95	199000	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
14-Sep-95	224875	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
19-Oct-95	207867	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
15-Nov-95	175002	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
19-Dec-95	329500	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
15-Jan-96	154500	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
7-Feb-96	305875	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
13-Mar-96	310375	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
23-Apr-96	261375	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
2-May-96	278750	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
19-Jun-96	114725	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
10-Jul-96	163325	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
7-Aug-96	180100	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
5-Sep-96	325325	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61

OCEAN MONITORING DATA FOR Total Phosphorous (mg-P/L)

September 1993 - September 1996

DATE	VOLUME DISPOSED (gallons)	STATION AND DEPTH																	
		CONTROL			STATION 1			STATION 2			STATION 3			STATION 4			STATION 5		
		1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)
10-Sep-93	310750	0.012	0.025	0.049	0.132	0.049	0.058	0.017	0.015	0.025	0.017	0.057	0.041	0.049	0.243	0.058	0.074	0.054	0.066
27-Oct-93	185000	0.014	0.016	0.016	0.026	0.017	0.033	0.115	0.240	0.052	0.039	0.016	0.026	0.028	0.023	0.026	0.014	0.015	0.016
17-Nov-93	301000	0.010	0.012	0.013	0.019	0.013	0.027	0.048	0.032	0.022	0.029	0.019	0.014	0.026	0.023	0.029	0.034	0.025	0.017
10-Dec-93	158000	0.034	0.022	0.093	0.025	0.036	0.063	0.022	0.084	0.062	0.038	0.034	0.065	0.031	0.083	0.042	0.046	0.038	0.024
21-Jan-94	259000	0.024	0.024	0.014	0.014	0.057	0.031	0.017	0.006	0.005	0.009	0.010	0.012	0.012	0.006	0.006	0.006	0.007	0.006
9-Feb-94	147000	0.032	0.028	0.032	0.042	0.044	0.061	0.047	0.047	0.048	0.061	0.038	0.049	0.045	0.030	0.030	0.030	0.038	0.045
9-Mar-94	292000	0.009	0.015	0.008	0.028	0.024	0.022	0.012	0.023	0.014	0.016	0.015	0.030	0.024	0.024	0.028	0.015	0.017	0.018
26-Apr-94	288000	0.058	0.114	0.045	0.021	0.018	0.028	0.023	0.027	0.021	0.018	0.018	0.015	0.015	0.020	0.020	0.015	0.015	0.024
23-May-94	157000	0.027	0.027	0.022	0.016	0.023	0.046	0.037	0.046	0.031	0.019	0.019	0.037	0.019	0.019	0.023	0.028	0.025	0.020
15-Jun-94	265000	0.037	0.067	0.026	0.045	0.030	0.036	0.037	0.178	0.080	0.039	0.037	0.025	0.027	0.029	0.038	0.031	0.031	0.015
21-Jul-94	259000	0.021	0.016	0.024	0.024	0.021	0.029	0.019	0.019	0.017	0.017	0.023	0.019	0.027	0.025	0.043	0.011	0.012	0.012
16-Aug-94	113300	0.025	0.022	0.027	0.026	0.023	0.053	0.044	0.038	0.032	0.041	0.032	0.034	0.026	0.052	0.115	0.048	0.059	0.057
20-Sep-94	282000	0.031	0.027	0.032	0.040	0.035	0.032	0.051	0.047	0.075	0.078	0.035	0.213	0.029	0.032	0.033	0.058	0.038	0.033
1-Oct-94	162000	0.014	0.015	0.035	0.026	0.029	0.033	0.022	0.023	0.019	0.031	0.017	0.015	0.014	0.018	0.025	0.016	0.016	0.016
17-Nov-94	268000	0.520	0.019	0.021	0.031	0.026	0.023	0.024	0.023	0.019	0.018	0.020	0.018	0.390	0.021	0.020	0.120	0.016	0.019
14-Dec-94	149000	0.023	0.026	0.017	0.038	0.044	0.035	0.018	0.015	0.571	0.018	0.015	0.016	0.020	0.021	0.023	0.019	0.018	0.017
27-Jan-95	284000	0.013	0.030	0.024	0.039	0.023	0.024	0.035	0.097	0.032	0.032	0.028	0.032	0.039	0.047	0.040	0.042	0.032	0.026
25-Feb-95	142000	0.014	0.018	0.016	0.036	0.034	0.034	0.022	0.021	0.020	0.016	0.018	0.019	0.015	0.015	0.022	0.197	0.018	0.015
3-Mar-95	241000	0.050	0.021	0.018	0.019	0.044	0.039	0.031	0.029	0.050	0.024	0.026	0.028	0.033	0.030	0.024	0.047	0.031	0.030
8-Apr-95	164000	0.030	0.017	0.021	0.029	0.024	0.032	0.024	0.016	0.014	0.027	0.029	0.027	0.025	0.040		0.019	0.022	0.027
3-May-95	195000	0.050	0.021	0.018	0.019	0.044	0.039	0.031	0.029	0.050	0.024	0.026	0.028	0.033	0.030	0.024	0.047	0.031	0.030
28-Jun-95	154000	0.063	0.047	0.076	0.067	0.077	0.056	0.072	0.053	0.045	0.048	0.056	0.050	0.307	0.053	0.056	0.065	0.053	0.049
7-Jul-95	244000	0.045	0.041	0.053	0.045	0.034	0.037	0.051	0.028	0.065	0.042	0.037	0.034	0.040	0.047	0.036	0.046	0.038	0.039
1-Aug-95	199000	0.020	0.022	0.026	0.025	0.034	0.020	0.028	0.025	0.021	0.061	0.024	0.022	0.017	0.019	0.019	0.019	0.024	0.022
14-Sep-95	224875	0.172	0.021	0.021	0.015	0.014	0.017	0.015	0.014	0.013	0.015	0.015	0.016	0.018	0.017	0.020	0.021	0.015	0.015
19-Oct-95	207867	0.044	0.043	0.038	0.029	0.037	0.038	0.034	0.040	0.038	0.046	0.024	0.037	0.152	0.034	0.041	0.027	0.034	0.037
15-Nov-95	175002	0.018	0.019	0.018	0.023	0.026	0.026	0.026	0.034	0.043	0.020	0.018	0.022	0.020	0.017	0.017	0.016	0.037	0.025
19-Dec-95	329500	0.027	0.026	0.030	0.030	0.033	0.028	0.105	0.079	0.052	0.037	0.034	0.029	0.041	0.045	0.049	0.018	0.023	0.017
15-Jan-96	154500	0.204	0.052	0.072	0.065	0.069	0.096	0.045	0.077	0.070	0.061	0.048	0.057	0.057	0.090	0.086	0.239	0.055	0.079
7-Feb-96	305875	0.044	0.047	0.050	0.048	0.026	0.043	0.034	0.036	0.035	0.029	0.028	0.035	0.055	0.123	0.045	0.090	0.027	0.032
13-Mar-96	310375	0.019	0.020	0.023	0.018	0.017	0.016	0.044	0.027	0.030	0.025	0.024	0.023	0.017	0.039	0.024	0.026	0.031	0.034
23-Apr-96	261375	0.020	0.017	0.025	0.014	0.021	0.023	0.029	0.027	0.038	0.039	0.040	0.041	0.125	0.025	0.025	0.024	0.026	0.026
2-May-96	278750	0.041	0.029	0.034	0.042	0.031	0.025	0.014	0.016	0.016	0.013	0.015	0.015	0.026	0.024	0.013	0.015	0.017	0.017
19-Jun-96	114725	0.030	0.032	0.035	0.035	0.571	0.036	0.023	0.033	0.034	0.035	0.034	0.038	0.035	0.034	0.030	0.037	0.031	0.038
10-Jul-96	163325	0.148	0.022	0.017	0.015	0.017	0.009	0.014	0.012	0.015	0.013	0.005	0.016	0.016	0.016	0.016	0.017	0.016	0.017
7-Aug-96	180100	0.038	0.038	0.047	0.239	0.029	0.046	0.041	0.047	0.044	0.040	0.043	0.042	0.041	0.040	0.047	0.043	0.037	0.036
5-Sep-96	325325	0.032	0.024	0.040	0.040	0.050	0.066	0.125	0.038	0.034	0.022	0.018	0.020	0.040	0.038	0.037	0.021	0.023	0.024

OCEAN MONITORING DATA FOR TOTAL NITROGEN (mg-N/L)

September 1993 - September 1996

DATE	VOLUME DISPOSED (gallons)	STATION AND DEPTH																	
		CONTROL			STATION 1			STATION 2			STATION 3			STATION 4			STATION 5		
		1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)
10-Sep-93	310750	0.133	0.106	0.114	0.597	0.170	0.352	0.121	0.150	0.187	0.176	0.148	0.152	0.152	0.174	0.154	0.151	0.202	0.223
27-Oct-93	185000	0.222	0.184	0.206	0.463	0.372	0.471	0.480	0.434	0.383	0.272	0.304	0.371	0.266	0.336	0.270	0.174	0.189	0.273
17-Nov-93	301000	0.033	0.116	0.132	0.160	0.159	0.158	0.148	0.156	0.175	0.135	0.177	0.157	0.126	0.191	0.190	0.103	0.102	0.105
10-Dec-93	158000	0.239	0.126	0.771	0.232	0.202	0.239	0.146	0.190	0.235	0.189	0.184	0.227	0.248	0.392	0.197	0.145	0.197	0.166
21-Jan-94	259000	0.168	0.161	0.179	0.350	0.330	0.406	0.348	0.220	0.357	0.204	0.198	0.185	0.273	0.235	0.212	0.128	0.120	0.118
9-Feb-94	147000	0.115	0.161	0.215	0.465	0.618	0.712	0.491	0.612	0.473	0.190	0.478	0.970	0.368	0.267	0.270	0.178	0.215	0.199
9-Mar-94	292000	0.120	0.194	0.165	0.308	0.344	0.388	0.195	0.178	0.228	0.228	0.165	0.292	0.253	0.240	0.308	0.247	0.247	0.198
26-Apr-94	288000	0.081	0.356	0.214	0.211	0.226	0.342	0.282	0.218	0.213	0.182	0.210	0.165	0.148	0.217	0.199	0.145	0.198	0.193
23-May-94	157000	0.210	0.215	0.202	0.150	0.187	0.565	0.260	0.272	0.488	0.208	0.191	0.241	0.173	0.640	0.164	0.136	0.118	0.363
15-Jun-94	265000	0.126	0.158	0.142	0.258	0.252	0.241	0.252	0.320	0.318	0.248	0.238	0.244	0.126	0.133	0.169	0.117	0.138	0.102
21-Jul-94	259000	0.252	0.135	0.122	0.169	0.148	0.418	0.164	0.200	0.147	0.180	0.518	0.161	0.268	0.213	0.418	0.112	0.155	0.130
16-Aug-94	113300	0.133	0.150	0.160	0.176	0.177	0.210	0.245	0.203	0.154	0.328	0.168	0.181	0.151	0.172	0.155	0.156	0.139	0.135
20-Sep-94	282000	0.249	0.210	0.208	0.249	0.198	0.158	0.312	0.522	0.659	0.492	0.243	0.713	0.103	0.157	0.121	0.203	0.201	0.205
1-Oct-94	162000	0.266	0.173	0.344	0.298	0.318	0.345	0.212	0.253	0.231	0.222	0.210	0.164	0.140	0.172	0.232	0.164	0.189	0.182
17-Nov-94	268000	(2.180)	0.309	0.181	0.248	0.278	0.237	0.175	0.165	0.110	0.181	0.191	0.146	0.860	0.120	0.189	0.130	0.150	0.130
14-Dec-94	149000	0.294	0.196	0.142	0.409	0.505	0.362	0.211	0.152	0.236	0.175	0.180	0.208	0.248	0.121	0.137	0.118	0.149	0.129
27-Jan-95	284000	0.135	0.168	0.132	0.281	0.202	0.249	0.362	0.346	0.248	0.299	0.270	0.286	0.260	0.267	0.326	0.197	0.214	0.171
25-Feb-95	142000	0.136	0.145	0.262	0.292	0.407	0.312	0.181	0.168	0.158	0.156	0.427	0.618	0.219	0.252	0.177	0.945	0.130	0.132
3-Mar-95	241000	0.159	0.222	0.195	0.785	0.591	0.280	0.155	0.226	0.561	0.298	0.240	0.355	0.432	0.235	0.248	0.400	0.293	0.236
8-Apr-95	164000	0.303	0.184	0.153	0.668	0.193	0.338	0.220	0.145	0.140	0.268	0.268	0.274	0.448	0.185		0.220	0.176	0.274
3-May-95	195000	0.124	0.134	0.668	0.262	0.318	0.330	0.399	0.157	0.127	0.157	0.173	0.262	0.195	0.167	0.141	0.484	0.345	0.422
28-Jun-95	154000	0.568	0.322	0.433	0.212	0.232	0.240	0.246	0.175	0.166	0.427	0.171	0.211	0.355	0.191	0.206	0.254	0.282	0.154
7-Jul-95	244000	0.215	0.143	0.245	0.154	0.130	0.098	0.166	0.125	0.140	0.188	0.088	0.261	0.144	0.168	0.170	0.163	0.123	0.119
1-Aug-95	199000	0.118	0.106	0.090	0.120	0.201	0.125	0.121	0.107	0.076	0.106	0.108	0.116	0.105	0.111	0.099	0.090	0.127	0.111
14-Sep-95	224875	0.175	0.144	0.155	0.160	0.142	0.128	0.112	0.107	0.136	0.144	0.118	0.130	0.102	0.105	0.152	0.122	0.106	0.115
19-Oct-95	207867	0.218	0.151	0.187	0.240	0.230	0.094	0.128	0.332	0.181	0.138	0.136	0.171	0.234	0.140	0.136	0.148	0.160	0.136
15-Nov-95	175002	0.152	0.144	0.211	0.280	0.262	0.221	0.280	0.217	0.384	0.114	0.103	0.160	0.269	0.159	0.191	0.133	0.180	0.195
19-Dec-95	329500	0.149	0.175	0.236	0.196	0.222	0.237	0.590	0.399	0.342	0.146	0.142	0.168	0.242	0.302	0.396	0.122	0.107	0.122
15-Jan-96	154500	0.104	0.122	0.680	0.124	0.213	0.183	0.148	0.255	0.183	0.088	0.153	0.126	0.158	0.228	0.143	0.149	0.114	0.264
7-Feb-96	305875	0.109	0.125	0.139	0.129	0.097	0.144	0.132	0.161	0.125	0.098	0.092	0.120	0.241	0.319	0.203	0.156	0.134	0.139
13-Mar-96	310375	0.116	0.109	0.140	0.126	0.127	0.133	0.168	0.115	0.183	0.142	0.161	0.152	0.123	0.118	0.113	0.119	0.111	0.116
23-Apr-96	261375	0.176	0.142	0.151	0.171	0.144	0.238	0.168	0.201	0.244	0.226	0.221	0.246	0.183	0.179	0.141	0.127	0.215	0.150
2-May-96	278750	0.124	0.118	0.153	0.264	0.149	0.180	0.106	0.106	0.111	0.105	0.142	0.116	0.102	0.110	0.098	0.100	0.102	0.124
19-Jun-96	114725	0.242	0.178	0.218	0.227	0.206	0.223	0.145	0.146	0.188	0.124	0.122	0.245	0.145	0.128	0.129	0.168	0.146	0.207
10-Jul-96	163325	0.125	0.137	0.151	0.116	0.110	0.164	0.163	0.146	0.156	0.138	0.160	0.115	0.117	0.123	0.114	0.135	0.137	0.119
7-Aug-96	180100	0.168	0.332	0.192	0.166	0.190	0.308	0.193	0.208	0.197	0.168	0.182	0.183	0.154	0.184	0.159	0.121	0.136	0.215
5-Sep-96	325325	0.134	0.116	0.199	0.187	0.226	0.136	0.159	0.131	0.139	0.128	0.129	0.159	0.138	0.162	0.207	0.161	0.147	0.148

OCEAN MONITORING DATA FOR AMMONIA (mg-N/L)

September 1993 - September 1996

DATE	VOLUME DISPOSED (gallons)	STATION AND DEPTH																	
		CONTROL			STATION 1			STATION 2			STATION 3			STATION 4			STATION 5		
		1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)	1 (m)	3 (m)	10 (m)
10-Sep-93	310750	0.010	0.012	0.014	0.089	0.043	0.080	0.019	0.065	0.084	0.082	0.079	0.068	0.042	0.077	0.083	0.067	0.105	0.109
27-Oct-93	185000	0.016	0.016	0.018	0.146	0.131	0.156	0.143	0.132	0.093	0.075	0.065	0.121	0.075	0.085	0.073	0.027	0.024	0.032
17-Nov-93	301000	0.013	0.013	0.033	0.032	0.045	0.075	0.034	0.063	0.083	0.048	0.079	0.062	0.030	0.065	0.083	0.026	0.018	0.023
10-Dec-93	158000	0.082	0.019	0.199	0.073	0.053	0.084	0.022	0.031	0.023	0.032	0.044	0.042	0.045	0.059	0.037	0.044	0.032	0.027
21-Jan-94	259000	0.005	0.008	0.014	0.060	0.041	0.061	0.031	0.026	0.037	0.048	0.037	0.032	0.052	0.051	0.035	0.010	0.012	0.010
9-Feb-94	147000	0.001	0.007	0.008	0.048	0.112	0.134	0.073	0.069	0.040	0.014	0.060	0.038	0.047	0.021	0.034	0.005	0.008	0.008
9-Mar-94	292000	0.012	0.033	0.022	0.125	0.123	0.123	0.035	0.040	0.064	0.070	0.045	0.084	0.118	0.117	0.141	0.069	0.057	0.053
26-Apr-94	288000	0.026	0.039	0.031	0.042	0.048	0.039	0.064	0.064	0.040	0.040	0.032	0.020	0.030	0.052	0.042	0.023	0.026	0.045
23-May-94	157000	0.031	0.021	0.010	0.008	0.011	0.030	0.057	0.042	0.064	0.030	0.028	0.047	0.028	0.075	0.034	0.018	0.007	0.053
15-Jun-94	265000	0.008	0.026	0.006	0.072	0.060	0.074	0.066	0.113	0.110	0.045	0.052	0.068	0.038	0.026	0.033	0.007	0.013	0.012
21-Jul-94	259000	0.024	0.007	0.008	0.012	0.008	0.034	0.015	0.012	0.006	0.025	0.050	0.013	0.076	0.076	0.202	0.010	0.017	0.029
16-Aug-94	113300	0.012	0.008	0.020	0.013	0.028	0.040	0.047	0.062	0.030	0.079	0.040	0.065	0.011	0.015	0.011	0.011	0.010	0.011
20-Sep-94	282000	0.015	0.007	0.016	0.053	0.039	0.027	0.142	0.097	(0.248)	0.091	0.069	0.140	0.008	0.006	0.012	0.017	0.009	0.010
1-Oct-94	162000	0.019	0.017	0.025	0.055	0.063	0.074	0.060	0.049	0.067	0.035	0.038	0.013	0.011	0.032	0.059	0.020	0.016	0.025
17-Nov-94	268000	0.250	0.008	0.001	0.021	0.035	0.022	0.034	0.032	0.014	0.010	0.030	0.026	0.026	0.020	0.022	0.005	0.003	0.004
14-Dec-94	149000	0.030	0.011	0.004	0.147	0.182	0.112	0.022	0.009	0.022	0.013	0.008	0.008	0.023	0.006	0.010	0.005	0.011	0.009
27-Jan-95	284000	0.008	0.007	0.009	0.075	0.026	0.047	0.124	0.116	0.077	0.119	0.096	0.090	0.090	0.113	0.139	0.033	0.021	0.018
25-Feb-95	142000	0.007	0.009	0.029	0.132	0.179	0.164	0.062	0.049	0.049	0.020	0.029	0.068	0.019	0.019	0.013	(0.524)	0.009	0.009
3-Mar-95	241000	0.020	0.014	0.020	0.142	0.095	0.058	0.017	0.023	0.084	0.062	0.053	0.062	0.105	0.063	0.066	0.086	0.084	0.058
8-Apr-95	164000	0.128	0.093	0.083	(0.224)	0.155	(0.247)	0.191	0.125	0.111	0.134	0.139	0.114	0.078	0.046		0.036	0.047	0.058
3-May-95	195000	0.008	0.010	(0.241)	0.016	0.038	0.032	0.013	0.011	0.015	0.016	0.012	0.045	0.011	0.011	0.012	0.260	(0.242)	0.197
28-Jun-95	154000	0.026	0.017	0.020	0.018	0.020	0.018	0.015	0.004	0.001	0.044	0.008	0.006	0.013	0.003	0.004	0.037	0.014	0.004
7-Jul-95	244000	0.016	0.013	0.018	0.011	0.014	0.007	0.015	0.010	0.021	0.019	0.048	0.023	0.019	0.026	0.014	0.023	0.022	0.020
1-Aug-95	199000	0.010	0.019	0.010	0.047	0.082	0.022	0.013	0.019	0.008	0.009	0.021	0.011	0.012	0.009	0.009	0.014	0.016	0.011
14-Sep-95	224875	0.017	0.005	0.006	0.006	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.004	0.007	0.004	0.010	0.008	0.009	0.006
19-Oct-95	207867	0.013	0.008	0.012	0.028	0.016	0.005	0.013	0.033	0.004	0.010	0.020	0.031	0.009	0.004	0.005	0.002	0.006	0.006
15-Nov-95	175002	0.017	0.014	0.029	0.079	0.074	0.054	0.102	0.073	0.127	0.011	0.009	0.019	0.037	0.017	0.028	0.015	0.018	0.025
19-Dec-95	329500	0.013	0.015	0.021	0.028	0.067	0.057	(0.351)	(0.253)	0.111	0.027	0.023	0.027	0.102	0.135	0.189	0.010	0.009	0.009
15-Jan-96	154500	0.008	0.008	0.103	0.023	0.029	0.030	0.023	0.031	0.032	0.006	0.018	0.009	0.010	0.013	0.004	0.004	0.005	0.014
7-Feb-96	305875	0.006	0.003	0.003	0.005	0.004	0.008	0.006	0.008	0.007	0.004	0.005	0.007	0.061	0.056	0.035	0.015	0.007	0.112
13-Mar-96	310375	0.005	0.005	0.005	0.007	0.008	0.009	0.019	0.007	0.060	0.023	0.039	0.037	0.006	0.007	0.007	0.019	0.006	0.005
23-Apr-96	261375	0.024	0.012	0.013	0.018	0.012	0.025	0.042	0.040	0.053	0.088	0.049	0.068	0.034	0.033	0.029	0.012	0.025	0.012
2-May-96	278750	0.010	0.006	0.005	0.119	0.038	0.034	0.003	0.003	0.004	0.005	0.011	0.006	0.006	0.007	0.003	0.004	0.004	0.006
19-Jun-96	114725	0.011	0.012	0.012	0.038	0.016	0.026	0.010	0.007	0.015	0.007	0.008	0.016	0.009	0.007	0.006	0.022	0.009	0.017
10-Jul-96	163325	0.016	0.010	0.008	0.007	0.006	0.021	0.048	0.028	0.036	0.016	0.013	0.010	0.006	0.007	0.006	0.009	0.006	0.007
7-Aug-96	180100	0.025	0.022	0.012	0.030	0.035	0.030	0.024	0.059	0.057	0.021	0.062	0.056	0.038	0.044	0.035	0.012	0.008	0.025
5-Sep-96	325325	0.007	0.007	0.010	0.009	0.013	0.013	0.015	0.007	0.005	0.006	0.005	0.005	0.005	0.006	0.011	0.006	0.005	0.004

Calculation of Dilution Using Available Field Data and Discharge Characteristics

	TP (mg-P/l)			TN (mg-N/l)			Ammonia (mg-N/l)		
Samoa Packing High Strength Waste Concetration	1200			6160			2430		
StarKist Samoa High Strength Waste Concetration	832			5560			3875		
Combined Median Concentration of High Strength Waste	1008			5848			3181		
Depth	**1 m**	**3 m**	**10 m**	**1 m**	**3 m**	**10 m**	**1 m**	**3 m**	**10 m**
Median Concentrations at:									
Background (Station 1C)	0.03	0.024	0.026	0.1505	0.151	0.187	0.013	0.012	0.0135
Station 1 @ 0.0 nmiles	0.029	0.03	0.033	0.232	0.206	0.239	0.035	0.038	0.034
Station 2 @ 0.25 nmiles	0.031	0.029	0.034	0.181	0.19	0.187	0.0275	0.0325	0.0385
Station 3 @ 0.5 nmiles	0.029	0.024	0.028	0.18	0.177	0.183	0.025	0.037	0.032
Station 4 @ 1.0 nmiles	0.028	0.03	0.0285	0.183	0.179	0.1735	0.028	0.026	0.0285
Station 5 - Farfield	0.028	0.026	0.024	0.148	0.149	0.15	0.015	0.0115	0.014
Calculated Dilutions at:									
Station 1 @ 0.0 nmiles	N/C	168,059	144,051	71,753	106,325	112,458	144,609	122,361	155,190
Station 2 @ 0.25 nmiles	N/C	201,671	126,044	191,733	149,945	N/C	219,406	155,190	127,255
Station 3 @ 0.5 nmiles	N/C	N/C	504,177	198,232	224,917	N/C	265,116	127,256	171,967
Station 4 @ 1.0 nmiles	N/C	168,059	403,342	179,934	208,852	N/C	212,092	227,242	212,092
Station 5 - Farfield	N/C	504,178	N/C	N/C	N/C	N/C	1,590,694	N/C	6,362,773

Calculation of Dilution Using Available Field Data and Discharge Characteristics

	TSS (mg/l)			TVSS (mg/l)			O&G (mg/l)		
Samoa Packing High Strength Waste Concetration	16800			8770			14780		
StarKist Samoa High Strength Waste Concetration	53900			36850			21780		
Combined Median Concentration of High Strength Waste	36092			23372			18420		
Depth	**1 m**	**3 m**	**10 m**	**1 m**	**3 m**	**10 m**	**1 m**	**3 m**	**10 m**
Median Concentrations at:									
Background (Station 1C)	1.4	1	1.7	0.4	0.4	0.6	0.61	0.61	0.61
Station 1 @ 0.0 nmiles	1.2	1.6	1.45	0.45	0.5	0.6	0.61	0.61	0.61
Station 2 @ 0.25 nmiles	1.4	1.5	1.4	0.5	0.6	0.6	0.61	0.61	0.61
Station 3 @ 0.5 nmiles	1.2	1	1.2	0.4	0.4	0.45	0.61	0.61	0.61
Station 4 @ 1.0 nmiles	1.6	1.45	1.4	0.5	0.4	0.4	0.61	0.61	0.61
Station 5 - Farfield	1.2	1.1	1.4	0.4	0.4	0.4	0.61	0.61	0.61
Calculated Dilutions at:									
Station 1 @ 0.0 nmiles	N/C	60,152	N/C	467,424	233,712	N/C	N/C	N/C	N/C
Station 2 @ 0.25 nmiles	N/C	72,182	N/C	233,712	116,856	N/C	N/C	N/C	N/C
Station 3 @ 0.5 nmiles	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Station 4 @ 1.0 nmiles	180,453	80,202	N/C	233,712	N/C	N/C	N/C	N/C	N/C
Station 5 - Farfield	N/C	360,910	N/C	N/C	N/C	N/C	N/C	N/C	N/C

Calculation of Distance Between Station 4 and Station 5 for Ocean Monitoring Sampling

Distance Corresponding to 1 min of Latitude = *1.01* *nmile/min*

Distance Corresponding to 1 min of Longitude = *0.98* *nmile/min*

Date	Station 4		Station 5		Difference		Distance between
	Lat 14°S+min.	Long 170°W+min	Lat 14°S+min.	Long 170°W+min	Lat minutes	Long minutes	Stations 4 & 5 nmiles
28-Jun-95	24.32	38.08	24.17	38.33	-0.15	0.25	0.29
3-May-95	24.35	39.67	24.31	40.03	-0.04	0.36	0.36
8-Apr-95	24.43	38.08	24.52	38.35	0.09	0.27	0.28
3-Mar-95	25.55	38.00	25.66	38.31	0.11	0.31	0.32
25-Feb-95	23.76	37.75	23.79	38.02	0.03	0.27	0.27
27-Jan-95	24.42	38.85	24.60	39.40	0.18	0.55	0.57
17-Nov-94	24.67	38.43	24.63	38.71	-0.04	0.28	0.28
1-Oct-94	24.14	37.48	23.98	37.64	-0.16	0.16	0.23
20-Sep-94	23.81	37.90	23.50	38.07	-0.31	0.17	0.35
16-Aug-94	24.39	37.70	24.33	37.94	-0.06	0.24	0.24
21-Jul-94	23.85	37.22	23.77	37.28	-0.08	0.06	0.10
15-Jun-94	24.20	38.24	23.82	38.16	-0.38	-0.08	0.39
23-May-94	24.84	36.72	24.75	36.74	-0.09	0.02	0.09
26-Apr-94	24.40	38.77	24.15	39.08	-0.25	0.31	0.40
9-Mar-94	24.22	36.30	24.23	35.97	0.01	-0.33	0.32
9-Feb-94	23.51	38.50	24.02	39.00	0.51	0.50	0.71
21-Jan-94	23.73	38.54	24.08	38.52	0.35	-0.02	0.35
10-Dec-93	24.60	38.30	24.85	39.01	0.25	0.71	0.74
17-Nov-93	24.83	39.21	24.67	39.40	-0.16	0.19	0.25
27-Oct-93	25.41	37.50	25.60	37.73	0.19	0.23	0.30
10-Sep-93	24.00	37.80	23.80	38.50	-0.20	0.70	0.72
						Min	0.09
						Max	0.74
						Mean	**0.37**

OPIN 023096USFI
Rcd 7/22/96

JOINT CANNERY OCEAN DUMPING STUDIES

IN

AMERICAN SAMOA

Submitted to

U.S. Environmental Protection Agency, Region 9
American Samoa Environmental Protection Agency

Prepared for

StarKist Samoa
(Permit OD 93-01 Special)
and
VCS Samoa Packing
(Permit OD 93-02 Special)

Prepared by

CH2M HILL

and

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July 1996

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Executive Summary

The ocean dumping permits issued to StarKist Samoa and VCS Samoa Packing require a variety of monitoring and reporting activities. One such activity is a re-evaluation of previous bioassay testing and dispersion modeling reported in previous studies. This activity is described in special condition 3.3.5 of the permits issued to each of the canneries. This report presents the results of the bioassay tests and modeling done under this special condition.

High strength waste, to be disposed of by ocean dumping, was sampled from each cannery as it was transferred to the FV *Tasman Sea*. Samples were taken three times, during various seasons of the year, and shipped to Advanced Biological Testing (ABT) in Tiburon, California. At ABT bioassays were conducted with a number of test organisms as required by the permits. The methods and test species used were modified in consultation with USEPA as the study progressed. The lowest LC50 recorded in the series of bioassays was 0.12 percent.

The previous modeling was done during the preparation of an Environmental Impact Statement done by U.S. Environmental Protection Agency. This modeling was reviewed and evaluated. CH2M HILL used a different approach to estimate an initial dilution (consisting of an immediate dumping dilution and a nearfield dilution). The two components of the initial dilution were based on propeller theory and the concept of a momentum jet. The farfield dilution was based on the same model (mathematical and physical description) previously used, but implemented with a spreadsheet application.

The results of the model, although considered quite conservative, indicated somewhat higher dilutions at the edge of the dumping zone than previously predicted by the model used in the FEIS. Direct comparisons cannot be made since the vessel in use is not the same. However, predictions for the worst case, corresponding to average ocean currents, in the summer, and at maximum discharge rate, indicate a concentration at the edge of the dumping zone that is 0.0021·(LC50) described above.

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1. Introduction

The Regional Administrator of EPA Region IX determined that ocean disposal of fish processing wastes off American Samoa meets EPA's ocean dumping criteria (40 CFR Parts 227 and 228). Based on this determination EPA issued special ocean dumping permits to StarKist Samoa, Inc. and VCS Samoa Packing, Inc. on September 1, 1993. Special condition 3.3.5 of both permits requires bioassay testing of the waste from each cannery and a re-evaluation of the model previously used to predict concentrations of fish processing wastes disposed of at the designated disposal site. A copy of this special condition is provided in Appendix 1. This section of the report describes the purpose of the report, presents pertinent background information, and describes the organization of the materials presented in subsequent sections.

Purpose

The purpose of this report is to document the results of the bioassay and modeling studies required by the special ocean dumping permits under special condition 3.3.5. StarKist Samoa (Permit No. OD 93-1 Special) and VCS Samoa Packing (Permit No. OD 93-01 Special) were required to conduct and submit the results of toxicity tests on fish processing wastes generated at the permittees' American Samoa packing plants. The wastes tested were DAF sludge and other high strength waste streams that are barged to sea for disposal at the permitted dump site. The report describes the methods and results of the bioassay tests.

Permit condition 3.3.5 requires that the bioassay results be used to re-evaluate the previous model predictions of dispersion of the plume created by dumping fish processing wastes at sea. The model re-evaluation was conducted by: applying a previously used model exactly as developed, evaluation of the previous model for application to the current disposal operations, and development and application of a revised more sophisticated model(s). The report describes these modeling exercises and the results of the model predictions.

Background

StarKist Samoa and Samoa Packing (the canneries) began ocean disposal of DAF sludge off the south coast of Tutuila Island in December of 1980 (Permit Number: OD 79-01/02 Special). A field study of the fate and transport of the waste was described by Soule and Oguri (1983). In 1990 the disposal site was moved further offshore into deeper water based on an Environmental Impact Statement done by EPA (1989) and a supplementary mathematical model study (SOS, 1990). The existing permit was issued for the deep water site in 1993 (effective date of 1 September 1993 - expiration date 31 August 1996).

The existing permits allow disposal at the deep water site mentioned above approximately 5.16 nautical miles offshore in a water depth of about 9000 feet. The dump site is a circle of 1.5 nautical mile radius. The permit allows the disposal of up to a total of 200,000 gallons per day including: DAF sludge (60,000 gallons per day) and high strength process stream wastes ((100,000

gallons per day of precooker water and 40,000 gallons per day of press water). The concentrations of various physical and chemical parameters are limited in the permits. Special conditions in the permits require monitoring and analysis of the fish processing wastes to be disposed of, monitoring of vessel operations and position, notices to regulatory agencies, receiving water monitoring, and biological community observations and reporting.

This report was prepared under special condition 3.3.5 as discussed above and reproduced in Appendix 1. A draft study plan was prepared and submitted to USEPA and ASEPA in November 1993 (CH2M HILL, 1993). Comments were received from EPA on the study plan in a letter dated 10 December 1993. These comments concerned details of the bioassay sample collection, shipping, and certain protocols of the bioassay tests. The comments were easily accommodated and the draft study plan was not revised. The final study plan consists of the Draft Study Plan and the EPA comments which are included as Appendix 2. In addition, some changes were made to the bioassay test protocols and procedures, with the concurrence of EPA. These changes are documented in descriptions of the bioassay tests below, and in the following section of the report.

Scope of Report

The special permit condition addresses two distinct efforts: bioassay testing and model reevaluation. Although the results of the bioassay testing can be used with the model results to predict the potential for toxicity, the two parts of the study are quite different and are best described independently. Therefore, this report is presented in three main parts: a description of the bioassay test results, a description of the results of the modeling, and a final section presenting conclusions and recommendations. References are provided and additional detailed information is provided in Appendices.

For the bioassay tests, this report basically summarizes the previous memoranda sent to EPA after each of the sampling and testing episodes. For the modeling portion of the studies the report extends the memorandum previously sent to EPA summarizing the results and provides detail descriptions of the modeling study to a level sufficient to allow independent review of the modeling. The interpretation of the modeling, incorporating the bioassay information, has not previously been addressed and is formalized in this report.

2. Bioassay Testing

Bioassay tests were conducted as required in the permits with modifications as approved by EPA and documented below. General guidance for these tests was provided by USEPA (1991), ASTM (1992), and the EPA/COE "Green Book" (1991). Specific guidance for performing biological-effects tests for Ocean Disposal permits are outlined in Part III, Section 11 of the Green Book; *Evaluation of Dredged Material Proposed for Ocean Disposal: Testing Manual* (EPA and COE, 1991). However, the fish processing wastes to be disposed under the permits are not similar to solid dredged materials. The high strength waste materials are mostly positively to neutrally buoyant liquid phase wastes. The physical and chemical nature of the wastes required that the tests be conducted as effluent tests, which was agreed to by EPA (see Appendix 2). The following sections briefly summarize the methodology for sampling and testing, and report the results of the tests. More detail is given in the Study Plan (Appendix 2) and the standard operating procedures (SOP) for the collection of the high strength wastes (HSW) (Appendix 2). Approved changes made to the permit conditions and study plan as the study proceeded are described and documented below.

HSW Sampling Procedures

High strength waste samples were collected at each cannery from the existing sampling ports in the storage tank transfer lines. Three samples were taken at 10 minute intervals while waste was being transferred from the storage tanks to the barge. Samples for the bioassay tests were composited from the three discrete samples. Waste from each cannery was sampled and tested separately. Detailed procedures used for sampling, sample handling, and shipping are included in the SOP referenced above. The sampling periods were modified from the original sampling plan as follows:

- Originally scheduled 30 November 1993: Sampled 16 February 1994
- Originally scheduled 28 February 1994: Sampled 20 October 1994
- Originally scheduled May 31, 1994: Sampled 23 June 1995

Changes in sampling and testing periods were approved by EPA as described in the correspondence included in Appendix 4.

Test Species

The permit condition requires toxicity testing with three species selected from three groups listed in section 3.3.5 of the permit. The study plan initially set up a proposal that the tests be conducted with the pacific mysid shrimp (*Holmesimysis costata*) juveniles, pacific sanddab (*Citharichthys stigmaeus*) juveniles, and purple sea urchin (*Strongylocentrotus purpuratus*) larvae. The rational for this selection is provided in the Study Plan (Appendix 2). It was further proposed that, if necessary, *Mytilus* sp. (mussels) would be used as a backup species to the sea ur-

chin and white shrimp (*Paneaus vannami*) would be used as a back-up test species for the mysid shrimp should the primary test species be unavailable at the time of the bioassays.

In their comments on the study plan (see Appendix 2) EPA recommended replacing *Holmesimysis costata* with *Mysidopis bahia* which was done. For the first of the three required testing episodes both *Mytilus edulis* (blue mussel) and *Strongylocentrotus purpuratus* were tested, and, as described in more detail below, *Mytilus* was selected for the following tests. Because of difficulties in spawning *Mytilus* was not tested during the third test.

Testing Methodology

The testing methodologies used for acclimation and holding of test organisms, sample preparation, and experimental conditions and procedures, QA/QC, and data analysis are described in the Study Plan (Appendix 2) and in the detailed laboratory reports (Appendix 5). However, one aspect of the testing procedures, the potential for and handling of high IDOD, deserves special note. Initial dissolved oxygen demand (IDOD) has been determined to be a problem with cannery effluent and high strength waste streams. Preliminary IDOD measurements were done at the canneries in October of 1993. The results indicate a typical IDOD demand within the first 15 minutes and a second high demand that occurs between 10 and 14 hours. The second demand can, if not anticipated, compromise and even make useless a bioassay test in progress. The results of these IDOD measurements were used for guidance in determining sample dissolved oxygen (DO) conditions and aeration procedures required for the bioassays in this study. Advanced Biological Testing of Tiburon, California, performed the bioassays and was able to anticipate and account for this aspect of the tuna cannery wastes.

Results of the Bioassay Tests

Three sets of bioassay tests were conducted on the HSW for each cannery. The results of these tests were reported to USEPA and ASEPA in separate memoranda for each testing episode. Modifications and changes to the original study plan were made for each of the tests as documented in the memoranda and in communications with EPA provided in Appendix 4. Each of these testing episodes is briefly reviewed below and the results of all of the tests are given in Table 2.1.

First Set of Bioassay Tests

Sampling for the first bioassays tests was done in February 1994 (see EPA comments on the Draft Study Plan in Appendix 2). Detailed methods and results of the tests are presented in the attached: *"Results of a Bioassay Conducted on Two High Strength Waste Samples from the Van Camp and StarKist Tuna Canneries in American Samoa"* prepared by Advanced Biological Testing Inc., Tiburon, California, and provided in Appendix 5. Acute effluent bioassays were conducted on four species including the three listed in the study plan plus one of the alternates. The species used were *Mysidopsis bahia* (mysid shrimp) juveniles, *Mytilus edulis* (blue mussel) larvae, *Strongylocentrotus purpuratus* (purple sea urchin) larvae, and *Citharichthys stigmaeus* (speckled sanddab) juveniles. The results of these bioassays are summarized in the Table 2.1 below and

were provided to EPA as a memorandum to the American Samoa Project Manager (CH2M HILL, 1994).

Based on the results of the first set bioassays, CH2M HILL recommended two changes to the HSW bioassay protocol as follows:

- Reduction of the upper end of the HSW concentration series for all bioassays to a maximum of 3.0 percent. This was done for the first set of tests after discussions with EPA as reported in the laboratory report (Appendix 5). No additional information is required at concentrations greater than 3.0 percent and reducing the maximum concentrations reduces the amount of HSW that needs to be sampled and shipped. We recommended a series of concentrations for the bioassays of 3.0%, 1.5%, 0.8%, 0.2%, 0.1%, and 0.05%.

- Continue running bioassays with *Mytilus edulis* while monitoring the effects of aeration on organism mortality and drop the use of *Strongylocentrotus purpuratus* larvae as test organisms for the HSW. This recommendation was made for the following reasons:

  - Special Condition 3.3.5 of the permits required only three organisms be tested; one organism each out of three specified groups. *Mysidopsis bahia* and *Citharichthys stigmaeus* satisfy the requirements for Groups 2 and 3. Group 1 contains larval stages of both bivalves and echinoderms and running just *Mytilus edulis* should satisfy this requirement.

  - Because of the high oxygen demand of the effluent, all test containers required aeration throughout the tests to maintain adequate oxygen concentrations for the test organisms. Aerating the chambers using *Mytilus edulis* and *Strongylocentrotus purpuratus* larvae as bioassay test organisms gives problematic results. Aeration is standard protocol for bioassays on fish and invertebrates when oxygen levels fall below 40% of saturation, but is not standard protocol for bioassays on larval bivalves and echinoderms. The effects of aerating the water on the survival of these organisms is not known. Because the *Mytilus edulis* bioassays are only run for two days (vs. four for the *Strongylocentrotus purpuratus*) the organisms are exposed for half the time and the effects of aeration may be reduced.

  - The mortality of the control group was substantial for the echinoderms and is unacceptable according to protocol. The cause of the high mortality in the control is not known.

The results and methods for the first set of tests and the recommendations described above were reviewed and accepted by EPA as documented in the attached communications dated 29 August 1994 (Appendix 4). The recommendation for reducing the maximum concentrations of the samples was accepted by U.S. EPA and, after consultation between Advanced Biological Testing and EPA, new test concentrations were established for the mysid, mussel, and sanddab tests of 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% as a volume dilution in 30 ppt sea water. The recommendation for dropping the urchin test was accepted by U.S. EPA. The mussel test was continued to investigate the effects of aeration as described below. Other recommendations

were made by EPA in the letter, which were adopted as described below and in the detailed laboratory reports.

Second Set of Bioassay Tests

The results of the second set of tests are presented in the attached: "*Results of a Bioassay Conducted on Two High Strength Waste Samples from the Van Camp and StarKist Tuna Canneries in American Samoa*" prepared by Advanced Biological Testing Inc. (ABT), Tiburon, California, (Appendix 6). The second sampling was conducted in October 1994. Acute effluent bioassays were conducted on *Mysidopsis bahia* (mysid shrimp) juveniles, *Mytilus edulis* (blue mussel) larvae, and *Citharichthys stigmaeus* (speckled sanddab) juveniles. The results of these bioassays are summarized in the Table 2.1 below and were provided to EPA as a memorandum to the American Samoa Project Manager (CH2M HILL, 1995a).

In the first test described above it was determined that due to the high oxygen demand, including a high immediate oxygen demand, of the effluent all test containers required aeration throughout the tests to maintain adequate oxygen concentrations. Aeration is standard protocol for bioassays on fish and invertebrates when oxygen levels fall below 40% of saturation, but is not standard protocol for bioassays on larval bivalves and echinoderms. Therefore, aerating the chambers containing *Mytilus edulis* may give problematic results. In the second test gentle aeration was initiated on Day 0, and continued for the duration of the tests. To assess the effects of aeration, an aeration control for the mussel test was run simultaneously. No statistical differences were observed between aerated and unaerated controls. It was recommended that this type of aeration continue to be used with the mussel test.

Third Set of Bioassay Tests

The results of the third set of tests are presented in the attached: "*Results of a Bioassay Conducted on Two High Strength Waste Samples from the Van Camp and StarKist Tuna Canneries in American Samoa*" prepared by Advanced Biological Testing Inc. (ABT), Tiburon, California, (Appendix 7). The third sampling was conducted in June 1995 this test was delayed to get better seasonal coverage with the concurrence of USEPA (see Appendix 4).

Acute effluent bioassays were conducted on *Mysidopsis bahia* (mysid shrimp) juveniles and *Citharichthys stigmaeus* (speckled sanddab) juveniles using HSW collected separately from the StarKist Samoa and VCS Samoa Packing canneries in Pago Pago Harbor, American Samoa. The results of these bioassays are summarized in Table 2.1 below and were provided to EPA as a memorandum to the American Samoa Project Manager (CH2M HILL, 1995b). For this sampling *Mytilus edulis* (blue mussel) larvae were unavailable as the mussels were spawning. The U.S. EPA reviewed the problem of the mussel spawning and waived the requirement to conduct the bioassay test on the mussel larvae for this sampling period (see Appendix 4).

Summary of Results of the Bioassay Tests

Table 2.1 summarizes the results of the bioassay tests. As noted above, each of the testing episodes is reported on in detail in Appendices 5, 6, and 7.

Table 2.1
Summary of High Strength Waste Bioassay Results.

Test Organism	Endpoint	StarKist Samoa			VCS Samoa Packing		
		2/94	10/94	6/95	2/94	10/94	6/95
Citharichthys stigmaeus (sanddab)	LC_{50}	0.27%	0.35%	0.396%	0.59%	0.37%	0.626%
	NOEC	0.20%	0.25%	0.25%	0.40%	0.25%	0.25%
	LOEC	0.40%	0.50%	0.50%	0.80%	0.50%	0.50%
Mysidopsis bahia (mysid shrimp)	LC_{50}	0.12%	1.16%	0.675%	0.59%	0.79%	0.625%
	NOEC	0.05%	0.50%	0.125%	0.05%	0.50%	0.25%
	LOEC	0.10%	1.00%	0.25%	0.10%	1.00%	0.50%
Mytilus edulis (blue mussel)	LC_{50}	>1.20%	>2.0%	[2]	>1.20%	>0.20%	[2]
	IC_{50}	<0.08%	0.10%	[2]	<0.08%	0.18%	[2]
Strongylocentrotus pupuratus (urchin)[1]	LC_{50}	1.20%	-	-	1.20%	-	-
	IC_{50}	<0.08%	-	-	0.10%	-	-

[1] Urchin test not conducted in second and third test periods (w/concurrence of U.S. EPA).
[2] Mussel larvae not available for test, requirement waived by U.S. EPA for this test.

3. Model Evaluation

This section describes the re-evaluation of the previous model predictions of dispersion of the plume created by dumping fish processing wastes at sea. The previous predictions are presented in Appendix B of the FEIS (EPA, 1989) and in a supplementary study (SOS, 1990). Appendix B of the FEIS is reproduced in Appendix 8 of this report for convenience. The model re-evaluation was conducted in three phases as describe below. The three steps were:

- The existing model formulation, as described in the 1989 FEIS were used as described. The previous model was implemented as an Excel 5.0 spreadsheet and the results of the new formulation checked against the previous results. The model predictions are then used by applying the new bioassay test results presented in the previous section and this evaluation is provided in the conclusions and recommendations section of the report below.
- The input data and assumptions used in the model were examined and evaluated. Sensitivity studies were done for critical parameters, including assumed values for diffusion coefficients, initial dilution, and ambient conditions. The appropriateness and applicability of previously assumed values are discussed.
- A somewhat different approach, for the initial dilution as the waste is pumped into the propeller slipstream was developed. The objective of the new approach for initial dilution with a different model is intended to account for changes in vessel characteristics and operational methods and to develop more representative overall model predictions.

A summary of the model evaluation was provided to USEPA and ASEPA in a memorandum prepared by CH2M HILL (1995c). The descriptions below expand and further document the summary previously provided.

Previous Model Formulation

The previous model (FEIS model), based on an approach originally developed by Brooks (1960), is typically very conservative in similar applications. Other assumptions in the model are also conservative. The results of the model are presented in terms of dilution (or concentration) of fish processing waste versus distance from the initial dump site. Based on the results of the bioassay tests, the distance from the dump site where the effluent is diluted to the limiting permissible concentration (LPC) level can be determined.

The FEIS model formulation, based on the approach presented by Brooks (1960), is essentially the same basic model as CDIFF (Yearsley, 1989). The formulation developed by Brooks calculates the lateral diffusion of a discharge plume as it is advected in the longitudinal direction and does not account for longitudinal dispersion. As initially developed by Brooks, the approach does not account for vertical diffusion, does not provide for the settlement of negatively buoyant constituents in the plume, and does not account for the dispersion

of a positively buoyant plume or positively buoyant components of the discharged material. In addition the model, as implemented in the FEIS, assumes a line source of constant source strength.

The FEIS model provides for a settling velocity by redefining the longitudinal coordinate at a downward angle defined by the relationship between the longitudinal current speed and assumed vertical settling velocity such that:

$$x' = x \cdot \cos(\theta)$$

where

$\theta = \tan(u/w_s)$

u = ambient horizontal, longitudinal velocity

w_s = settling velocity

The FEIS model also accounts for vertical diffusion by applying a concentration reduction factor based on a Fickian diffusion coefficient (K_v). This factor is applied to the calculated centerline concentration (C_{max}) by

$$C_{max} \cdot \{(H/4) \cdot (2 \cdot K_v \cdot t + H^2/16)^{-0.5}\}$$

to calculate an adjusted value of C_{max} accounting for vertical diffusion, where H is the initial vertical plume dimension and t is travel time along the plume trajectory. The two changes described above are the only modifications made to the original Brooks formulation. The FEIS model input variables include ambient current speed, initial dilution, settling velocity, and initial plume dimensions.

Based on the descriptions in the 1989 FEIS, the existing model was reproduced and tested. We were not able to exactly reproduce the model results for all cases and believe there may some errors, simplifications or inconsistencies in the original formulation. However, these errors are not "fatal" and generally not significant. In fact the differences noted below may be simply caused by differences in the numerical formulation between the two approaches. The maximum disagreement between results from our formulation and the initial FEIS formulation of the model are on the order of 10 percent, and typically much smaller. Tables 3.1 and 3.2 show the comparison of published predictions for the FEIS model and the CH2M HILL spreadsheet model predictions based on the same set of differential equations. Previous model predictions appear to have been reasonable, and probably conservative, for the development of the ocean dumping siting and operational procedures.

Evaluation of the Previous Model

The FEIS model is evaluated below on the basis of the assumptions and input used to develop and implement the model. These factors fall into three categories which are examined to determine the general and specific applicability of the model approach and the model formulation and implementation, respectively. The three categories considered are: [1] assumptions in-

volved in the basic formulation of the model involving the fundamental physics and mathematics used; [2] the assumptions and methodology used to chose the magnitudes of the variables describing the important physical processes; and [3] the values used for the description of ambient conditions and characteristics of the waste material. Each of these categories of model assumptions and input was examined and re-evaluated, as discussed in more detail below. In addition to the direct re-evaluation of the model assumptions and inputs, the sensitivity of the model to important variables was assessed.

The FEIS model is based on differential equations that consider lateral and vertical diffusion. Longitudinal diffusion (in the direction of the ambient current is neglected because of it's relative magnitude which is small compared to other terms. This assumption is well founded for the current patterns observed and anticipated in the disposal area. The actual equations were developed by Brooks (1960) and can be rearranged to resemble the classical error function by adding an exponential decay term. For open ocean applications the diffusivity is expressed in terms of a 4/3 power relationship, which is a widely accepted approach (see for example Fischer et al. (1979). The affect of vertical diffusion is assumed to be Fickian, an appropriate term is multiplied with the error function to predict total diffusion from both lateral and vertical components. The approach taken in the FEIS model appears reasonable for application to the farfield following the initial development of the waste plume. It is considered a conservative (underprediction of dilution) approach. It is noted that the model as reproduced by CH2M HILL on a spreadsheet application uses a numerical approximation to the error function (with an associated error of less than $2 \cdot 10^{-7}$). Differences between the FEIS model and the CH2M HILL implementation of that model described above may be explained, at least in part, by differences in the approximations used for the error function.

The vertical diffusion in the FEIS model is dependent on a coefficient of vertical diffusion which is assumed constant during the winter and depth dependent during the summer (as reflected in the results in Tables 3.1a and 3.2). The reasoning behind this approach is based on the seasonal existence of a thermocline in the summer. The vertical diffusion coefficient is the only depth varying parameter in the governing equations used in the FEIS model. Based on this formulation, all calculations within a certain range of depths should result in constant dilution depending on the value of the coefficient. However, this is not the case with the FEIS model predictions, and

In the FEIS model the initial plume depth is take to be H/4, where the dimension H is obtained from the equation,

$$U \cdot L \cdot H \cdot C_0 = Q$$

where,

U = ambient velocity,
L = a characteristic length parameter,
C_0 = the initial waste concentration (at the beginning of farfield dilution),

and

Q = the flow rate of the waste stream from the barge.

The width of the initial plume is taken to be twice the turning radius of the dumping vessel. A characteristic length of the vessel, set equal to the geometric mean of the half beam, and the draft of the vessel, is the length parameter used in the equation to calculate initial concentration. The FEIS modeling report does not clearly justify this assumption. One of the suggested modi-

fications to the model, as described below, is a better description of the initial dilution of the plume. The formulation used in the FEIS model is not particularly well founded in physics, although it appears to be quite conservative and is acceptable from a regulatory basis where any uncertainty should be on the conservative side.

The FEIS model makes several assumptions concerning the initial dumping of the waste. First, the relative velocity term that is used in the equation for calculating the initial concentration is simply the speed of the vessel (over the bottom). The assumption is made that as the ship circles in a constant ambient current, the net effect of the ocean current cancels out. In addition, the flow value used is a time average which changes in response to relative velocity. Thus, it may be considered that there is no net effect on initial concentration because the calculation of C_0 involves flow in the numerator and relative velocity in the denominator. Regardless of the rationale, the ambient current speed is at least an order of magnitude smaller than the vessel speed, thus the use of vessel speed for relative velocity is a reasonable assumption.

Assumptions used, once the initial dumping has occurred, include maintaining the majority of the plume near the surface, surface waves can be disregarded, the plume does not reach the 120 fathom contour, and the pumping rate mixes the flow without altering the wake pattern of the vessel. All of these assumptions are physically reasonable or, if over-simplified, result in a conservative approach (dilution will be under predicted).

Three areas for improvement in the FEIS model have been identified as a result of the evaluation summarized above. One of these involves the modeling of the initial dilution processes which determine the plume size and initial concentration used as an initial condition in the farfield model. The other two areas involve the actual formulation of the farfield model and are discussed below. These problems with model formulation probably explain, at least in part, the differences in predictions of the FEIS model and CH2M HILL's application of that model as discussed above. No reason to significantly modify, or replace, the farfield model (essentially the FEIS model) has been identified other than to address the points discussed below. However, it is believed that a more realistic approach to initial dilution is available and has been incorporated into the overall model, as described in the following section on revised model predictions.

In the FEIS modeling report, the values given for the vertical diffusion coefficient, K_v, are based on seasonal variability. As described above winter values are held constant. Summer values are presented for depth ranges of 100 meter intervals: 0 to 100 meters, 100 to 200 meters, and below 200 meters. This is the only depth dependent variable in the model. The results shown in Appendix B of the FEIS (see page B-18) show different values of C_{MAX}/C_0 for two fall velocities of 0.1 cm/sec and 0.01 cm/sec for, and only for, the case of 0.2 knot ambient current (values are the same for the two fall velocities for other ambient currents). Since all depths are less than 100 meters for these two cases, K_v is constant and the differences are curious.

For the reason described above, CH2M HILL's implementation of the FEIS model could not replicate the results for this current speed (see Table 3.2). In addition, the CH2M HILL implementation could not reproduce the deep (fall velocity of 1 cm/sec) case within an accuracy of as much as about 10 percent (see Table 3.2). The latter discrepancy may well be related to the other problems. The original model code was not obtained, so a definitive answer concerning these problems was not available. However, the differences are not particularly troublesome, given

the conservative nature of the model to begin with, and do not compromise the results of the original study in any way. Overall agreement remains very good.

Another possible problem with the implementation of the FEIS model occurs when the two waste pumping rates are considered. The modeling report indicates that the discharge rate from the vessel is 140 gpm per knot of vessel speed, up to 10 knots. Initial concentration of waste is a function of flow divided by relative velocity. This implies that the initial concentration will remain about the same, particularly since the vessel speed is taken as the relative velocity as discussed above. However, the initial concentrations reported are 0.000222 and 0.000621, for a discharge of 500 gpm and 1400 gpm, respectively. It appears that the vessel speed was not varied with discharge rate. Again, this leads to overly conservative predictions, as the initial concentration for the higher discharge rate is over-stated.

The FEIS model was developed based on a different vessel, using a different operational mode of discharge, than currently used. CH2M HILL has considered the current vessel and operational procedures. Based on our evaluation of the existing model, including the possible errors mentioned above and the changes in discharge operation, we believe a revised model for the initial dilution process (prediction of initial concentration) is appropriate. The revisions should account for both the discharge of the material directly between the two counter rotating propellers of the FV *Tasman Sea* and a more sophisticated approach to dilution in the propeller slip stream. Subsequent dilution can then be calculated following methods similar to those used previously, and using CH2M HILL's spreadsheet formulation of the initial FEIS farfield model.

Revised Model Formulation and Predictions

An independent model was developed and used to evaluate the dispersion of waste discharged from the barge. The purpose of this model is to provide an alternative to more realistically describe the fate and transport of the discharge. The primary differences between the FEIS and the CH2M HILL model approaches are the use of initial dilutions as determined based on the dynamics of the propeller slipstream and the use of characteristics of the current dumping vessel..

The new model developed by CH2M HILL consists of three parts:

- Dumping dilution - results from the initial discharge into the propeller wash and is numerically equivalent to the propeller discharge rate plus the waste discharge rate divided by the waste discharge rate

- Nearfield Dilution - results from the entrainment of sea water into the momentum jet from the propellers which contains the waste discharge

- Farfield Dilution - results from the subsequent dilution of the plume and is essentially the same model used previously.

The formulation and predictions for each of the three parts of the model are described below.

The vessel characteristics assumed for the models are based on the known vessel characteristics as described by the vessel operator and are as follows:

Number of Propellers:	2 - counter rotating (to CL from above)
Propeller Diameter:	4 feet
Propeller Spacing:	15 feet on center
RPM/Speed:	500 rpm at slow ahead (6 knots - stabilized)
	700 rpm at 8 knots
	900 rpm at 10 to 11 knots
Draft:	12 feet (propeller CL at 10 feet)
Beam:	38 feet
Discharge Pipe:	6 in diameter to CL of propeller pair

Dumping Dilution

The dumping dilution is the immediate dilution realized as the discharge pipe releases waste at the stern of the vessel between the two counter-rotating propellers. It is calculated as the propeller discharge rate (water flow through the propeller) plus the waste discharge rate divided by the waste discharge rate. The discharge rate through the propeller can be calculated using propeller theory. The most direct calculation is based on the momentum theory of propellers and a practical explanation and description , with further references, can be found in Liou and Herbich (1976). CH2M HILL project staff have used this approach to calculate induced water speeds by ferries in Puget Sound (Washington), barges on the Cohansey River (New Jersey) to evaluate subsequent induced sediment transport.

The flow rate through the propeller immediately behind the vessel (V_0) is given by:

$$V_0 = (1+b)\cdot V_A$$

where

V_A is the ship speed (knots),

and

$b = 2a = 2\cdot(1/\eta_1 - 1)$,

η_1 = ideal efficiency = $2/((1+(C_T+1)^{1/2})$.

The term C_T is the thrust loading coefficient,

$$C_T = T/(0.5\cdot\rho\cdot A_0\cdot(V_A)^2)$$

where

T = thrust developed = $K_T\cdot\rho\cdot n^2\cdot D^4/3600$

K_T = the thrust coefficient described below

ρ= density of water

A_0 = disk area of propeller

n = rpm of propeller

D = diameter of propeller

There term K_T is the thrust coefficient which is a function of the propeller-characteristic curve and is approximated as a function of the speed coefficient, J_T, as described in Liou and Herbich for a typical case as:

$$K_T = 0.48 - 0.41 \cdot J_T$$

and

$$J_T = 101.33 \cdot V_A / (n \cdot D)$$

where variables are as defined above and n is the propeller rpm.

Application of the above relationships, using the vessel characteristics provided, results in the following immediate of dumping dilutions: 398.9:1 and 365.7:1 for discharge flows of 1400 gpm and 840 gpm, respectively, and for a single propeller stream. For the dual propellers the dumping dilutions become 796.2:1 and 731.4 for the same flows. The vessel is assumed to be traveling at 10 knots and at 6 knots for discharge rates of 1400 gpm and 840 gpm, respectively. This is the reasonable range of speeds the vessel can make in the open sea. These flows correspond to winter (June 1 through November 30) time permitted disposal rates of 140 gpm/knot with a maximum of 10 knots. The summer permitted limit is at 120 gpm/knot with a maximum of 10 knots and the dilutions would be approximately 1.17 times those listed above.

Nearfield Dilutions

The use of propeller theory to determine the immediate initial dilution replaces the initial dilution (or concentration, C_0) used in the FEIS model. As described above, CH2M HILL also applied another model between the initial dilution and the farfield method based on the Brooks method. This was done to account for the rapid mixing within the propeller slip-stream. The model assumes that all of the waste discharged is entrained in the slipstream. This is considered a very good assumption, and, based on the disposal method, it is difficult to see how the situation could be otherwise.

The nearfield approach used considers conservation of momentum in a round momentum jet (the propeller slip stream). The centerline velocity, U_{CL}, and flow at any distance x from the point of discharge, Q_X, are given by:

$$U_{CL} = (1/\alpha \cdot x) \cdot [K_0/(2\pi \cdot I_2)]^{1/2}$$

and

$$Q_X = \alpha \cdot x \cdot I_1 \cdot [K_0/(2\pi \cdot I_2)]^{-1/2}$$

where

$K_0 = Q_0 \cdot V_0$ with subscript $_0$ indicating initial conditions
I_1, I_2, and α = constants

nearfield dilution at a distance x from the point of discharge is given by Q_X/Q_0. The dilution as a function of x will remain the same for various vessel speeds, since the initial flow through the propeller changes in direct response to vessel speed. The momentum theory for propellers also provides a means to calculate velocity and is given in Liou and Herbich as referenced above:

$$V(r,x) = (V_0 \cdot D_0 / x) \cdot 10^{\varepsilon}$$

where

$\varepsilon = 0.79 - 33 \cdot (r/x)^2$
r = distance in the radial direction

and on the centerline (r = 0)

$$V(x) = U_{CL} = (V_0 \cdot D_0 / x) \cdot 6.17$$

As a check the calculations for velocity were done using both equations for centerline velocity and agreement was within 0.5 percent.

Table 3.3 shows the dilution for a single propeller as a function of depth. The dilution for two propellers will be twice that for a single propeller except that the dilution will be affected because of the interference between the two jets when they merge. This will result in a smaller "entrainment area" (the surface area of the plume) exposed to "clean" (ambient as opposed to the water in the second plume) water. In addition the plumes will intercept the surface and this will also reduce the entrainment area. When these results are considered, and the geometry of a round jet is maintained, the surface area available for entrainment is reduced to about 50 percent of the area of an otherwise undisturbed double plume, or approximately the same as an undisturbed single plume, past a point about 300 feet from the point of discharge. The calculation scheme and results for determining the factor by which the surface area is affected are provided in Appendix 8.

Of course the interference of side-by-side plumes and the surface will also act to change the shape of the plume, and result in increased surface area compared to the calculations above. Other factors such as concentration gradients across the plume and the actual flow filed also act to make the use of an entrainment area approach somewhat conservative. However, to maintain a good degree of conservatism, we have assumed the dilution for both slipstreams combined, once the plumes merge, will be reduced by the entrainment ratio as calculated. Thus the corrected dilutions are as shown in Table 3.3. It is assumed that the value at 1000 feet is taken as the value for the nearfield dilution in the calculations of total dilution described below. This is a conservative (under predicts dilution) approach since there will be additional dilution in the propeller stream further than this distance.

Farfield Dilutions

As mentioned above, CH2M HILL used the previously applied farfield transport model as implemented on an Excel spreadsheet. The FEIS model is described in Appendix 8 which is Appendix B of the FEIS referenced above. The physical and mathematical basis of the model is as described in Appendix 8 and that description is not reproduced here. As discussed above, when using the same input data as used in the FEIS modeling, the results are in excellent agreement, except for those cases previously indicated. The geometry and dimensions of the current vessel are used. Initial concentration is set to unity to calculate relative dilutions (or concentrations).

The two key parameters used in this model are the vertical diffusion coefficient, K_v and the horizontal dissipation parameter, A. The results are not particularly sensitive to K_v and is, as expected moderately sensitive to variations in A. Since the time of the FEIS model there is no data that would indicate that these constants should be changed from the previous values, and the same values were used. In addition, a literature survey of recommended values

for A indicate that the value used is reasonable for open ocean applications. Fischer (1979) recommends using a value between 0.0002 and 0.001; Yearsley (1989) recommends the same range; Grace (1978) recommends 0.00015 to 0.005; and Baumgartner et al.(1993) recommend 0.0002 to 0.001. These suggested ranges are generally for application to nearshore coastal and inland waters. For open ocean water, with no effects of boundaries and significant wind and wave action, the high end of the suggested range is appropriate. Thus, the value previously used in the FEIS model (0.001) has been retained. Note that units of A as discussed above are $ft^{2/3}/sec$.

As in the case of the previous modeling, the farfield dilution is seasonally dependent based on the strength and structure of the thermocline. Farfield predictions were done for the same set of conditions as done previously:

- A range of ambient ocean current speeds of 0.2 to 1.0 knots
- A range of vessel speeds of 6 and 10 knots
- Winter conditions with no change in K_v with depth
- Summer conditions with K_v dependent on depth (only the surface layer was modeled for this case because that is a worst case condition)

The results of the farfield modeling are summarized in Table 3.4 and detailed model output is provided in Appendix 10. Table 3.4 reports the farfield dilution at distances of 2.5 and 5 nautical miles from the release area corresponding to the approximate downcurrent edge of permitted dump zone and the closest point to possible land influence. (These distances are somewhat less than actual distances to the points referenced.) Ocean currents of 0.4 knots and 0.8 knots, corresponding to minimum and maximum expected ocean currents (as discussed in the FEIS) are described for vessel speeds of 6 and 10 knots. Additional cases are provided in Appendix 10.

Summary of Model Predictions

The dilutions for the range of seasonal and operational parameters are as follows:

- Dumping dilution: The immediate dilution on dumping ranges from approximately 730:1 to 930:1 depending on discharge rate (seasonal constraint) and vessel speed, assuming a maximum permitted discharge per knot of vessel speed.

- Nearfield dilution: The dilution within the propeller slipstream, for first 1000 feet, is predicted to be about 42:1.

- Farfield Dilution: Using essentially the same model as applied in the FEIS the farfield dilution is predicted to range from approximately 11:1 to 30:1 prior to reaching the edge of the dumping zone, and 24:1 to 77:1 prior to reaching the shore line or closest reef area. The farfield dilution depends on a number of environmental and operational variables and can vary from season to season and from day to day.

The dilutions described above are developed in a multiplicative fashion where the dilution is applied to the concentrations at the beginning of the individual mixing processes. Thus the overall dilution at the edge of the dumping zone is the product of the numerical values of the three dilutions described above:

Total dilution = (dumping dilution) x (nearfield dilution) x (farfield dilution)

The preliminary results of the model predict dilutions of approximately 440,000:1 to 510,000:1 at the edge of the dumping zone. These dilutions are predicted under conservative (underpredicted dilutions) and worst case conditions. The range of dilutions, and corresponding concentrations of waste are described in more detail in the following section.

Table 3.1
Comparison of Original FEIS and CH2M HILL Reformulated Model Predicitions

Distance (n. mi.)	Winter Conditions			Summer Conditions		
	CH2MHILL Model	FEIS Model	Percent error	CH2M HILL Model	FEIS Model	Percent error
Cmax/Co for Current Speed of 0.2 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.06745			0.10016		
1.0	0.03365	0.03364	-0.03	0.05001	0.04999	-0.04
1.5	0.02044	0.02043	-0.04	0.03039	0.03038	-0.05
2.0	0.01380	0.01379	-0.07	0.02053	0.02052	-0.05
2.5	0.00997	0.00996	-0.07	0.01483	0.01482	-0.07
3.0	0.00754	0.00754	-0.06	0.01123	0.01122	-0.07
3.5	0.00591	0.00591	-0.06	0.00880	0.00880	-0.02
4.0	0.00476	0.00476	-0.04	0.00709	0.00709	0.03
Cmax/Co for Current Speed of 0.2 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.06745			0.10016		
1.0	0.03365	0.03364	-0.03	0.05001	0.05000	-0.02
1.5	0.02044	0.02043	-0.04	0.03039	0.03039	-0.01
2.0	0.01380	0.01380	0.00	0.02053	0.02052	-0.05
2.5	0.00997	0.00996	-0.07	0.01483	0.01483	-0.01
3.0	0.00754	0.00754	-0.06	0.01123	0.01123	0.02
3.5	0.00591	0.00591	-0.06	0.00880	0.00880	-0.02
4.0	0.00476	0.00476	-0.04	0.00709	0.00709	0.03
Cmax/Co for Current Speed of 0.4 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.05648			0.08393		
1.0	0.03386	0.03385	-0.02	0.05037	0.05035	-0.04
1.5	0.02305	0.02305	-0.02	0.03431	0.03430	-0.03
2.0	0.01685	0.01684	-0.04	0.02508	0.02507	-0.03
2.5	0.01291	0.01290	-0.04	0.01921	0.01920	-0.06
3.0	0.01023	0.01022	-0.08	0.01523	0.01522	-0.04
3.5	0.00832	0.00831	-0.10	0.01238	0.01238	-0.03
4.0	0.00690	0.00690	-0.06	0.01028	0.01028	0.00
Cmax/Co for Current Speed of 0.4 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.05648			0.08393		
1.0	0.03386	0.03385	-0.02	0.05037	0.05036	-0.02
1.5	0.02305	0.02305	-0.02	0.03431	0.03430	-0.03
2.0	0.01685	0.01684	-0.04	0.02508	0.02507	-0.03
2.5	0.01291	0.01290	-0.04	0.01921	0.01921	-0.01
3.0	0.01023	0.01022	-0.08	0.01523	0.01522	-0.04
3.5	0.00832	0.00832	0.02	0.01238	0.01238	-0.03
4.0	0.00690	0.00690	-0.06	0.01028	0.01028	0.00
Cmax/Co for Current Speed of 0.8 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.04161			0.06190		
1.0	0.02828	0.02827	-0.02	0.04209	0.04207	-0.04
1.5	0.02139	0.02138	-0.04	0.03184	0.03183	-0.04
2.0	0.01694	0.01693	-0.06	0.02522	0.02521	-0.05
2.5	0.01382	0.01382	-0.02	0.02058	0.02058	-0.01
3.0	0.01153	0.01153	-0.02	0.01717	0.01717	-0.01
3.5	0.00979	0.00979	0.01	0.01458	0.01457	-0.04
4.0	0.00843	0.00842	-0.08	0.01255	0.01254	-0.06
Cmax/Co for Current Speed of 0.8 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.04161			0.06190		
1.0	0.02828	0.02827	-0.02	0.04209	0.04209	0.01
1.5	0.02139	0.02138	-0.04	0.03184	0.03184	-0.01
2.0	0.01694	0.01694	0.00	0.02522	0.02522	-0.01
2.5	0.01382	0.01382	-0.02	0.02058	0.02058	-0.01
3.0	0.01153	0.01153	-0.02	0.01717	0.01717	-0.01
3.5	0.00979	0.00979	0.01	0.01458	0.01457	-0.04
4.0	0.00843	0.00842	-0.08	0.01255	0.01254	-0.06

Table 3.2
Comparison of Original FEIS and CH2M HILL Reformulated Model Predicitions

Distance (n. mi.)	Summer Deep			Summer Mid-Depth		
	CH2MHILL Model	FEIS Model	Percent error	CH2M HILL Model	FEIS Model	Percent error
Cmax/Co for Current Speed of 0.2 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.10348			0.10016		
1.0	0.05168	0.05423	4.70	0.05001	0.04999	-0.04
1.5	0.03141	0.03242	3.11	0.03039	0.03038	-0.05
2.0	0.02122	0.02172	2.31	0.02053	0.02052	-0.05
2.5	0.01533	0.01562	1.87	0.01483	0.01482	-0.07
3.0	0.01161	0.01179	1.57	0.01123	0.01133	0.90
3.5	0.00910	0.00922	1.33	0.00880	0.00947	7.06
4.0	0.00733	0.00741	1.13	0.00709	0.00805	11.95
Cmax/Co for Current Speed of 0.2 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.10348			0.10016		
1.0	0.05168	0.05423	4.70	0.05001	0.05000	-0.02
1.5	0.03141	0.03242	3.11	0.03039	0.03039	-0.01
2.0	0.02122	0.02172	2.31	0.02053	0.02052	-0.05
2.5	0.01533	0.01562	1.87	0.01483	0.01483	-0.01
3.0	0.01161	0.01179	1.57	0.01123	0.01133	0.90
3.5	0.00910	0.00922	1.33	0.00880	0.00947	7.06
4.0	0.00733	0.00741	1.13	0.00709	0.00805	11.95
Cmax/Co for Current Speed of 0.4 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.08674			0.08393		
1.0	0.05206	0.05794	10.15	0.05037	0.05035	-0.04
1.5	0.03546	0.03798	6.63	0.03431	0.03430	-0.03
2.0	0.02592	0.02726	4.92	0.02508	0.02507	-0.03
2.5	0.01986	0.02067	3.93	0.01921	0.01920	-0.06
3.0	0.01574	0.01627	3.27	0.01523	0.01522	-0.04
3.5	0.01280	0.01317	2.80	0.01238	0.01238	-0.03
4.0	0.01063	0.01089	2.43	0.01028	0.01028	0.00
Cmax/Co for Current Speed of 0.4 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.08674			0.08393		
1.0	0.05206	0.05795	10.16	0.05037	0.05036	-0.02
1.5	0.03546	0.03799	6.66	0.03431	0.03430	-0.03
2.0	0.02592	0.02727	4.95	0.02508	0.02507	-0.03
2.5	0.01986	0.02067	3.93	0.01921	0.01921	-0.01
3.0	0.01574	0.01627	3.27	0.01523	0.01522	-0.04
3.5	0.01280	0.01317	2.80	0.01238	0.01238	-0.03
4.0	0.01063	0.01089	2.43	0.01028	0.01028	0.00
Cmax/Co for Current Speed of 0.8 knots and Discharge of 500gpm						
0.0	1.00000			1.00000		
0.5	0.06398			0.06190		
1.0	0.04350	0.04207	-3.40	0.04209	0.04207	-0.04
1.5	0.03291	0.03532	6.81	0.03184	0.03183	-0.04
2.0	0.02607	0.02859	8.81	0.02522	0.02521	-0.05
2.5	0.02127	0.02287	6.98	0.02058	0.02058	-0.01
3.0	0.01775	0.01883	5.74	0.01717	0.01717	-0.01
3.5	0.01507	0.01585	4.94	0.01458	0.01457	-0.04
4.0	0.01297	0.01355	4.28	0.01255	0.01254	-0.06
Cmax/Co for Current Speed of 0.8 knots and Discharge of 1400gpm						
0.0	1.00000			1.00000		
0.5	0.06398			0.06190		
1.0	0.04350	0.04208	-3.38	0.04209	0.04208	-0.02
1.5	0.03291	0.03533	6.84	0.03184	0.03184	-0.01
2.0	0.02607	0.02859	8.81	0.02522	0.02522	-0.01
2.5	0.02127	0.02287	6.98	0.02058	0.02058	-0.01
3.0	0.01775	0.01884	5.79	0.01717	0.01717	-0.01
3.5	0.01507	0.01585	4.94	0.01458	0.01457	-0.04
4.0	0.01297	0.01355	4.28	0.01255	0.01254	-0.06

Table 3.3
Nearfield Dilution Calculations

Distance (feet)	Centerline Plume Velocity (ft/sec)		Flow (ft^3/sec)	Dilution	Entrainment Coefficient	Adjusted Dilution
	Momentum	Propeller				
25	53.49	53.74	1394	2.04	1.00	2.04
100	13.37	13.43	5576	8.15	0.79	6.44
200	6.69	6.72	11151	16.29	0.58	9.45
300	4.46	4.48	16727	24.44	0.55	13.44
400	3.34	3.36	22302	32.58	0.53	17.27
500	2.67	2.69	27878	40.73	0.53	21.59
600	2.23	2.24	33453	48.88	0.52	25.42
700	1.91	1.92	39029	57.02	0.52	29.65
800	1.67	1.68	44604	65.17	0.52	33.89
900	1.49	1.49	50180	73.31	0.51	37.39
1000	1.34	1.34	55755	81.46	0.51	41.54

Table 3.4

Farfield Dilution Model Results

Ocean Current (knots)	Vessel Speed (knots)	Dilution	
		Winter Conditions	Summer Conditions
Dilution at 2.5 Nautical Miles Down Current			
0.4	6	29.6	20.0
	10	17.9	12.1
0.8	6	76.6	18.6
	10	16.6	11.2
Dilution at 5 Nautical Miles Down Current			
0.4	6	27.6	51.5
	10	46.6	31.5
0.8	6	59.1	39.7
	10	35.5	23.9

4. Conclusions and Recommendations

This section presents the overall conclusions drawn from the model predictions, the model limitations, and recommendations based on the results of the study.

Conclusions

Table 4.1 shows the prediction of total dilution and final concentration prior to the point where the plume reaches the edge of the dumping zone (taken as 2.5 nautical miles down current). In the table, C/C_0 is the ratio of final to initial concentration and can be applied to calculate the concentration of any known constituent in the waste. The final concentration is also given in terms of an approximate value for the whole waste in mg/l, assuming the waste is about the density of water. At the edge of the dump zone the dilution of the waste is about 0.00025 percent of a sample in the center of the plume. Reference to Table 3.1 shows that the lowest LC50 of all bioassays conducted was 0.12 percent. Therefore, the concentration at the edge of the permitted dumping zone is 0.0021·LC50.

Table 4.2 shows the same information described above for the plume prior to reaching the shoreline (taken as 5 nautical miles down current). The model was formulated and implemented in a conservative fashion and the dilutions are expected to be underpredicted (concentrations over predicted).

Limitations

Most numerical models of the type used here contain coefficients (e.g. friction factors, diffusion coefficients) that are often study site specific. Although there are generally accepted values for these coefficients, the range observed in nature is high and the models can be somewhat sensitive to the values selected. The process of calibration and verification generally uses measured values of forcing functions and responses to determine the appropriate coefficients for the model configuration at the study site. Typically a set of field data is used to determine the correct values to use for the coefficients. However, this was beyond the scope of the present study and there is little or no available and appropriate data for this task. In this case the model sensitivity determination, the use and justification of reasonable values from the literature and similar studies, and the incorporation of a prudent level of conservatism is required and was accomplished.

Recommendations

CH2M HILL project staff, on the basis of the results of the study, have no recommendations for additional studies of this type.

Table 4.1
Predicted Dilution and Concentration at the Down Current Edge of the Ocean Dumping Zone

Season	Ocean Current (knots)	Vessel Speed (knots)	Loading (gpm)	Dumping Dilution	Nearfield Dilution	Farfield Dilution	Total Dilution	Final Concentration C/Co	Final Concentration (mg/l)
Winter	0.4	6	840	796.2	41.5	29.6	978,052	0.000001022	0.001022
Winter	0.4	10	1400	731.4	41.5	17.9	543,320	0.000001841	0.001841
Winter	0.8	6	720	796.2	41.5	76.6	2,531,040	0.000000395	0.000395
Winter	0.8	10	1200	731.4	41.5	16.6	503,861	0.000001985	0.001985
Summer	0.4	6	840	931.6	41.5	20.0	773,190	0.000001293	0.001293
Summer	0.4	10	1400	855.7	41.5	12.1	429,709	0.000002327	0.002327
Summer	0.8	6	720	931.6	41.5	18.6	719,067	0.000001391	0.001391
Summer	0.8	10	1200	855.7	41.5	11.2	397,747	0.000002514	0.002514

Table 4.2
Predicted Dilution and Concentration near the Closest Reefline or Shoreline

Season	Ocean Current (knots)	Vessel Speed (knots)	Loading (gpm)	Dumping Dilution	Nearfield Dilution	Farfield Dilution	Total Dilution	Final Concentration C/Co	Final Concentration (mg/l)
Winter	0.4	6	840	796.2	41.5	27.6	911,967	0.000001097	0.001097
Winter	0.4	10	1400	731.4	41.5	46.6	1,414,454	0.000000707	0.000707
Winter	0.8	6	720	796.2	41.5	59.1	1,952,800	0.000000512	0.000512
Winter	0.8	10	1200	731.4	41.5	35.5	1,077,535	0.000000928	0.000928
Summer	0.4	6	840	931.6	41.5	51.5	1,990,964	0.000000502	0.000502
Summer	0.4	10	1400	855.7	41.5	31.1	1,104,458	0.000000905	0.000905
Summer	0.8	6	720	931.6	41.5	39.7	1,534,782	0.000000652	0.000652
Summer	0.8	10	1200	855.7	41.5	23.9	848,764	0.000001178	0.001178

5. References

American Society for Testing and Materials, ASTM. 1992. Standard Practice for Conducting Static Acute Toxicity Tests with Embryos/Larvae of Four Species of Saltwater Bivalve Molluscs. Designation E724-92. Annual Book of Standards, Vol:11.04. ASTM, Philadelphia, PA.

Baumgartner, D.J., W.E. Frick, and P.J.W. Roberts, 1993. Dilution Modeling for Effluent Discharges (Second Edition). Office of Research and Development, U.S. Environmental Protection Agency, EPA/600/R-93/139. July 1993.

Brooks, N.H., 1960. "Diffusion of Sewage Effluent in an Ocean Current," Proceedings of the First Conference on Waste Disposal in Marine Environment, Pergamon Press, NY.

CH2M HILL, 1995a. Bioassay Testing of High Strength Waste: StarKist Samoa, Inc. and VCS Samoa Packing. Memorandum from Steve Costa/CH2M HILL to Pat Young/USEPA, 26 January 1995.

CH2M HILL, 1995b. Bioassay Testing of High Strength Waste: StarKist Samoa, Inc. and VCS Samoa Packing (23 June 1995 Sampling). Memorandum from Steve Costa/CH2M HILL to Pat Young/USEPA, 7 August 1995.

CH2M HILL, 1995c. Summary of Ocean Dumping Modeling Results: StarKist Samoa, Inc. and VCS Samoa Packing. Memorandum from Steve Costa/CH2M HILL to Pat Young/USEPA, 7 August 1995.

CH2M HILL, 1994. Bioassay Testing of StarKist Samoa, Inc. and VCS Samoa Packing High Strength Waste. Memorandum form Steve Costa/CH2M HILL to Pat Young/USEPA, 1 July 1994.

CH2M HILL, 1993. Draft Study Plan for Joint Cannery Ocean Dumping Studies in American Samoa. Prepared for StarKist Samoa and VCS Samoa Packing, 11 November 1993).

Fischer, H.B. et al., 1979. Mixing in Inland and Coastal Waters. Academic Press, New York.

Grace, R.A., 1978. Marine Outfall Systems: Planning, Design, and Construction. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Liou, Y.-C. and J.B. Herbich, 1976. Sediment Movement Induced by Ships in Restricted Waterways. Texas A&M University, Sea Grant Report TAMU-SG-76-209. August, 1976.

SOS Environmental, Inc. and Environmental & Ocean Technology, Inc., 1990. Mathematical/Computer Modeling for Fish Waste Disposal at an Ocean Disposal Site off Tutuila Island, American Samoa. March 1990.

Soule, D.F. and M. Oguri, 1983. A Report on Ocean Disposal of Fish Processing Wastes off Pago Pago, American Samoa. Prepared for EPA Region 9 and NOAA for StarKist Foods and Ralston Purina. June 1983.

United States Environmental Protection Agency. 1991. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. Fourth Edition. EPA/600/4-90/027. September 1991. 293 pp.

United States Environmental Protection Agency, United States Army Corps of Engineers. 1991. Evaluation of Dredged Material Proposed for Ocean Disposal: Testing Manual. EPA-503/8-91/001. February, 1991.

U.S. Environmental Protection Agency, Region 9, 1989. Final Environmental Impact Statement for the Designation of an Ocean Disposal Site off Tutuila Island, American Samoa for Fish Processing Wastes. San Francisco, CA, 3 February 1989.

Yearsley, J.R., 1989. "Diffusion in Near-shore and Riverine Environments," EPA 910/9-87-168. EPA Region 10, Seattle, Washington.

Appendix 1
Special Condition 3.3.5 of
Ocean Dumping Permits

3.3.5. Eighteen months from the effective date of this special permit, the permittee shall submit a report to EPA and ASEPA on the results of suspended phase bioassay tests and reevaluation of the model used to predict the concentrations of fish processing wastes disposed at the designated site. The suspended phase bioassays shall be conducted using at least one species from each of the following three groups: Group 1 = *Mytilus* sp. (mussel), *Crassostrea* sp. (oyster), *Acartia tonsa* (copepod), or *Trypneustes* sp. (sea urchin) larvae; Group 2 = *Holmesimysis costata* (mysid shrimp) or *Penaeus vannamei* (white shrimp); and Group 3 = *Citharicthys stigmaeus* (speckled sanddab) or *Coryphaena hippurus* (dolphinfish) juveniles.

Appropriate suspended phase bioassay protocols, either protocols approved by EPA or protocols published by the American Society for Testing and Materials (ASTM), shall be followed. Suspended particulate phase bioassays shall be run using the following fish processing waste concentrations: 100%, 75%, 50%, 25%, 10%, 5%, and a control (0%). A minimum of five replicates are required per dilution concentration. Concurrent reference toxicant tests shall be conducted when the suspended phase bioassays are run.

A sampling and testing plan shall be submitted to EPA Region IX and ASEPA by October 1, 1993 for approval before the bioassay tests are conducted. Samples for the suspended particulate phase bioassays shall be composited from the permittee's onshore storage tanks. Three samples shall be taken from the onshore storage tank transfer line at 10 minute intervals. These samples shall be composited to produce one sample for analysis. The permittee's samples shall not be combined with fish processing waste from any other permittee. The permittee shall take samples on the following dates: November 30, 1993, February 28, 1994 and May 31, 1994. Samples shall be collected and shipped to the testing laboratory according to EPA-approved methods to

ensure that the samples do not change before the bioassay tests begin. All suspended particulate phase bioassays shall be started within 10 days of sampling.

The testing plan submitted by October 1, 1993 should also include a proposal to reevaluate the disposal site model using results obtained from the new series of suspended phase bioassays. These bioassays are being required to confirm the toxicity of the fish processing wastes and to reevaluate the disposal operations based on the use of a different disposal vessel.

The bioassay and computer model confirmation report shall contain the following information:

3.3.5.1. INTRODUCTION AND PROJECT DESCRIPTION

The project description should include the following information about fish processing waste toxicity, previous bioassay test results, previous modelling at the ocean disposal site, and the design of the new bioassay tests.

3.3.5.2. MATERIALS AND METHODS

Fish processing waste sampling and sample handling procedures should be described or referenced.

References for laboratory protocols for suspended phase bioassay tests.

1) EPA-approved methods and references.

2) Test species used in each test, the supplier or collection site for each test species, and QA/QC procedures for maintaining the test species.

3) Source of seawater used in reference, control and bioassay tests.

4) Data and statistical analysis procedures.

5) Limiting Permissible Concentration (LPC) calculations.

6) Description of model selected to evaluate dispersal of fish processing wastes at the ocean disposal site. Use of this model shall be approved by EPA Region IX and ASEPA before it is used by the permittee to evaluate the fish processing waste disposal plume.

3.3.5.3. DESCRIPTION OF SAMPLING PROCEDURES

QA/QC procedures and actual sampling procedures used during fish processing waste stream sampling and handling of the samples.

3.3.5.4. FINAL RESULTS, ANALYSIS OF DATA AND DISCUSSION

1) Complete bioassay data tables and summary bioassay tables shall be furnished in the report. All data tables should be typed or produced as a computer printout.

2) The permittee shall analyze the bioassay data and calculate the LPC of the material as defined at 40 C.F.R. § 227.27(a-b).

3) The permittee shall use the LPC in the approved plume model to determine the concentration of fish processing wastes disposed at the designated ocean disposal site which complies with EPA's Ocean Dumping Criteria defined at 40 C.F.R. Parts 227 and 228.

3.3.5.5. REFERENCES

This list should include all references used in the field sampling program, laboratory protocols, LPC calculations, modelling analyses, and historical data used to evaluate the fish processing waste disposal operations at the designated ocean disposal site.

3.3.5.6. DETAILED QA/QC PLANS AND INFORMATION

The following topics should be addressed in the QA Plan:

1) QA objectives.

2) Organization, responsibilities and personnel qualifications, internal quality control checks.

3) Sampling and analytical procedures.

4) Equipment calibration and maintenance.

5) Sample custody and tracking.

6) documentation, data reduction, and reporting.

7) Data validation.

8) Performance and systems audits.

9) Corrective action.

10) Reports.

Appendix 2
Study Plan (Draft and Incorporated EPA Comments)

DRAFT STUDY PLAN

FOR

JOINT CANNERY OCEAN DUMPING STUDIES

IN

AMERICAN SAMOA

Prepared for

StarKist Samoa
(Permit OD 93-01 Special)

and

VCS Samoa Packing
(Permit OD 93-02 Special)

Prepared by

CH2M HILL

11 November 1993

STUDY PLAN
FOR
JOINT CANNERY OCEAN DUMPING STUDIES
IN
AMERICAN SAMOA

Special ocean dumping permits have been issued to StarKist Samoa, Inc. and VCS Samoa Packing, Inc. because the Regional Administrator of EPA Region IX has determined that disposal of fish processing wastes off American Samoa meets EPA's ocean dumping criteria at 40 CFR Parts 227 and 228. Special condition 3.3.5 of both permits requires bioassay testing of the waste from each cannery and a re-evaluation of the model previously used to predict concentrations of fish processing wastes disposed of at the designated site. A copy of this special condition is provided in Appendix 1 of the study plan.

The special permit condition addresses two distinct efforts: bioassay testing and model re-evaluation. Although the results of the bioassay testing will be used in the final steps of the model re-evaluation, the two parts of the study are quite different and are best described independently. Therefore, this study plan is presented in two parts:

- Part I: Plan of Study for Bioassay Toxicity Tests
- Part II: Plan of Study for Modeling Re-evaluation

The two portions of the study will be conducted independently except as noted above. References are provided separately for part of the study plan. Additional information is provided in Appendices.

Part I

PLAN OF STUDY FOR BIOASSAY TOXICITY TESTS

INTRODUCTION

Under special conditions 3.3.5 of the Ocean Disposal Dumping Permits, StarKist Samoa and VCS Samoa Packing are required to conduct and submit the results of toxicity tests on fish processing wastes generated at the permittees' American Samoa packing plants. The toxicity tests are to be initiated within 10 days following sampling on November 30, 1993, February 28, 1994, and May 31, 1994. The wastes to be tested include DAF sludge and other high strength waste streams that are barged to sea for disposal at the permitted dump site. This part of the study plan describes the methods proposed to conduct the bioassay tests. The results of the tests will also be incorporated into the modeling re-evaluation described below in Part II of the study plan.

General guidance for these tests is provided by USEPA (1991), ASTM (1992), and the EPA/COE "Green Book" (1991). Specific guidance for performing biological-effects tests for Ocean Disposal permits are outlined in Part III, Section 11 of the Green Book; *Evaluation of Dredged Material Proposed for Ocean Disposal: Testing Manual* (EPA and COE, 1991). However, the fish processing wastes to be disposed under this permits are not similar to solid dredged materials. The high strength waste materials are mostly liquid phase wastes which are positively to neutrally buoyant with a small fraction of negatively buoyant solid particles. This waste is not expected to behave in a fashion typical of solid, generally negatively buoyant, dredge spoil material when disposed of by dumping at sea. Therefore, the physical and chemical nature of the wastes requires modifications to the suspended bioassay tests as outlined in the Green Book.

The following Methods sections include the specific modifications required to properly evaluate the toxicity of the tuna cannery high strength wastes. A description of the proposed reporting schedule and format for the bioassay test results is provided in the Reports section.

SAMPLING METHODS

Sample Composition

High strength waste samples will be collected at each cannery from the existing sampling ports in the storage tank transfer lines. Three samples will be taken at 10 minute intervals while waste is being transferred from the storage tanks to the barge. Samples for the

bioassay tests will be composited from the three discrete samples. Waste from each cannery will be collected and shipped separately and shall not be combined.

Sampling Times

Sampling will be conducted on the following days, if possible:

- Tuesday, November 30, 1993
- Monday, February 28, 1994
- Tuesday, May 31, 1994

If a cannery is shut down, or material is not being transferred to the barge on that day, sampling will be done at the first available time.

Sample Shipping and Handling

EPA approved chain-of custody, sample shipping and handling, and record keeping will be conducted to preserve and monitor the integrity of the samples used for the required bioassays. Samples will be cooled at the canneries after collection and then packed in ice for shipment. The permit requires tests will be initiated within 10 days of sample collection. There are significant and well recognized problems with shipment of material from American Samoa. Every reasonable effort will be made to meed the required 10-day maximum holding time. If the holding times are exceeded for some reason, EPA Region IX will be contacted to determine if the tests should be initiated or if new samples should be collected and shipped.

TEST METHODS

Selected Species

The permit condition requires testing of three species selected from three groups listed in section 3.3.5 of the permit. We propose tests be conducted with the pacific mysid shrimp (*Holmesimysis costata*) juveniles, pacific sanddab (*Citharicthys stigmaeus*) juveniles, and purple sea urchin (*Strongylocentrotus purpuratus*) larvae. These species and life stages were chosen because they represent sensitive crustacean, fish, and zooplankton components of the marine community, tolerate laboratory conditions, and can be readily tested as young life-stages. These species are also routinely used in conducting bioassays for the ocean disposal

permit program. Of great importance are the practicality and year-round availability of the appropriate life-stages of all three of the above species.

The shrimp and fish species were selected from the lists (Group 2 and Group 3, respectively) specified in the permit special condition. The sea urchin species (*Strongylocentrotus purpuratus*) was not listed in the permit (Group 1). We have recommended a different species because it is important that the same species and life-stages be used for each test series conducted. Three test series of bioassays will be conducted over approximately 9 months. The rationale for recommending a different species is as follows:

- The mollusc species listed in Group 1 (*Mytilus* sp. and *Crassostrea* sp.) and the copepod (*Acartia tonsa)* are potentially difficult to obtain at the appropriate life stage at all of the times specified in the permit condition.

- Therefore, sea urchin larvae, also listed in Group 1, are proposed for these tests instead of mollusc or copepod because of their availability at all times of the year.

- However, the sea urchin specifically listed (*Trypneustes* sp.) is not readily available and may be difficult to obtain, particularly at the specific times as required in the permit and an alternate sea urchin species (*Strongylocentrotus purpuratus*) is recommended.

With a limited number of opportunities to evaluate the toxicity of the material to be disposed, it is important to compare the results of bioassay tests using the same species and life-stages.

If necessary, *Mytilus* sp. (mussels) will be used as a backup species to the sea urchin and white shrimp (*Paneaus vannamai*) will be used as a back-up test species for the mysid shrimp should the primary test species be unavailable at the time of the bioassays. All reasonable efforts will be made to consistently use the primary test species.

Acclimation and Holding

All test organisms will be brought into the laboratory and gently acclimated to test conditions and control water (dilution water) for a minimum of 24 hours prior to test initiation. Salinity, temperature, and dissolved oxygen conditions during test organism holding and acclimation will be monitored to ensure proper acclimation is obtained prior to starting the bioassay tests.

Sample Preparation

Properly refrigerated wastewater samples will brought up to test temperature prior to further test solution preparation. If the salinity of the waste solution is greater than 2 grams per liter less than that of the disposal site receiving water, salinity of the test waste solution will be adjusted with anhydrous sea salts up to the receiving water salinity. Time will be allowed for waste solution pH and salinity equilibration prior to bioassay initiation. Similarly, test control water will be adjusted to appropriate test salinity prior to test initiation.

Initial dissolved oxygen demand (IDOD) has been determined to be a problem with cannery effluent and high strength waste streams. Preliminary IDOD measurements were done at the canneries in October of 1993. The results are given in Appendix 2 of the study plan. IDOD determinations will be conducted and recorded for the samples prior to the start of the bioassays. The results of these IDOD measurements will be used to determine sample dissolved oxygen (DO) conditions and aeration procedures required for the bioassays.

Experimental Conditions

Serial dilutions using filtered natural seawater obtained from the Bodega Bay Marine Laboratory, California will be prepared by volumetric addition of diluent and high strength waste effluents from each cannery. Glass graduated cylinders and other non-contaminating labware will be used to prepare the test solutions. The permit condition requires dilutions of 100, 75, 50, 25, 10, and 5% waste concentrations, as well as a control. Based on previous bioassay results for both the high strength wastes and the joint cannery effluent discharged through the outfall, we recommend that the dilutions used be concentrations of 50, 25, 10, 5, 2.5, 1.25, 0.62, and 0.31 % waste. Control water consisting of diluent water only will also be tested. Five replicate test vessels will be prepared for each test solution and control.

Test vessels will be maintained in controlled temperature incubators or water baths and allowed to acclimate to test conditions prior to the test initiation. Temperature, salinity, pH, ammonia and DO will be measured prior to test organism assignment into the test vessels. If DO concentrations are less than 40-percent of saturation or less than 4 mg/liter in any test solution or control, aeration will be initiated sufficient to maintain adequate DO levels in all test vessels and in all test concentrations (and controls) to maintain DO concentrations at a levels sufficient to support the organisms. Test photoperiod will be controlled by automatic timers to ensure adequate light for the bioassays.

Test temperatures for the fish, crustacean, and sea urchin bioassays will be 15, 15 and 18 degrees celsius respectively. Salinity for these tests will be that of the receiving water at the disposal site. Test organisms will be randomly assigned into the test vessels. Test vessels will be covered with loose fitting glass or non-contaminating covers and placed into the temperature controlled incubators.

The bioassays will be conducted for 96 hours (4 days). Daily observations to enumerate live fish and mysids and to monitor water quality parameters will be conducted throughout the bioassays. Equal volumes of food will be added to only the mysids to reduce cannibalization of this species within the test vessels.

The effect measured in the fish and mysid bioassays is mortality as defined as: no observed movement exhibited by the test organism after gentle swirling of the test container or probing. The test endpoint for the sea urchin larvae bioassay is mortality and/or larval abnormality as compared to the control organisms.

QUALITY CONTROL AND QUALITY ASSURANCE

The quality assurance objective is to characterize the potential toxicity of each of the canneries high strength waste to marine organisms by collecting bioassay test data of known and acceptable quality. The qualifications of the laboratory and personnel conducting the tests is provided in Appendix 3. The procedures described in the Test Methods section above describe the QA/QC procedures for sampling, analytical procedures, equipment calibration, sample custody, and data reduction and analysis.

Mortality in the controls of less than 10-percent in the fish and crustacean tests and 30-percent in the sea urchin tests after 96 hours will indicate successful tests. If these criteria are not met then EPA will be consulted to determine whether additional tests should be considered. Concurrent reference toxicant tests with the fish and mysid test species will be conducted using sodium chloride and reference toxicant tests with the sea urchin will use copper sulfate solutions with test concentrations bracketing the known acute toxic concentration (LC50) for each species tested. These tests will be conducted for a 24 hour duration. If the concurrent reference toxicant test LC50 falls within ± 2 standard deviations of the testing laboratory's cumulative sum LC50 for that species the tests will be considered acceptable.

DATA ANALYSIS AND REPORTING

Test data analysis and calculations

Acute mortality and/or larval abnormality data will be used to calculate an acute median lethal (LC50) or effect (EC50) concentration. A computer program (TOXDAT) will facilitate the calculation of the 96 hour LC50 (or EC50 for the zooplankton tests) by either: Probit, Spearman-Karber, or the Trimmed Spearmean-Karber Methods. The analysis used will depend on the distribution of the mortality data obtained from these toxicity tests. These LC50 or EC50 values will then be used to calculate Limiting Permissible Concentrations (LPC's).

Reports

A report of the results of the bioassay tests will be prepared following each of the tests. The report format will be as described in the permit conditions (Sections 3.3.5.1 through 3.3.5.5). Specific information including bioassay materials and methods, sampling procedures, results, data analysis, and discussion will be included in the report. General guidance for the bioassay reports will be that of EPA (1991).

REFERENCES

American Society for Testing and Materials, ASTM. 1992. Standard Practice for Conducting Static Acute Toxicity Tests with Embryos/Larvae of Four Species of Saltwater Bivalve Molluscs. Designation E724-92. Annual Book of Standards, Vol:11.04. ASTM, Philadelphia, PA.

United States Environmental Protection Agency. 1991. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. Fourth Edition. EPA/600/4-90/027. September 1991. 293 pp.

United States Environmental Protection Agency, United States Army Corps of Engineers. 1991. Evaluation of Dredged Material Proposed for Ocean Disposal: Testing Manual. EPA-503/8-91/001. February, 1991.

Part II

PLAN OF STUDY FOR MODELING RE-EVALUATION

INTRODUCTION

Permit condition 3.3.5 of the Ocean Disposal Dumping Permits for StarKist Samoa and VCS Samoa Packing requires that the bioassay results be used re-evaluate the previous model predictions of dispersion of the plume created by dumping fish processing wastes at sea. The previous predictions are presented in the FEIS (EPA, 1989) and in a supplementary study (SOS, 1990). A field study of the fate of the wastes is described by Soule and Oguri (1983). A description of the previous model and the details of the past modeling results are found in Appendix B of the FEIS.

We propose to conduct the model re-evaluation in three phases:

[1] The existing model formulation, as described in the 1989 FEIS (Appendix B) will be used "as is" with model predictions evaluated using the new bioassay test results. Any differences in conclusions between earlier work and the reevaluation will be presented and discussed.

[2] The input data and assumptions used in the model will be examined and evaluated. Sensitivity studies will be done for critical parameters, including assumed values for diffusion coefficients, initial dilution, and ambient conditions. The appropriateness and applicability of previously assumed values will be discussed.

[3] A different, more sophisticated model(s), and/or modifications to the previous model, using appropriate assumptions, will be applied as an independent check of the previous model predications. The model selection will be based on the results of step [2] above. The objectives of the re-evaluation with a different model is to account for changes in vessel characteristics and operational methods and to develop a more representative model.

The previous model, based on an approach originally developed by Norman Brooks, is typically very conservative in similar applications. Other assumptions in the model are also conservative. The use of a different or modified model will allow an evaluation of the degree of conservatism being applied. The initial dilution assumptions will also be examined. The propeller stream of the vessel will be modeled, using an established model developed at Texas A&M and modified by CH2M HILL, to assess the actual degree of the initial mixing.

Conclusions and recommendations will be presented based on the independent assessment. The three phases of the model re-evaluation are described below.

MODELING METHODS

Re-evaluation of Previous Model Predictions

The results of the previous model are presented in terms of dilution (or concentration) of fish processing waste versus distance from the initial dump site. Based on the results of the bioassay tests, the distance from the dump site where the effluent is diluted to the limiting permissible concentration (LPC) level can be determined.

The previous model provided results parametricly with assumed ocean current speed, pumping rate, settling velocity, and other variables. The re-evaluation will examine the range of ambient receiving water conditions, pumping rates, and effluent characteristics for the new bioassay results to determine worst case conditions.

Appropriate changes in model input parameters, such as vessel beam, vessel speed, or pumping rate, will be incorporated but the model formulation will remain as originally developed. A verification run using identical input for a previous model run will be done to confirm the same formulation is being used. A discussion of any differences between previous predictions and those for the new bioassay test results and compliance with permit conditions will be developed from the results of this phase of the model re-evaluation.

Re-evaluation of Model Assumptions and Input

The model assumptions and input can be considered in three categories:

- Model formulation assumptions: assumptions involved in the basic formulation of the model involving the fundamental physics and mathematics used

- Model development assumptions and input: the assumptions and methodology used to chose the magnitudes of the variables describing the important physical processes

- Model execution assumptions and input: the values used for the description of ambient conditions and characteristics of the waste material.

Each of these categories of model assumptions and input will be examined and re-evaluated. Each of the categories of assumptions and input is discussed in more detail below. In addition to the direct re-evaluation of the model assumptions and inputs, the sensitivity of the model will to important variables will be assessed. The results of the model predictions, and the conclusions drawn from the previous model results (for previous bioassay tests and the new bioassay tests) will be examined and discussed in terms of model assumptions and inputs. Evaluations of the degree of conservatism in the previous model formulation and execution will be presented.

Model Formulation Assumptions. The previous model formulation was based on the approach presented by Brooks (1960), and is essentially the same basic model as CDIFF (Yearsley, 1989). The formulation developed by Brooks calculates the lateral diffusion of a discharge plume as it is advected in the longitudinal direction and does not account for longitudinal dispersion.

As initially developed by Brooks, the approach does not account for vertical diffusion, does not provide for the settlement of negatively buoyant constituents in the plume, and does not account for the dispersion of a positively buoyant plume or positively buoyant components of the discharged material. In addition the model, as implemented in the FEIS, assumes a line source of constant source strength and does not simulate the discharge from a vessel traveling in an arbitrary path for a finite length of time.

The FEIS model provides for a settling velocity by redefining the longitudinal coordinate at a downward angle defined by the relationship between the longitudinal current speed and assumed vertical settling velocity such that:

$$x' = x \bullet \cos(\theta)$$

where

$\theta = \tan(u/w_s)$

u = ambient horizontal, longitudinal velocity

w_s = settling velocity

The FEIS model also accounts for vertical diffusion by applying a concentration reduction factor based on a Fickian diffusion coefficient (K_v). This factor is applied to the calculated centerline concentration (C_{max}) by

$$C_{max} \bullet \{(H/4) \bullet (2K_v t + H^2/16)^{-0.5}\}$$

to calculate an adjusted value of C_{max} accounting for vertical diffusion, where H is the initial vertical plume dimension and t is travel time along the plume trajectory.

Each of the basic assumptions of the model and the modifications made for the FEIS model, as discussed above, will be evaluated. In particular the assumption of a continuous line source will be examined and the implications of applying the model to a source discharge of a finite time interval will be evaluated.

Model Development Assumptions. The values chosen to describe the physical processes will be evaluated. These values include the lateral and vertical diffusion coefficients. In addition the model formulation assumptions include the spatial and temporal scales over which the model predictions are used.

Model Execution Input Variables. The previous model input variables, not discussed in the model assumptions section above, include ambient current speed, initial dilution, settling velocity, and initial plume dimensions. An evaluation of the methodology and assumptions used to select the values used for these variables will be done. Changes in the values due to changes in vessel and operational procedures will be addressed. This evaluation will be extended by the sensitivity study descried below.

Model Sensitivity. The sensitivity of the model to each of input variables and to assumptions about the parameters used to describe the physical processes will be evaluated. This will be done by running the model for a range of values.

Development of Independent Model

An independent model will be developed and used to evaluate the dispersion of waste discharged from the barge. The purpose of this model is to provide a more sophisticated alternative to more realistically describe the fate and transport of the discharge. The model will, at a minimum, include the effects of diffusion in both horizontal directions (longitudinal and lateral) and will model a discharge of finite time. In addition the model will account for the spatial pattern of the discharge.

The model will use initial dilutions as determined from the size of the propeller slipstream. Vertical diffusion will be accounted for using a technique similar to that used in the FEIS model. It is anticipated that the major difference in the model predictions will be reflected in the degree of conservatism involved in the model formulations and development. Any differences in model inputs and predictions will be justified and explained.

QUALITY CONTROL AND QUALITY ASSURANCE

The objective of the quality control and quality assurance (QA/QC) effort is to provide a high level of confidence that the models are providing physically realistic predictions. QA/QC will be achieved through use of the proven models executed by staff familiar with those models. Specific QA/QC measures include: validation of model code and that the models are providing physically realistic predictions, addressing a range of potential conditions where appropriate, sensitivity analyses, and documentation and maintenance of input and output files generated during modeling activities.
The models employed in the study are mathematical representations of physical processes. The mathematical equations used are solved numerically (approximate solutions) using a digital computer. It is important that this process, which is considerably removed from the actual physical processes and behavior of the ocean, accurately simulate what happens in the ocean. The process of validation uses representative parameters for simplified system configurations to determine if the predictions reflect reality. The process of validation begins as the initial model computer code is written and continues as long as the model code is used. It is particularly important that any changes in model code be checked for validity. The final element of validation is a determination of how sensitive a model is to changes in input parameters. An extremely sensitive model probably does not provide results with a high confidence level. Sensitivity checks will be carried out for each of the models for potentially critical parameters.

Most numerical models of the type used here contain coefficients (e.g. friction factors, diffusion coefficients) that are often study site specific. Although there are generally accepted values for these coefficients, the range observed in nature is high and the models can be somewhat sensitive to the values selected. The process of calibration and verification uses measured values of forcing functions and responses to determine the appropriate coefficients for the model configuration at the study site. Typically a set of field data is used to determine the correct values to use for the coefficients. However, this is beyond the scope of the present study and there is little or no available and appropriate data for this task. In this case the model sensitivity studies, the use and justification of reasonable values for the literature and similar studies, and the incorporation of a prudent level of conservatism is required.

DATA ANALYSIS AND REPORTING

A report documenting the results of all analyses will be prepared. The report will include summaries of all input data, modeling procedures, and model results. All pertinent model results and output files (as appropriate) will be reproduced as an appendix to the report.

Model results will be presented both in tabular form and graphically (i.e. contour plots) as appropriate. The report will include: an executive summary; an introduction describing the background, rationale, and general approach of the study; a description of the methods used including model formulation and input data; a description of the model results; an evaluation of the model validity for predicting dilution and plume characteristics; and, an evaluation of the concentration of the fish processing wastes within and at the boundary of the permitted ocean dumping site.

REFERENCES

Brooks, N.H., 1960. "Diffusion of Sewage Effluent in an Ocean Current," Proceedings of the First Conference on Waste Disposal in Marine Environment, Pergamon Press, NY.

SOS Environmental and Environmental & Ocean Technology, 1990. "Mathematical/Computer Modeling of Fish Waste Disposal at an Ocean Disposal Site off Tutuila Island, American Samoa". Report prepared for StarKist Seafood and Van Camp Seafood

Soule, D.F. and M. Oguri, 1983. "A report on Ocean Disposal of Fish Processing Wastes off Pago Pago , American Samoa. Report to EPA and NOAA for StarKist Foods and Van Camp Seafood. Los Angeles, California

U.S. Environmental Protection Agency, 1989. Final Environmental Impact Statement for the Designation of an Ocean Disposal Site off Tutuila Island, American Samoa for Fish Processing Waste. EPA Region 9, San Francisco, CA.

Yearsley, J.R., 1989. "Diffusion in Near-shore and Riverine Environments," EPA 910/9-87-168. EPA Region 10, Seattle, Washington.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

RECEIVED
DEC 14 1993
CH2M HILL
SAN FRANCISCO

December 10, 1993

Steven L. Costa
Project Manager
CH2M Hill
P.O. Box 12681
Oakland, CA 94604-2681

Re: Comments to Draft Study Plans for Joint Cannery Ocean Disposal Bioassay Toxicity Tests and Modeling Re-evaluation

Dear Steve:

We have reviewed the draft study plans for the biotoxicity tests and modeling re-evaluation. Attached are comments on the bioassay toxicity tests which should be addressed before the plan will be approved. Questions regarding these comments should be addressed to Amy Wagner at (510) 412-2329. A final study plan should be submitted for approval upon resolution of these comments.

Due to the delay in submittal of the draft study plan, we are allowing the first sampling episode to occur in January 1994, rather than in November 1993, as indicated in the ocean disposal permits. Thus we approve your request that each of the subsequent three sampling episodes be delayed by the same amount to maintain the desired spacing. However, the completion date for the overall study will not be changed.

The modeling re-evaluation study plan is approved as submitted. However, as we previously discussed, the additional, more sophisticated model referenced in the plan has not been selected yet and will be submitted for EPA's review prior to its utilization.

Please call Pat Young at 415/744-1594 if you have any questions.

Sincerely,

Norman L. Lovelace, Chief
Office of Pacific Island and Native American Programs (E-4)

cc: Jim Cox, Van Camp Seafood Company
Norman Wei, StarKist Seafood Company
Tony Tausaga, American Samoa EPA
Sheila Wiegman, American Samoa EPA

Attachment

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

DEC 09 1993

SUBJECT: Review of Draft Bioassay and Modeling Re-evaluation Plans for Tuna Cannery Ocean Disposal Permits

TO: Pat Young
American Samoa Program Manager

FROM: Amy Wagner
Laboratory Section

Debra Denton, Permits Issuance Section, and I have reviewed Part I (Bioassay Toxicity Tests) in the above entitled document. We do not recommend approval of the plan until the following issues are addressed or considered. Any questions concerning these comments can be adressed to me at (510) 412-2329.

1.Introduction, I-1: Considering the nature of the waste discharge, we agree that the fish processing wastes should be considered as whole effluent and not tested in the suspended particulate phase.

2.Sample Shipping and Handling, page I-2: Understanding the logistical difficulties in shipping samples from the South Pacific, it should be recognized that a 10 day hold time could result in an increase or decrease of toxicity. It is likely that the BOD will increase over time as reflected by IDOD values determined in the last toxicity tests on cannery effluent. Every effort to minimize the hold time should be made.

3.Selected Species, page I-2: Holmesimysis costata may not be an appropriate surrogate crustacean due to the low test temperature required and the crustacean's sensitivity to aeration. The use of the 96-hour static renewal acute test with Mysidopsis bahia is recommended as a more representative tropical species relevant to the study area.

4.Sample Preparation, page I-4: Artificial sea salts for brine manipulations of effluents can often cause toxicity. Use of natural seawater brine effluents (obtained from freezing or evaporating natural seawater) is recommended.

5.Experimental Conditions, I-4: The dilution series proposed seems more appropriate than the permit requirements based on toxicity seen at low concentrations of the cannery effluent. This dilution series may have to be modified after the first round of testing.

6.Experimental Conditions, I-5: The test temperatures proposed for the crustacean and sea urchin bioassays are higher than standard method requirements. Tests with M. bahia and P. vannamei are run at 20C, while tests using S. purpuratus are normally run at 12-15C.

7. Experimental Conditions, I-5: Methods for fish, mysid, and sea urchin toxicity tests should be cited (manual or reference) in this section since all test conditions (ie. static renewals, number test organisms) are not listed.

8. Quality Control and Quality Assurance, I-5: Sodium chloride is not a standard reference toxicant used in marine fish and mysid tests. In addition, this salt may cause an osmoregulatory rather than a toxicity response in the test organism causing variable sensitivity and dose-responses. Sodium dodecyl chloride, copper sulfate, or zinc sulfate are recommended reference toxicants for these test organisms.

cc: Terry Oda, Chief
Permits Issuance Section (W-5-1)

Appendix 3
SOP for Sample Collection

Standard Operating Procedures
High Strength Waste Sampling
for Bioassay Toxicity Tests

Introduction

Starkist Samoa, Inc. and VCS Samoa Packing are each required under their Ocean Disposal Dumping Permits to conduct definitive acute bioassays on their high strength waste (HSW) streams that are barged to sea for disposal at the permitted dump site. The following gives detailed procedures for collecting, preparing, and shipping samples for these analyses.

Each cannery is required to collect a composite sample of high strength waste while the waste is being transferred from the storage tanks to the barge. Currently a one gallon composite is required for the bioassay tests. The procedures described below are applicable to sampling at each of the canneries.

List of Equipment/Supplies

The following supplies will be required for collecting composite high strength waste samples and preparing them for delivery to the laboratories:

- Three (3) 1/2 to 1 gallon sampling containers
- One 1-gallon cubitainer or other appropriate container (container should be heavy-duty plastic with secure cap, <u>do not ship samples in glass containers</u>)
- Permanent marker for marking sample containers
- Cooler with ice (or refrigerator space) for storing sample
- Cooler for shipping samples (note: Cooler should be sized to hold sample(s) with sufficient room for ice.)
- Cubed ice (enough ice to fill airspace in cooler)
- Chain of Custody Forms (supplied by CH2M HILL or by laboratory conducting the analysis)

Sampling

The following describes the general sampling procedures:

1) **Collect "Grab" Samples.** Sampling should take place the day of or evening before the samples are shipped to the lab. Collect <u>three</u> 1/2 to 1-gallon grab samples from existing sampling ports in the storage tank transfer lines at the time waste is being transferred from the storage tanks to the barge. The samples should be collected at <u>10 minute intervals</u>. Record the time each grab was taken. Store all samples in coolers on ice or in a

refrigerator at a temperature of approximately 4°C. Do **NOT** store samples in a freezer or using a method that would otherwise freeze the samples.

2) **Composite Samples.** Using a permanent marker, label the 1-gallon cubitainer with the following information:
   - Facility samples were collected from
   - Date
   - Time each grab sample was collected

   Combine the three grab samples by measuring 1/3 gallon of each into the 1-gallon cubitainer. Seal the sample container by placing plastic inside the cap and taping the cap down.

3) **Complete Chain of Custody Form.** One chain-of-custody form is required for each cooler in which samples are shipped. An example of a completed chain-of-custody form is included as Attachment A, along with a blank copy. Fill out the chain-of-custody form in triplicate or copy keeping one copy and sending two with the samples to the laboratory.

Shipping

The samples should be shipped the fastest way possible to:

Dr. Kurt Kline
Advanced Biological Testing, Inc.
3150 Paradise Drive, Building 50
Tiburon, CA 94920

Phone: (415) 435-7878; Fax: (415) 435-7882

The samples from each cannery can be shipped in separate coolers or in the same cooler. Place the composite sample into the cooler in which sample(s) is to be shipped. Ice, or an equivalent means such as chemical cold packs, should be used to fill in the empty space in the cooler and keep the sample(s) cold during shipping. Do not use dry ice to ship the sample. If cubed ice is used, precautions should be taken to prevent the melted ice from leaking out of the cooler during shipping. These include taping any drain plugs in the cooler shut with duct tape or strapping tape, and "double-bagging" the ice cubes in zip-lock bags, i.e. sealing the ice cubes in one bag, then sealing the bag containing ice in a second bag. As much air as possible should be removed from the bags prior to sealing. (Too much air inside the bags will expand during flight and pop the bag open).

The chain-of-custody form should signed, placed in a zip-lock bag, and taped with duct tape to the inside of the cooler lid. The cooler should be taped securely with strapping tape or other strong packaging tape to prevent it from opening during shipping.

Attachment A
Example Chain-of-Custody Form

CH2M HILL

QUALITY ANALYTICAL LABORATORIES

CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES

CH2M HILL Project #: OPE3Ø7Ø2.DS.BT

Purchase Order #:

Project Name: OCEAN DUMPING PERMIT HIGH STRENGTH WASTE BIOASSAY

Company Name/CH2M HILL Office: CH2M HILL /SFO

Project Manager & Phone #: Mr. [ ] Ms. [ ] Dr. [X] STEVE COSTA 510 251-2888 X2251

Report Copy to: SAME

Requested Completion Date: A.S.A.P.

Sampling Requirements: SDWA [ ] NPDES [ ] RCRA [ ] OTHER OCN

Sample Disposal: Dispose [X] Return [ ]

LAB TEST CODES

SHADED AREA - FOR LAB USE ONLY: Lab 1 # / Lab 2 / Quote # / Kl Request # / Project # / No. of Samples / Page / of / COC Rev / Login / LIMS Ver / Ack Gen

Sampling Date	Sampling Time	Type COMP	Type GRAB	Matrix WATER	Matrix SOIL	CLIENT SAMPLE ID (9 CHARACTERS)	# OF CONTAINERS	BIOASSAY GROUP 1	BIOASSAY GROUP 2	BIOASSAY GROUP 3	REMARKS	LAB 1 ID	LAB 2 ID
10/18	1000	X		X		STARKIST	1	X	X	X	1-1gal cubitainer ON ICE		

ANALYSES REQUESTED

EXAMPLE DO NOT USE

Sampled By & Title (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time
Cliff Johnson CLIFF JOHNSON	10/18 1000		
Received By (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time
Received By (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time
Received By (Please sign and print name)	Date/Time	Shipped Via: UPS BUS Fed-Ex Hand Other DHL	Shipping #
Work Authorized By (Please sign and print name)		Remarks: SAMPLE IS COMPOSITE OF 3 GRAB SAMPLES TAKEN AT 10 MINUTE INTERVALS	

HAZWRAP/NESSA Y N

QC Level 1 2 3 Other

COC Rec ICE

Ana Req TEMP

Cust Seal PH

Instructions and Agreement Provisions on Reverse Side

DISTRIBUTION: ORIGINAL - LAB, Yellow - LAB, Pink - Client

REV 11/92 FORM 340

CH2M HILL

QUALITY ANALYTICAL LABORATORIES

CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES

CH2M HILL Project #

Purchase Order #

Project Name

Company Name/CH2M HILL Office

Project Manager & Phone #
Mr. [ ]
Ms. [ ]
Dr. [ ]

Report Copy to:

Requested Completion Date:

Sampling Requirements: SDWA ☐ NPDES ☐ RCRA ☐ OTHER ____

Sample Disposal: Dispose ☐ Return ☐

Sampling Date	Sampling Time	Type COMP	Type GRAB	Matrix WATER	Matrix SOIL	CLIENT SAMPLE ID (9 CHARACTERS)	# OF CONTAINERS	LAB TEST CODES	ANALYSES REQUESTED	REMARKS	LAB 1 ID	LAB 2 ID

SHADED AREA FOR LAB USE ONLY

Lab 1 # | Lab 2 #

Quote # | Kiz Request #

Project #

No. of Samples | Page | of

COC Rev | Login | LIMS Ver | Ack Gen

Sampled By & Title (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time
Received By (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time
Received By (Please sign and print name)	Date/Time	Relinquished By (Please sign and print name)	Date/Time
Received By (Please sign and print name)	Date/Time	Shipped Via: UPS BUS Fed-Ex Hand Other____	Shipping #
Work Authorized By (Please sign and print name)	Remarks		

HAZWRAP/NESSA: Y N

QC Level: 1 2 3 Other:

COC Rec | ICE

Ana Req | TEMP

Cust Seal | Ph

Instructions and Agreement Provisions on Reverse Side

DISTRIBUTION: ORIGINAL - LAB, Yellow - LAB, Pink - Client

REV 11/[illegible] FORM 3[illegible]

Appendix 4
EPA Communications on Bioassay Testing

OPINAP FAX TRANSMISSION
USEPA Region 9
Office of Pacific Island and Native American Programs (E-4)
75 Hawthorne Street
San Francisco, CA 94105
FAX NO: (415) 744-1604
VERIFICATION NO: (415) 744-1599

DATE: July 7, 1995 PAGES (incl. cover): 1

TO: Kurt Kline
Advanced Biological Testing Inc.

FAX: 415/435-7882 Phone: 415/435-7878

SUBJECT: Bioassay Test of Cannery Waste on Bi-valve Larvae

FROM: Pat Young, American Samoa Program Manager
USEPA Region 9
Phone: (415) 744-1594

Amy Wagner discussed with me the problems you were having with spawning the mussel larvae necessary for conducting bioassay tests on the cannery waste, and whether you should continue with the tests even though the cannery waste sample is now over 10 days old. Although the sample has been stored properly and refrigerated, we are concerned that given its high organic content and the waste's tendency to increase its ammonia content over time, no meaningful comparison or correlation of results could be made among the results of bioassay tests conducted on mussel larvae using 10-day-old cannery waste and the results obtained with the sand dab and mysid using the fresh sample. Rather than having you conduct the entire series again with the three species using new samples, and given the unrealibility of the mussel spawning, we waive the requirement to conduct the bioassay test on the mussel larvae for this round of sampling.

Should you have any questions, please feel free to call me.

cc: Steve Costa, CH2MHill
Jim Cox, Van Camp Seafoods
Norman Wei, Star-Kist Samoa
Amy Wagner, EPA Lab
Alan Ota, EPA (W-8-3)
Sheila, Wiegman, ASEPA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

September 30, 1994

1994

Steven L. Costa
Project Manager
CH2M Hill
P.O. Box 12681
Oakland, CA 94604-2681

Re: Third Bioassay Test of Ocean Disposed High-Strength Waste of StarKist Samoa, Inc. and VCS Samoa Packing Company

Dear Steve:

We have reviewed the two options proposed in your letter of September 14, 1994 for the timing of the third bioassay test required by the canneries' ocean disposal permits. We believe that information obtained during the different seasons would prove valuable. Thus, your proposal to change the schedule of the final bioassay test from December 1994 to June 1995 is approved. We understand that this will extend the term of the study beyond that stated in the permits. Since the modeling and evaluation will have been started on the first sets of data, we would expect to see the final study results by October 1995. As you know, the permits expire on August 31, 1996, and the canneries should reapply for permit renewal a few months prior to this expiration date. Because of the implications this report has for the designated ocean disposal site, we would like to receive the modeling and evaluation report with ample time to review it prior to the reapplication period.

Please call me at (415) 744-1594 if we need to discuss this further.

Sincerely,

Pat Young

Pat Young
American Samoa Program Manager
Office of Pacific Island and Native American Programs (E-4)

cc: Jim Cox, Van Camp Seafood Company
Norman Wei, StarKist Seafood Company
Tony Tausaga, American Samoa EPA
Sheila Wiegman, American Samoa EPA
Allan Ota, W-3-3
Amy Wagner, P-3-1

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

August 29, 1994

Steven L. Costa
Project Manager
CH2M Hill
P.O. Box 12681
Oakland, CA 94604-2681

Re: Comments on Bioassay Testing of Ocean Disposed High-Strength Waste of StarKist Samoa, Inc. and VCS Samoa Packing Company

Dear Steve:

We have reviewed the report of June 29, 1994 for the first of three rounds of bioassays of high-strength waste, as required by the canneries' ocean disposal permits. The report is based on two sampling events: the first was collected on February 16, 1994; and, a second sample was required and tested in March 1994, due to test failure of the echinoderms in the first sample. Your proposed changes to the study methods, as outlined in your memo of July 1, 1994, are acceptable. Enclosed is a memo from Amy Wagner of EPA's Laboratory Support Section, detailing the acceptable changes. Please call Amy at (510) 412-2329 if you have any questions on her comments.

We note that the second and third rounds of testing were scheduled for May and August 1994, and we would like to know if these tests were conducted as scheduled and, if not, the rescheduled dates, and when we can anticipate the reports on these bioassays. Please relay this information to Pat Young, American Samoa Program Manager, or if you have any questions, call her at (415) 744-1594.

Sincerely,

M. T. Lee
for Norman L. Lovelace, Chief
Office of Pacific Island and Native
American Programs (E-4)

Enclosure

cc: Jim Cox, Van Camp Seafood Company
Norman Wei, StarKist Seafood Company
Tony Tausaga, American Samoa EPA
Sheila Wiegman, American Samoa EPA
Allan Ota, W-3-3
Amy Wagner, P-3-1

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX LABORATORY
1337 S. 46TH STREET BLDG 201
RICHMOND, CA 94804-4698

AUG 29 1994

MEMORANDUM

SUBJECT: Review of Bioassay Testing of Starkist, Samoa, Inc. and VCS Samoa Packing High Strength

FROM: BB for ALW
Amy Wagner
Laboratory Section (P-3-1)

THRU: Brenda Bettencourt
Brenda Bettencourt, Chief
Laboratory Section (P-3-1)

TO: Pat Young
OPINAP (E-4)

Allan Ota
Wetlands and Sediment Management Section (W-3-3)

At your request, I have reviewed "Results of a Bioassay Conducted on Two High Strength Waste Samples from the Van Camp and Starkist Tuna Canneries in American Samoa." The following recommendations are based on the results of the first round of testing.

1. p. 11. The salinity of the *Mysidopsis bahia* tests were 25 ppt, presumably based on the salinity of the shipping water. An effort should be made to find a supplier that raises mysids in a salinity closer to that of the discharge site, between 30-35 ppt.

2. Appendix, p. 1. It is recommended that the water quality measurements pH, dissolved oxygen, and initial salinity be measured for all samples upon receipt.

3. Appendix, Table 10. The salinities of 26-28 ppt most likely caused the high mortality in controls with the sea urchin toxicity test. If necessary, brine adjustments should be used to increase the salinity of test samples to the test method requirements of 30 $\pm$ 2 ppt.

4. To reduce salinity elevation throughout the tests, an attempt should be made to cover test containers to reduce evaporation.

Based on the results of these tests, the following changes in the bioassay methods recommended by CH2M Hill in the cover memo are acceptable.

1. The series of the concentrations for toxicity tests can be reduced to 2.0%, 1.0%, 0.5%, 0.25%, 0.125%, and 0.0625% instead of the suggested series.

2. *Mytilus edulis* can be used instead of *Strongylocentrotus purpuratus* as the third test organism. The oyster *Crassostrea virginica* may be substituted for the mussel test during the months when mussels cannot be spawned.

3. Aeration should be provided in the mussel test containers due to high biological oxygen demand of the effluent. In addition to a control with aeration, a control without aeration should be run. A t-test should be used to determine if the there is any significant effect of aeration.

Any questions on the comments can be addressed to me at (510) 412-2329.

cc: Jeff Rosenbloom, Chief
Wetlands and Sediment Management Section (W-3-3)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

RECEIVED
DEC 14 1993
CH2M HILL
SAN FRANCISCO

December 10, 1993

Steven L. Costa
Project Manager
CH2M Hill
P.O. Box 12681
Oakland, CA 94604-2681

Re: Comments to Draft Study Plans for Joint Cannery Ocean Disposal Bioassay Toxicity Tests and Modeling Re-evaluation

Dear Steve:

We have reviewed the draft study plans for the biotoxicity tests and modeling re-evaluation. Attached are comments on the bioassay toxicity tests which should be addressed before the plan will be approved. Questions regarding these comments should be addressed to Amy Wagner at (510) 412-2329. A final study plan should be submitted for approval upon resolution of these comments.

Due to the delay in submittal of the draft study plan, we are allowing the first sampling episode to occur in January 1994, rather than in November 1993, as indicated in the ocean disposal permits. Thus we approve your request that each of the subsequent three sampling episodes be delayed by the same amount to maintain the desired spacing. However, the completion date for the overall study will not be changed.

The modeling re-evaluation study plan is approved as submitted. However, as we previously discussed, the additional, more sophisticated model referenced in the plan has not been selected yet and will be submitted for EPA's review prior to its utilization.

Please call Pat Young at 415/744-1594 if you have any questions.

Sincerely,

Norman L. Lovelace, Chief
Office of Pacific Island and Native
American Programs (E-4)

cc: Jim Cox, Van Camp Seafood Company
Norman Wei, StarKist Seafood Company
Tony Tausaga, American Samoa EPA
Sheila Wiegman, American Samoa EPA

Attachment

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

DEC 09 1993

SUBJECT: Review of Draft Bioassay and Modeling Re-evaluation Plans for Tuna Cannery Ocean Disposal Permits

TO: Pat Young
American Samoa Program Manager

FROM: Amy Wagner
Laboratory Section

Debra Denton, Permits Issuance Section, and I have reviewed Part I (Bioassay Toxicity Tests) in the above entitled document. We do not recommend approval of the plan until the following issues are addressed or considered. Any questions concerning these comments can be adressed to me at (510) 412-2329.

1.Introduction, I-1: Considering the nature of the waste discharge, we agree that the fish processing wastes should be considered as whole effluent and not tested in the suspended particulate phase.

2.Sample Shipping and Handling, page I-2: Understanding the logistical difficulties in shipping samples from the South Pacific, it should be recognized that a 10 day hold time could result in an increase or decrease of toxicity. It is likely that the BOD will increase over time as reflected by IDOD values determined in the last toxicity tests on cannery effluent. Every effort to minimize the hold time should be made.

3.Selected Species, page I-2: Holmesimysis costata may not be an appropriate surrogate crustacean due to the low test temperature required and the crustacean's sensitivity to aeration. The use of the 96-hour static renewal acute test with Mysidopsis bahia is recommended as a more representative tropical species relevant to the study area.

4.Sample Preparation, page I-4: Artificial sea salts for brine manipulations of effluents can often cause toxicity. Use of natural seawater brine effluents (obtained from freezing or evaporating natural seawater) is recommended.

5.Experimental Conditions, I-4: The dilution series proposed seems more appropriate than the permit requirements based on toxicity seen at low concentrations of the cannery effluent. This dilution series may have to be modified after the first round of testing.

6.Experimental Conditions, I-5: The test temperatures proposed for the crustacean and sea urchin bioassays are higher than standard method requirements. Tests with M. bahia and P. vannamei are run at 20C, while tests using S. purpuratus are normally run at 12-15C.

7. Experimental Conditions, I-5: Methods for fish, mysid, and sea urchin toxicity tests should be cited (manual or reference) in this section since all test conditions (ie. static renewals, number test organisms) are not listed.

8. Quality Control and Quality Assurance, I-5: Sodium chloride is not a standard reference toxicant used in marine fish and mysid tests. In addition, this salt may cause an osmoregulatory rather than a toxicity response in the test organism causing variable sensitivity and dose-responses. Sodium dodecyl chloride, copper sulfate, or zinc sulfate are recommended reference toxicants for these test organisms.

cc: Terry Oda, Chief
Permits Issuance Section (W-5-1)

Appendix 5
Laboratory Results Submitted by ABT - First Test

RESULTS OF A BIOASSAY CONDUCTED ON TWO HIGH STRENGTH WASTE SAMPLES FROM THE VAN CAMP AND STARKIST TUNA CANNERIES IN AMERICAN SAMOA

Prepared for:

CH2M Hill California, Inc.
1111 Broadway
Oakland, CA 94607
Project # PDX 30702

Prepared by:

Advanced Biological Testing Inc.
98 Main St., # 419
Tiburon, Ca. 94920

June 29, 1994

Ref: 9309-2

1.0 INTRODUCTION

At the request of CH2M Hill (Project # PDX 30702), Advanced Biological Testing conducted acute effluent bioassay testing on *Mysidopsis bahia*, *Mytilus edulis*, *Strongylocentrotus purpuratus* and *Citharichthys stigmaeus* using high strength wastes (HSW) collected separately from the Van Camp (HSW-1) and Starkist (HSW-2) tuna canneries in American Samoa. The study was run using methods generally specified in EPA 1991 and in a Sampling and Testing Plan submitted to the EPA.

The study was conducted at the Advanced Biological Testing Laboratory in Tiburon, California, and was managed by Mr. Mark Fisler.

2.0 METHODS

2.1 EFFLUENT SAMPLING

The high strength wastes were sampled as composites on February 16, 1994 by personnel from CH2M Hill. Due to shipping and airline scheduling problems, frequently encountered in this region, the sample was received by the laboratory on February 19, 1994. Two five gallon carboys were provided from each cannery defined as HSW-1 (VCS) and HSW-2 (SK) and were maintained in ice-filled coolers from the date of sampling until laboratory receipt. The sample were at 2-3°C upon receipt.

Due to the test failure in the echinoderms, both of the HSW were resampled on March 30, 1994, and shipped to ABT arriving on April 4, 1994.

2.2 SAMPLE PREPARATION

2.2.1 Testing on the speckled sanddab, *Citharichthys stigmaeus*

After extensive discussions with the EPA regarding the proposed testing concentrations, the high strength wastes were tested at eight concentrations starting from 3.0% and dropping using a 50% dilution factor. The final concentrations were 3.0, 1.5, 1.25, 0.8, 0.4, 0.2, 0.1 and 0.05% as vol:vol dilutions in seawater. The diluent was filtered seawater from the Bodega Bay Marine Laboratory. The dilutions were brought up to the test temperature (14°C) and aerated continuously. Based upon data provided by CH2M Hill, and subsequently supported by information from the EPA, these effluents have an extremely high biological oxygen demand, therefore aeration was carried out from the beginning of the test.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 25, 12.5, 6.25, 3.1, and 1.6 mg/L in 30 ppt seawater in a 24 hour test.

2.2.2 Testing on the mysid, *Mysidopsis bahia*

Both of the high strength wastes were tested twice, once in a concentration series of 25, 12.5, 6.25, 3.1, 1.6, 0.8, and 0.4% vol:vol in seawater, and after discussions with the EPA, a second

time at a lower concentration series of 1.6, 0.8, 0.4, 0.2, 0.1 and 0.05% vol:vol dilutions. The diluent was filtered seawater from the Bodega Bay Marine Laboratory. The dilutions were brought up to the test temperature (20°C) and aerated continuously.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 20, 10, 5, 2.5 and 1.25 mg/L in 30 ppt seawater in a 96 hour test.

2.2.3 Echinoderm and Bivalve Larval Bioassay

Test solutions used in the bioassays were prepared using San Francisco Bay seawater at 28 ppt in serial dilution (0.5) to create 0.08%, 0.15%, 0.3%, 0.6% and 1.2% test concentrations for the bioassays. The echinoderm test failed control survival in two testing attempts using the initial HSW delivered on February 19, 1994. A second sample was requested from each cannery which was delivered on April 4, 1994. The echinoderm test again marginally failed the controls and the results of the study are presented for information. The bivalve study conducted concurrently with the echinoderm bioassay passed the control criteria.

The reference toxicant for the echinoderm and bivalve larval bioassays was copper at test concentrations of 0.56, 3.2, 10, 32, and 56 µg/L.

2.2.4 *Citharichthys stigmaeus*

The bioassays were carried out on juvenile *Citharichthys stigmaeus*, supplied by J. Brezina and Associates in Dillon Beach, California. The animals were received at ABT on February 19, 1994. The test conditions are summarized in Table 1. Five replicates of each concentration were tested with ten juvenile fish per replicate. Water quality was monitored daily as initial quality on Day 0 and final water quality on Days 1-4. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature.

2.2.5 *Mysidopsis bahia*

The first bioassay was carried out on 7-10 day old larval *Mysidopsis bahia*, supplied by J. Brezina and Associates in Dillon Beach, California. The animals were received at ABT on February 19, 1994. The test conditions for this test are summarized in Table 2. The second test was carried out on larval mysids supplied by Aquatox from Hot Springs, Arkansas. The animals

were received at ABT on February 26, 1994. The test conditions for the second test are summarized in Table 3.

Five replicates of each concentration were tested with ten larval mysids per replicate. Water quality was monitored daily as initial quality on Day 0 and final water quality on Days 1-4. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature.

2.2.6 Echinoderm Larval Development Test

The echinoderm larvae survival and development test followed draft ASTM methods (ASTM, 1994). Purple urchins, *Strongylocentrotus purpuratus,* were obtained from A. K. Siewers, Santa Cruz, California. Adults were induced to spawn by intercoelomic injection of 0.5M KCl. Released eggs were placed in individual containers of filtered seawater, and sperm was collected dry and held on ice. Gametes were mixed and allowed to fertilize for up to two hours. Fertilized eggs were then separated from sperm and debris by filtering the suspension at 20 µm. Egg stock density was estimated by counting an aliquot of dilute stock concentrate. Equal volumes of concentrate were added to each replicate to an initial density of 15-30 embryos per mL. Initial stocking density was confirmed by counting a 5 mL aliquot from at least three control replicates.

Testing was conducted at 16 ± 2°C under a 14 hour light and 10 hour dark photoperiod. Temperature, pH, dissolved oxygen, and salinity were recorded at 0, 24, 48 and 72 hours in water quality replicates. Total ammonia was measured in the 1.2% sample at 0 and 48 hours. At the end of the exposure period, a 5 mL sub-sample was taken from each test replicate and preserved with buffered formalin. Sub-samples were counted in a Sedgwick-Rafter cell, and the total number of normal and abnormal larvae were counted.

2.2.7 *Mytilus edulis* Larval Survival and Development Test

The bivalve larvae survival and development test was run in parallel with the echinoderm using the second set of effluents. The test followed methods in ASTM (1993). Bay mussels, *Mytilus edulis,* were obtained from A. K. Siewers, Santa Cruz, California. Adults were induced to spawn by heat shocking. Released gametes were placed in individual containers of filtered seawater and examined for viability. Gametes were mixed and allowed to fertilize for up to two hours, under gentle aeration. Fertilized eggs were then separated from sperm and debris by filtering the suspension at 20 µm. Egg stock density was estimated by counting an aliquot of dilute stock concentrate. Equal volumes of concentrate were added to each replicate to an initial density of

15-30 embryos per mL. Initial stocking density was confirmed by counting a 5 mL aliquot from at least three control replicates.

Testing was conducted at 16 ± 2°C under a 14 hour light and 10 hour dark photoperiod. Temperature, pH, dissolved oxygen, and salinity were recorded at 0 and 48 hours; temperature was also recorded at 24 hours. Total ammonia was measured in 1.2% sample at 0 and 48 hours. At the end of the exposure period, a 5 mL sub-sample was taken from each test replicate and preserved with buffered formalin. Sub-samples were counted in a Sedgwick-Rafter cell, and the total number of normal and abnormal larvae were counted.

Dissolved oxygen levels of test solutions of HSW-2 fell below 60% saturation in both the bivalve and echinoderm tests. Gentle aeration was started on Day 1, and continued for the duration of the tests. To assess the effects of aeration, control replicates 4 and 5 were aerated beginning on Day 1 for both the bivalve and echinoderm tests. No statistical differences were observed between aerated and unaerated control replicates.

2.3 STATISTICAL ANALYSIS

At the conclusion of the test, the survival data were evaluated statistically using ToxCalc™ to determine ECp, NOEC, and TU values where appropriate. ToxCalc™ is a comprehensive statistical application that follows standard guidelines for acute and chronic toxicity data analysis.

At the conclusion of the echinoderm tests, data were evaluated statistically to estimate the LC50 and IC50 values for the elutriate tests. The LC50 and IC50 values were estimated using the Probit or the Linear Interpolation (Bootstrap) Method.

The LC50 and the IC50 for the bivalve larvae copper reference toxicant test were both within two standard deviations of the laboratory means of 26.3 µg/L and 8.9 µg/L, respectively, indicating normal sensitivity of the test organisms. No laboratory means for the echinoderm larvae copper reference toxicant test have yet been established.

Statistical effects can be measured by the ECp, the estimated concentration that causes any effect, either lethal (LC) or sublethal (IC), on p% of the test population. The LCp is the point estimate of the concentration at which a lethal effect is observed in p% of the test organisms. ECp values include 95% confidence limits if available.

The NOEC (No Observable Effect Concentration) is the highest tested concentration at which mortality is not significantly different from the control.

3.0 RESULTS

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 20 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected at approximately 1 hour after test initiation in all of the concentration even with supplemental aeration therefore aeration was maintained in all chambers for the duration of the test. Ammonia was measured in two replicates from each concentration daily and was a potentially significant toxic component of the test for all concentrations.

3.1 *Citharichthys stigmaeus*

The LC50 for HSW-1 was 0.59%. Mortality in the effluent was rapid at the highest concentrations, occurring in 2-4 hours. There was significant mortality at 3.0, 1.5, and 0.8% concentrations compared to the control at 96 hours. The NOEC was 0.4% and the LOEC was 0.8%

The LC50 for HSW-2 was 0.27%. Mortality in the effluent was rapid at the highest concentrations, generally occurring in 2-4 hours. There was significant mortality at 3, 1.5, 0.8 and 0.4% concentrations compared to the control at 96 hours. The NOEC was 0.2%, and the LOEC was 0.4%.

The reference toxicant test required the use of the Trimmed Spearman-Karber method and generated an LC50 of 4.34 mg/L, an NOEC of 3.1 mg/L, and an LOEC of 6.25 mg/L. This is the first reference toxicant test on *Citharichthys* at this laboratory, therefore no database has been established by this laboratory.

3.2 *Mysidopsis bahia*

The LC50 results for both HSW effluents in the initial tests were <0.4%. Based upon the fact that no definitive LC50 could be calculated, the tests were rerun as described in the methods.

The LC50 for HSW-1 was 0.59%. Mortality in the 1.6% and 0.8% effluent was incomplete at 24 hours. At 96 hours, there was significant mortality at 1.6, 0.8, 0.4, and 0.1% concentrations compared to the control. The NOEC was 0.05% and the LOEC was 0.1%.

In the second test series the LC50 for HSW-2 was 0.12%. Mortality in the 1.6% and 0.8% effluent was complete at 24 hours. There was significant mortality at 96 hours in the 1.6, 0.8, 0.4, 0.2 and 0.1% concentrations compared to the control. The NOEC was 0.05%, and the LOEC was 0.1%.

The reference toxicant test had an LC50 of 8.90 mg/L, with an NOEC of <1.25 mg/L and an LOEC of 1.25 mg/L. This is the first reference toxicant test on *Mysidopsis* at this laboratory, therefore no database has been established.

3.3 ECHINODERM LARVAL BIOASSAY

Control survival was marginal and unacceptable according to the protocol at 64.4% with 5.7% abnormal development. Total survival was relatively high and equal to control survival in all concentrations, however all of the embryos were abnormally developed at 0.15% to 1.2% in HSW-1 and from 0.08% to 1.2% in HSW-2. The LC50 for both effluents was greater than 1.2% however the IC50 was 0.1% for HSW-1 and <0.08% for HSW-2.

The reference toxicant analysis yielded an LC50 of 11.8 µg/L and an IC50 of 10.1 µg/L. The use of the echinoderm larval bioassay is still limited and no data is available for comparison.

3.4 BIVALVE LARVAL BIOASSAY

Control survival was acceptable at 98.1% with 6.3% abnormal development. Total survival was relatively high in all concentrations, however all of the embryos were abnormally developed at 0.15% to 1.2% in HSW-1 and HSW-2. The LC50 for both effluents was greater than 1.2% however the IC50s were <0.08% for both HSW-1 and HSW-2.

The LC50 and IC50 for the bivalve larvae copper reference toxicant test were both within two standard deviations of the laboratory means of 26.3 µg/L and 8.9 µg/L, respectively, indicating normal sensitivity of the test organisms.

3.5 AMMONIA MEASUREMENTS

Ammonia in both of the HSW was very high. When measured in a 25% dilution in seawater, ammonia levels ranged from 160 to 180 mg/L. If converted to the 100% concentration, the

ammonia level would be above 640 mg/L. Tested concentrations in the *Citharichthys* bioassay ranged from 0.08 to 0.17 mg/L in the lowest concentration (0.05%) to 3.44 to 9.65 mg/L in the 3.0% dilution. At each test concentration, HSW-2 generated the higher ammonia levels. The toxicity of ammonia to sanddabs is well documented and the measured levels in the three highest concentrations in HSW-2 and the two highest concentrations in HSW-1 were sufficient to cause toxicity in the test animals in 24 hours. The mysid test results appear to indicate a slightly higher tolerance to ammonia as has been shown in the literature.

TABLE 1

Bioassay Procedure And Organism Data For the Survival Bioassay Using *Citharichthys stigmaeus* (U.S. EPA 1991)

Parameter	Data
Test Species	*Citharichthys stigmaeus*
Supplier	J. Brezina and Associates
Collection location	Tomales Bay
Date Acquired	2/19/94
Acclimation Time	24 hours
Acclimation Water	30 ppt seawater
Acclimation Temperature	15±2°C
Age group	Juveniles, 3-5 cm TL
Sample Identification	
Sample ID(s)	940219-1, -2
Date Sampled	2/16/94
Date Received at ABT	2/19/94
Volume Received	Ten gallons
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	96 hour static acute, renewal at 48 hours
Test Dates	2/19/94 to 2/23/94
Control Water	Bodega Bay seawater
Test Temperature	15 ± 1°C
Test Photoperiod	16 L : 8 D
Initial Salinity	30 ± 2 ppt
Test Chamber	20 L polyethylene chamber
Animals/Replicate	10 animals/replicate
Exposure Volume	5 L
Replicates/Treatment	5
Feeding	None
Deviations from procedures	Due to aeration, salinity increased throughout test.

TABLE 2

Bioassay Procedure And Organism Data For the Survival Bioassay Using *Mysidopsis bahia* (U.S. EPA 1991)

Parameter	Data
Test Species	*Mysidopsis bahia*
Supplier	J. Brezina and Associates
Date Acquired	2/19/94
Acclimation Time	overnight
Acclimation Water	Shipping water
Acclimation Temperature	20 ± 2°C
Age group	larvae
Sample Identification	
Sample ID(s)	940219-1, -2
Date Sampled	2/16/94
Date Received at ABT	2/19/94
Volume Received	Ten gallons
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute; static; renewal at 48 hours
Test Dates	2/19/94 to 2/23/94
Control Water	Bodega Bay seawater
Test Temperature	20 ± 2°C
Test Photoperiod	14 L : 10 D
Initial Salinity	25 ppt
Test Chamber	1000 mL jars
Animals/Replicate	10 animal/replicate
Exposure Volume	500 mL
Replicates/Treatment	5
Feeding	Brine shrimp (24 hr old nauplii)
Deviations from procedures	Due to aeration, salinity increased throughout test

TABLE 3

Bioassay Procedure And Organism Data For the Survival Bioassay Using *Mysidopsis bahia* (U.S. EPA 1991)

Parameter	Data
Test Species	*Mysidopsis bahia*
Supplier	Aquatox
Date Acquired	2/26/94
Acclimation Time	Overnight
Acclimation Water	Shipping water
Acclimation Temperature	20 ± 2°C
Age group	larvae
Sample Identification	
Sample ID(s)	940219-1, -2
Date Sampled	2/16/94
Date Received at ABT	2/19/94
Volume Received	Ten gallons
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute; static; renewal at 48 hours
Test Dates	2/27/94 to 3/2/94
Control Water	Bodega Bay seawater
Test Temperature	20 ± 2°C
Test Photoperiod	14 L : 10 D
Initial Salinity	25 ppt
Test Chamber	1000 mL jars
Animals/Replicate	10 animal/replicate
Exposure Volume	500 mL
Replicates/Treatment	5
Feeding	Brine shrimp (24 hr old nauplii)
Deviations from procedures	Due to aeration, salinity increased throughout test

TABLE 4

Bioassay Procedure And Organism Data For The Bioassay Using Larvae of *Strongylocentrotus purpuratus* (modified ASTM 1994)

Parameter	Data
Test Species	*Strongylocentrotus purpuratus*
Supplier	A.K. Siewers, Santa Cruz, CA
Date Acquired	4/7/94
Acclimation Time	None
Acclimation Water	Not applicable
Acclimation Temperature	Not applicable
Age group	Fertilized embryos, 2 hours
Sample Identification	
Sample ID(s)	940404-3, -4
Date Sampled	3/30/94
Date Received at ABT	4/4/94
Volume Received	Two liters
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute/static; 96 hours
Test Dates	4/7/94 to 4/11/94
Control Water	San Francisco Bay seawater, 0.45 µm filtered and uv-sterilized
Test Temperature	16 ± 2°C
Test Photoperiod	14 L : 10 D
Salinity	30 ± 2 ppt
Test Chamber	125 mL beakers
Animals/Replicate	Approximately 30 embryos per mL
Exposure Volume	100 mL
Replicates/Treatment	5
Feeding	None
Deviations from procedures	Chambers were gently aerated with low bubble aeration

TABLE 5

Bioassay Procedure And Organism Data For The 48 Hour Bioassay Using Larvae of *Mytilus edulis* (ASTM 1993)

Parameter	Data
Test Species	*Mytilus edulis*
Supplier	A.K. Siewers, Santa Cruz, CA
Date Acquired	4/7/94
Acclimation Time	None
Acclimation Water	Not applicable
Acclimation Temperature	Not applicable
Age group	Fertilized embryos, 2 hours
Sample Identification	
Sample ID(s)	940404-3,-4
Date Sampled	3/30/94
Date Received at ABT	4/4/94
Volume Received	Two liters
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute; static; 48 hours
Test Dates	4/7/94 to 4/9/94
Control Water	San Francisco Bay seawater, 0.45 µm filtered and uv-sterilized
Test Temperature	16 ± 2°C
Test Photoperiod	14 L : 10 D
Salinity	30 ± 2 ppt
Test Chamber	125 mL beakers
Animals/Replicate	Approximately 30 embryos per mL
Exposure Volume	100 mL
Replicates/Treatment	3
Feeding	None
Deviations from procedures	Chambers were gently aerated with low bubble aeration

TABLE 6

SUMMARY OF RESULTS FOR THE HIGH STRENGTH WASTE BIOASSAYS

Species	Test	Endpoint	HSW-1	HSW-2
Citharichthys stigmaeus	96 hr static	LC50	0.59%	0.27%
Mysidopsis bahia	96 hr static	LC50	0.59%	0.12%
Strongylocentrotus purpuratus	96 hr static	LC50	>1.2%	>1.2%
		IC50	0.10%	<0.08%
Mytilus edulis	48 hr static	LC50	>1.2%	>1.2%
		IC50	<0.08%	<0.08%

Note:
HSW-1: Van Camp
HSW-2: Starkist

TABLE 7

SUMMARY OF RESULTS FOR THE REFERENCE TOXICANT (S.D.S.) TEST

Citharichthys stigmaeus

Concentration (mg/L)	% Survival	ECp (mg/L)		NOEC (mg/L)	LOEC (mg/L)
Control	93.3	**EC50**	4.3449	3.1	6.25
1.6	80.0				
3.1	100.0				
6.2	0.0				
12.5	0.0				
25	0.0				

Mysidopsis bahia

Concentration (mg/L)	% Survival	ECp (mg/L)		NOEC (mg/L)	LOEC (mg/L)
Control	90.0	**EC50**	8.90 (3.04-69.22)	<1.25	1.25
1.25	70.0				
2.5	56.7				
5	46.7				
10	46.7				
20	36.7				

* Statistically significant.
ICp/LCp: Inhibition/Lethal Concentration for p% of the organisms.
NOEC: No Observable Effect Concentration.
TU: 100%/NOEC.

4.0 REFERENCES

U.S. EPA. 1991. Methods for measuring acute toxicity of effluents to freshwater and marine organisms, 4th ed. EPA 600/4-90/027, September, 1991.

ASTM. 1993. Annual Book of Standards. Vol. 11.04. Standard guide for conducting static acute toxicity tests starting with embryos of four species of saltwater bivalve mollusca. E-724-89.

ASTM. 1994. Annual Book of ASTM Standards Vol. 11.04. Guide for conducting static acute toxicity tests with echinoid embryos. Proposed Standard in review.

APPENDIX A

ANALYTICAL DATA

APPENDIX TABLE 1

SAMPLE WATER QUALITY

Date	Day	Sample	pH (units)	DO (mg/L)	Total NH3 (mg/L)	Initial Salinity (ppt)
4/7/94	0	HSW-1, 1.2%	7.62	8.0	62.5	26
	0	HSW-2, 1.2%	6.87	7.9	51.6	26
4/9/94	2	HSW-1, 1.2%	-	-	26.4	-
	2	HSW-2, 1.2%	-	-	41.2	-
4/11/94	4	HSW-1, 1.2%	-	-	33.5	-
	4	HSW-2, 1.2%	-	-	41.9	-

APPENDIX TABLE 2

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.02	6.2	0.02	14.0	32.0	8.07	5.5	0.01	13.2	31.5	8.08	5.5		13.8	32.9	8.03	6.0		14.0	35.0	8.06	6.1	0.02	14.4	36.0
	2						8.11	5.8		13.7	31.0	8.13	5.6	0.12	14.2	31.7	8.12	6.0		14.3	33.0	8.13	6.1		15.0	33.0
	3						8.10	6.0		13.8	30.9	8.12	5.7		14.2	31.8	8.11	6.0		14.4	32.0	8.12	5.8		15.2	33.0
	4						8.10	6.0		13.2	31.6	8.13	5.7		13.6	33.1	8.11	6.0	<0.10	13.9	35.0	8.13	5.6		14.6	36.0
	5						8.10	6.0		13.3	31.7	8.12	5.6		13.9	33.3	8.12	6.0		14.0	34.0	8.13	5.8		14.7	37.0
0.05	1	8.00	6.3	0.19	14.0	32.2	8.04	6.0	0.08	13.5	33.8	8.07	5.6		13.9	36.2	8.07	6.0		14.0	38.0	8.07	5.8	0.10	14.8	40.0
	2						8.03	6.0		13.6	33.8	8.07	5.5	0.05	13.9	36.4	8.04	6.0		14.1	38.0	8.06	5.6		14.7	40.0
	3						8.05	6.0		13.5	32.7	8.10	5.5		14.1	33.6	8.08	6.0		14.2	35.0	8.10	5.6		14.6	35.0
	4						8.01	6.0		13.5	32.3	8.07	5.6		14.1	33.4	8.06	6.0	<0.10	14.2	34.0	8.04	5.8		14.7	35.0
	5						8.05	5.9		13.6	33.1	8.09	5.6		14.1	34.1	8.09	6.0		14.2	35.0	8.10	5.8		14.9	36.0
0.1	1	8.01	6.2	0.25	14.0	32.1	8.06	6.0	0.13	13.5	31.8	8.12	5.6		13.9	32.6	8.11	6.0		14.1	34.0	8.13	5.8	0.12	14.9	34.0
	2						8.03	5.9		13.8	31.7	8.10	5.7	0.08	14.2	32.6	8.10	6.0		14.4	33.0	8.10	5.8		14.9	34.0
	3						8.01	5.8		13.3	32.8	8.08	5.7		13.8	34.8	8.06	5.9		14.0	37.0	8.06	5.6		14.4	39.0
	4						8.04	5.9		13.8	32.6	8.12	5.8		14.5	33.9	8.11	6.0	<0.10	14.6	35.0	8.11	5.7		14.9	36.0
0.2	1	8.01	6.0	0.54	14.0	32.1	8.04	5.7	0.20	14.2	30.0	8.14	5.9		14.4	31.1	8.13	6.0		14.3	32.0	8.13	6.0	0.17	14.9	34.0
	2						8.01	5.8		14.1	29.9	8.14	5.8	0.17	14.5	30.5	8.16	6.0		14.6	31.0	8.16	5.9		14.9	32.0
	3						7.98	5.8		13.9	29.8	8.12	5.8		14.2	30.3	8.13	5.9		14.9	31.0	8.14	5.9		15.0	32.0
	4						8.02	5.8		13.9	29.8	8.15	5.8		14.2	30.5	8.15	6.3	NT	14.9	31.0	8.16	5.8		15.0	32.0
	5						8.03	5.8		13.8	29.8	8.13	5.8		14.2	30.5	8.15	6.3		14.9	31.0	8.17	5.8		15.0	32.0
0.4	1	7.93	6.1	0.89	14.0	32.0	7.95	5.4	0.33	13.7	30.1	8.12	5.4		14.2	30.8	8.14	6.3		14.3	32.0	8.17	5.8	0.31	15.0	32.0
	2						7.98	5.6		14.4	30.2	8.13	5.8	0.25	14.8	31.1	8.17	6.3		14.9	32.0	8.18	5.8		14.7	33.0
	3						8.00	5.9		14.4	30.2	8.15	5.7		14.3	31.6	8.18	6.3		14.6	33.0	8.06	5.8		14.6	34.0
	4						7.76	4.6		14.0	29.9	8.06	5.8		14.5	30.3	8.09	6.2	0.17	14.7	31.0	8.11	5.8		14.6	36.0
	5						7.93	5.2		13.5	30.4	8.11	5.6		14.0	31.4	8.13	6.2		14.0	32.0	8.19	5.6		14.3	34.0
0.8	1	7.68	6.1	2.01	14.0	32.0	7.89	5.2	0.64	13.7	30.8	8.15	5.6		14.1	31.7	8.15	6.2		14.2	33.0	8.10	5.8	0.51	14.7	33.0
	3						7.82	5.1		13.1	31.2	8.09	5.6	0.40	13.7	32.6	8.06	6.3		13.90	34.0	8.10	5.8		14.20	36.0
	4						7.95	5.4		14.1	30.8	8.16	5.5		14.5	32.0	8.17	6.4	0.48	14.3	34.0	8.18	5.8		14.4	35.0
	5						7.88	5.4		13.2	31.5	8.13	5.7		14.5	32.7	8.16	6.3		14.5	34.0	8.21	5.8		14.3	35.0
1.5	1	7.51	6.0	3.56	14.0	32.2	7.83	5.2	1.43	13.3	32.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.76	4.8		13.5	31.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.75	5.0		12.9	32.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.76	5.2		12.9	32.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.76	5.1		12.9	32.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3.0	1	7.23	5.9	11.1	14.0	32.1	7.85	5.6	3.44	13.6	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.74	4.6		13.9	33.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.81	5.0		13.9	33.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.75	4.7		14.1	33.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.81	5.0		19.2	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		7.23	5.9	0.02	14.0	32.0	7.74	4.6	0.01	12.9	29.8	8.06	5.4	0.05	13.6	30.3	8.03	5.9	<0.10	13.9	31.0	8.04	5.6	0.02	14.2	32.0
Max		8.02	6.3	11.1	14.0	32.2	8.11	6.0	3.44	19.2	33.8	8.16	5.9	0.40	14.8	36.4	8.18	6.4	0.48	14.9	38.0	8.21	6.1	0.51	15.2	40.0

Note: — = All animals dead.
NT = Not taken.
0.1 replicate 5 not stocked.
0.8 replicate 2 lost due to lab error.

APPENDIX TABLE 2 (Cont'd)

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.02	6.2	0.02	14.0	32.0	8.08	5.5	0.01	13.2	31.5	8.02	5.5		13.8	32.9	8.03	6.0		14.0	35.0	8.06	6.1	0.02	14.4	36.0
	2						8.11	5.8		13.7	31.0	8.13	5.6	0.12	14.2	31.7	8.12	6.0		14.3	33.0	8.13	6.1		15.0	33.0
	3						8.10	6.0		13.8	30.9	8.12	5.7		14.2	31.8	8.11	6.0		14.4	32.0	8.12	5.8		15.2	33.0
	4						8.10	6.0		13.2	31.6	8.13	5.7		13.6	33.1	8.11	6.0	<0.10	13.9	35.0	8.13	5.6		14.6	36.0
	5						8.10	6.0		13.3	31.7	8.12	5.6		13.9	33.3	8.12	6.0		14.0	34.0	8.13	5.8		14.7	37.0
0.05	1	7.89	6.1	0.32	14.0	32.0	7.98	6.0		13.5	36.2	8.02	5.6		13.9	41.1	8.02	6.4		14.0	38.0	8.03	5.2	0.13	14.4	40.0
	2						8.03	6.2	0.17	14.5	34.0	8.11	5.6	0.12	15.0	35.4	8.13	6.4		15.2	38.0	8.15	5.6		15.2	40.0
	3						8.01	6.0		13.6	33.7	8.05	5.7		14.1	34.9	8.10	6.3		14.4	36.0	8.10	5.6		14.2	37.0
	4						8.02	6.0		13.3	34.5	8.04	5.8		13.7	36.9	8.07	6.3	<0.10	13.9	38.0	8.06	5.6		14.0	40.0
	5						8.01	6.0		13.3	34.5	8.04	5.6		13.8	36.5	8.05	6.3		14.0	38.0	8.06	5.6		14.0	40.0
0.1	1	7.96	6.0	0.56	14.0	32.2	8.02	6.1		13.3	35.0	8.03	5.4		13.7	37.8	8.04	6.2		13.9	40.0	8.06	5.8	0.12	13.9	40.0
	2						8.03	6.1	0.24	14.2	33.6	8.09	5.5	0.13	14.9	34.5	8.11	6.3		14.9	35.0	8.13	5.8		14.6	36.0
	3						8.02	6.0		13.8	34.2	8.05	5.7		14.2	36.1	8.06	6.3		14.4	38.0	8.08	5.8		14.3	40.0
	4						8.02	5.9		14.3	33.5	8.07	5.5		14.9	34.2	8.09	6.3	<0.10	15.0	35.0	8.11	5.8		14.7	36.0
	5						8.04	6.1		13.2	33.6	8.07	5.6		14.8	34.4	8.11	6.3		14.0	35.0	8.13	5.8		13.9	36.0
0.2	1	7.87	6.1	1.32	14.0	32.0	8.03	6.0		13.2	33.5	8.11	5.6		13.9	34.3	8.12	6.3		14.1	35.0	8.15	5.8	0.20	13.8	36.0
	2						8.02	6.0	0.53	13.2	33.6	8.10	5.7	0.20	13.9	34.6	8.12	6.3		14.1	35.0	8.14	5.8		13.7	37.0
	3						8.03	6.0		13.5	33.5	8.10	5.8		14.1	34.1	8.13	6.3		14.3	35.0	8.15	5.8		13.9	36.0
	4						8.01	6.0		13.5	33.7	8.09	5.8		14.0	34.8	8.12	6.3	0.22	14.3	36.0	8.14	5.8		13.9	37.0
	5						8.02	6.0		13.8	33.8	8.10	5.7		14.2	34.8	8.04	6.3		14.3	35.0	8.15	5.8		14.2	36.0
0.4	1	7.66	6.0	3.00	14.0	32.1	7.95	5.8		13.2	35.1	7.99	5.4		13.8	38.2	8.08	6.3		13.9	41.0	8.05	5.8	0.30	13.7	40.0
	2						7.97	5.8	0.86	13.2	34.5	8.06	5.3	0.32	13.9	36.3	8.10	6.3		14.1	38.0	8.08	5.8		13.7	41.0
	3						7.99	6.0		14.5	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.99	5.9		14.4	33.5	7.89	5.1		15.0	34.1	—	—	—	—	—	—	—	—	—	—
	5						7.99	5.9		14.4	33.6	8.04	5.4		14.8	34.5	8.13	6.3	0.23	14.9	35.0	8.15	5.8		15.2	36.0
0.8	1	7.35	6.0	6.34	14.0	32.0	7.88	5.4		13.5	35.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.93	5.7	1.95	14.1	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.91	5.7		13.9	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.93	5.7		13.9	33.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.92	5.8		14.2	33.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.5	2	7.00	5.9	14.6	14.0	32.0	7.84	5.5		14.1	33.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.80	5.4	4.23	14.2	33.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.85	5.4		13.9	33.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.85	5.4		13.9	33.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3.0	1	6.81	5.7	28.5	14.0	32.0	7.89	5.7		13.9	33.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.86	5.9	9.65	13.8	33.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.88	5.9		13.6	33.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.81	5.8		13.0	34.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.81	5.8		12.9	34.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		6.81	5.7	0.02	14.0	32.0	7.80	5.4	0.17	12.9	30.9	7.89	5.1	0.12	13.6	31.7	8.02	6.0	<0.10	13.9	32.0	8.03	5.2	0.12	13.7	33.0
Max		8.02	6.2	28.50	14.0	32.2	8.11	6.2	9.65	14.5	36.2	8.13	5.8	0.32	15.0	41.1	8.13	6.4	0.23	15.2	41.0	8.15	6.1	0.30	15.2	41.0

Note: — = All animals dead.

APPENDIX TABLE 3

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.05	1	10	10	10	10	10	100	
	2	10	10	9	9	9	90	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.1	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	9	90	
	4	10	10	10	10	10	100	97.5
0.2	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	9	9	90	98.0
0.4	1	10	10	10	10	10	100	
	2	10	7	6	6	6	60	
	3	10	10	8	8	8	80	
	4	10	9	9	9	9	90	
	5	10	10	9	9	9	90	84.0
0.8	1	10	5	3	3	1	10	
	3	10	10	9	9	9	90	
	4	10	9	1	1	0	0	
	5	10	5	5	3	3	30	32.5
1.5	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
30	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Notes: — = All animals dead.

APPENDIX TABLE 3 (Cont'd)

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.05	1	10	10	10	10	9	90	
	2	10	10	10	10	9	90	
	3	10	10	10	10	10	100	
	4	10	10	10	10	9	90	
	5	10	10	10	10	10	100	94.0
0.1	1	10	10	10	9	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.2	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	9	9	9	90	
	5	10	10	9	9	9	90	96.0
0.4	1	10	4	3	2	2	20	
	2	10	4	3	3	2	20	
	3	10	0	—	—	—	0	
	4	10	3	0	—	—	0	
	5	10	3	3	3	3	30	14.0
0.8	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
1.5	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
3	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Notes: — = All animals dead.

APPENDIX TABLE 4

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal
Control	**1**	8.02	5.8	15.9	32	7.20	5.7	15.2	31
	2					7.31	5.0	15.1	31
	3					7.31	4.7	15.1	31
1.6	**1**	8.03	5.8	15.9	32	7.49	4.7	15.1	31
	2					7.52	4.2	15.1	31
	3					7.51	4.1	15.2	31
3.1	**1**	8.03	5.8	15.9	32	7.49	4.0	15.1	31
	2					7.43	4.0	15.2	30
	3					7.51	3.9	15.1	31
6.25	**1**	8.03	5.8	15.9	32	7.49	4.1	15.1	31
	2					7.48	4.1	15.1	30
	3					7.47	4.0	15.1	31
12.5	**1**	8.04	5.8	15.9	32	7.40	3.9	15.1	31
	2					7.44	3.7	15.1	31
	3					7.51	3.7	15.1	31
25	**1**	8.03	5.7	15.9	32	7.44	3.0	15.1	31
	2					7.42	3.1	15.1	31
	3					7.36	3.2	15.0	31
Min		8.02	5.7	15.9	32	7.20	3.0	15.0	30
Max		8.04	5.8	15.9	32	7.52	5.7	15.2	31

APPENDIX TABLE 5

Citharichthys stigmaeus
SURVIVAL DATA
FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	% Survival	Average % Survival
Control	1	5	4	80	
	2	5	5	100	
	3	5	5	100	93.3
1.6	1	5	2	40	
	2	5	5	100	
	3	5	5	100	80.0
3.1	1	5	5	100	
	2	5	5	100	
	3	5	5	100	100.0
6.25	1	5	0	0	
	2	5	0	0	
	3	5	0	0	0.0
12.5	1	5	0	0	
	2	5	0	0	
	3	5	0	0	0.0
25	1	5	0	0	
	2	5	0	0	
	3	5	0	0	0.0

APPENDIX TABLE 6

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.06	5.4		18.0	32.0	8.14	5.2	<0.01	19.6	32.0	8.11	5.1		19.8	33.0	8.11	4.6	<0.10	21.7	33.9	8.08	4.9	<0.10	21.1	34.1
	2						8.13	5.2		19.9	32.0	8.08	5.2		20.1	33.0	8.07	4.6		21.6	33.6	8.07	5.1		21.1	34.1
	3						8.16	5.1		19.7	32.0	8.12	5.4		20.2	33.6	8.11	4.5		21.6	34.7	8.09	5.1		21.1	34.0
	4						8.16	5.2		19.7	32.0	8.12	5.4		20.2	33.3	8.14	4.5		21.6	33.9	8.12	5.0		21.0	33.8
	5						8.15	5.2		19.7	32.0	8.11	5.5		20.2	33.1	8.11	4.5		21.5	34.0	8.10	4.9		21.0	34.1
0.05	1	8.08	5.4	0.13	18.0	32.0	8.14	5.2	0.12	19.8	32.0	8.13	5.4	0.14	20.1	33.6	8.13	4.5	0.13	21.7	34.8	8.12	5.0	0.13	20.9	34.1
	2						8.15	5.2		19.8	32.0	8.14	5.6		20.2	32.7	8.15	4.4		21.6	33.6	8.13	5.0		21.1	34.1
	3						8.13	5.2		19.6	32.0	8.11	5.6		20.2	32.8	8.13	4.5		21.6	33.6	8.14	5.1		21.1	34.3
	4						8.10	5.0		19.6	32.0	8.11	5.6		20.1	32.3	8.12	4.5		21.4	32.8	8.12	5.1		20.0	34.2
	5						8.04	5.1		19.5	32.0	8.08	5.5		20.1	32.4	8.06	4.5		21.3	33.3	8.10	5.0		20.0	34.0
0.1	1	8.06	5.4	0.25	18.0	32.0	8.02	5.0	0.19	19.6	32.0	8.09	5.4	0.29	20.2	33.1	8.06	4.6	0.23	21.7	33.9	8.12	5.0	0.24	21.0	35.1
	2						7.92	5.0		19.6	32.0	8.03	5.4		20.1	33.1	8.02	4.4		21.5	34.1	8.10	5.1		21.0	35.0
	3						7.99	4.9		19.5	32.0	8.10	5.3		19.9	33.0	8.13	4.4		21.3	35.0	8.13	4.9		20.9	35.1
	4						8.00	5.0		19.4	32.0	8.10	5.3		19.9	33.3	8.10	4.5		21.2	34.7	8.10	5.0		20.9	35.1
	5						8.02	5.0		19.3	32.0	8.10	5.3		19.9	33.5	8.16	4.6		21.1	35.4	8.09	5.0		20.9	35.7
0.2	1	8.04	5.2	0.61	18.0	32.0	7.91	5.0	0.38	19.6	32.0	8.11	5.4	0.38	20.0	32.6	8.14	4.8	0.41	21.5	34.2	8.18	4.9	0.52	21.0	34.8
	2						7.75	4.4		19.1	32.0	8.07	5.4		19.6	36.0	8.05	4.6		20.9	41.1	8.21	5.0		21.0	41.2
	3						7.58	3.8		19.0	32.0	8.04	5.5		19.5	35.2	8.04	4.5		20.7	38.7	8.20	5.0		21.1	38.7
	4						7.76	4.2		18.9	32.0	8.06	5.5		19.6	35.6	8.05	4.5		20.9	38.3	8.17	5.1		21.0	38.9
	5						7.81	4.4		19.0	32.0	8.07	5.4		19.5	35.0	8.11	4.5		20.9	35.9	8.17	5.1		21.0	36.2
0.4	1	8.02	5.2	1.17	18.0	32.0	7.83	4.2	0.71	19.5	32.0	8.16	5.4	0.74	19.9	32.9	8.20	4.6	0.82	21.4	34.0	8.21	5.1	1.09	20.9	34.8
	2						7.87	4.6		19.5	32.0	8.18	5.4		19.9	32.9	8.20	4.6		21.0	33.7	8.18	5.2		20.9	34.0
	3						7.73	3.8		19.5	32.0	8.19	5.2		19.9	33.0	8.20	4.6		21.2	33.8	8.19	5.1		20.9	33.9
	4						7.79	4.8		19.4	32.0	8.17	5.1		19.9	32.9	8.15	4.5		21.2	33.5	8.21	5.1		20.8	33.9
	5						7.91	4.4		19.4	32.0	8.19	5.1		19.9	33.0	8.20	4.5		21.0	33.6	8.21	5.1		20.8	33.9
0.8	1	7.92	5.3	3.62	19.9	32.0	7.62	3.8	1.52	19.5	32.0	8.22	5.3	1.38	19.9	33.2	8.23	4.6	1.42	21.3	33.9	8.22	5.1	1.53	21.0	34.1
	2						7.70	3.4		19.5	32.0	8.21	5.2		19.9	32.4	8.21	4.5		21.2	33.5	8.22	5.0		21.1	34.2
	3						7.61	3.4		19.4	32.0	8.19	5.1		19.9	33.2	8.19	4.4		21.1	34.0	8.21	5.0		21.0	34.7
	4						7.82	3.8		19.4	32.0	8.22	5.0		19.9	32.9	8.23	4.4		21.2	34.0	8.27	5.1		21.0	34.7
	5						7.59	3.0		19.4	32.0	8.24	5.0		19.9	33.0	8.23	4.4		21.2	34.0	8.24	5.0		21.0	34.2
1.6	1	7.88	5.2	7.14	20.2	32.0	7.61	1.4	3.27	19.6	32.0	8.25	5.2	3.45	20.1	32.7	8.23	4.6	3.27	21.3	33.8	8.28	4.9	3.12	21.1	34.1
	2						7.67	1.8		19.4	32.0	8.25	5.1		19.9	32.9	8.22	4.5		21.1	33.7	8.24	4.9		21.1	34.2
	3						7.68	1.8		18.6	32.0	8.15	5.0		19.5	34.4	—	—	—	—	—	—	—	—	—	—
	4						7.51	0.4		19.1	32.0	8.24	5.0		19.6	32.4	—	—	—	—	—	—	—	—	—	—
	5						7.70	2.4		18.9	32.0	8.19	5.0		19.4	36.1	8.12	4.5		20.6	40.8	8.31	5.0		20.9	33.9
Min		7.88	5.2	0.13	18.0	32.0	7.51	0.4	<0.01	18.6	32.0	8.03	5.0	0.14	19.4	32.3	8.02	4.4	<0.10	20.6	32.8	8.07	4.9	<0.10	20.0	33.8
Max		8.08	5.4	7.14	20.2	32.0	8.16	5.2	3.27	19.9	32.0	8.25	5.6	3.45	20.2	36.1	8.23	4.8	3.27	21.7	41.1	8.31	5.2	3.12	21.1	41.2

Note: — = All animals dead.

APPENDIX TABLE 6 (Cont'd)

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.06	5.4		18.0	32.0	8.14	5.2	<0.01	19.6	32.0	8.11	5.1		19.8	33.0	8.11	4.6	<0.10	21.7	33.9	8.08	4.9	<0.10	21.1	34.1
	2						8.13	5.2		19.9	32.0	8.08	5.2		20.1	33.0	8.07	4.6		21.6	33.6	8.07	5.1		21.1	34.1
	3						8.16	5.1		19.7	32.0	8.12	5.4		20.2	33.6	8.11	4.5		21.6	34.7	8.09	5.1		21.1	34.0
	4						8.16	5.2		19.7	32.0	8.12	5.4		20.2	33.3	8.14	4.5		21.6	33.9	8.12	5.0		21.0	33.8
	5						8.15	5.2		19.7	32.0	8.11	5.5		20.2	33.1	8.11	4.5		21.5	34.0	8.10	4.9		21.0	34.1
0.05	1	8.04	5.2	0.13	19.9	32.0	8.00	5.0	0.11	19.2	32.0	8.11	4.9	0.12	19.9	32.7	8.12	4.6	0.12	21.1	33.6	8.18	5.0	0.11	21.0	34.1
	2						7.97	4.8		19.1	32.0	8.09	4.9		19.6	33.0	8.08	4.5		20.9	33.7	8.19	5.1		21.1	34.2
	3						7.96	4.8		18.9	32.0	8.07	4.8		19.4	34.0	8.06	4.4		20.6	34.7	8.22	5.1		21.1	34.1
	4						7.96	4.8		18.6	32.0	8.08	4.8		19.2	34.2	8.05	4.4		20.4	35.8	8.21	5.1		21.1	34.1
	5						8.03	4.9		18.6	32.0	8.09	4.8		19.3	34.4	8.04	4.5		20.4	36.6	8.19	5.0		21.0	34.2
0.1	1	8.05	5.2	0.25	19.6	32.0	8.00	5.0	0.18	19.1	32.0	8.12	4.9	0.16	19.6	34.7	8.15	4.4	0.17	20.9	36.0	8.19	5.0	0.17	21.0	36.3
	2						7.97	5.0		19.1	32.0	8.15	5.0		19.6	34.6	8.15	4.5		20.7	33.7	8.20	5.0		21.1	36.4
	3						8.01	5.0		18.9	32.0	8.15	4.9		19.4	35.4	8.15	4.6		20.5	34.7	8.16	5.0		21.1	34.7
	4						7.97	4.9		18.8	32.0	8.15	4.9		19.4	35.2	8.14	4.4		20.3	36.0	8.17	5.0		21.1	35.2
	5						8.07	4.9		18.7	32.0	8.17	5.0		19.3	34.6	8.18	4.4		20.2	39.0	8.19	5.0		21.1	39.7
0.2	1	7.96	5.2	0.61	20.1	32.0	7.74	4.4	0.57	19.0	32.0	8.16	5.0	0.30	18.7	31.8	8.14	4.4	0.32	19.4	32.5	8.21	5.0	0.39	21.1	33.4
	2						7.78	4.6		19.1	32.0	8.15	4.9		18.7	32.5	8.13	4.5		19.4	32.8	8.09	5.1		21.0	34.2
	3						7.81	4.5		18.9	32.0	8.14	5.0		18.6	32.4	8.15	4.4		19.2	32.9	8.21	4.9		21.0	34.1
	4						7.85	4.6		18.8	32.0	8.16	5.0		18.4	32.4	8.16	4.4		19.1	33.7	8.23	4.9		21.0	34.1
	5						7.81	4.6		18.6	32.0	8.15	5.0		18.4	33.7	8.15	4.5		19.1	35.1	8.16	5.1		21.1	34.2
0.4	1	7.92	5.2	1.17	20.2	32.0	7.76	3.6	1.08	19.1	31.0	8.15	5.0	1.10	18.9	31.5	8.19	4.6	1.20	19.5	32.4	8.23	5.1	1.16	21.1	33.7
	2						7.75	3.6		19.1	32.0	8.16	5.0		18.6	33.9	8.14	4.5		19.5	35.9	8.18	5.1		21.1	36.2
	3						7.59	1.8		18.7	32.0	8.14	5.0		18.4	34.1	8.10	4.4		19.2	36.5	8.19	5.1		21.1	37.0
	4						7.73	3.4		18.6	32.0	8.16	5.0		18.4	33.7	8.14	4.3		19.2	35.1	8.19	5.0		21.1	36.1
	5						7.80	3.6		18.6	32.0	8.16	5.0		18.5	33.8	8.16	4.3		19.2	35.6	8.22	5.0		21.1	36.1
0.8	1	7.79	5.2	3.62	20.2	32.0	7.52	1.2	2.17	19.0	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.61	1.8		19.0	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.54	2.2		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.71	2.2		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.66	2.6		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.6	1	7.67	5.0	7.14	20.0	32.0	7.58	2.8	4.43	19.0	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.39	2.6		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.46	1.4		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.38	1.6		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.49	1.6		18.9	32.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		7.67	5.0	0.13	18.0	32.0	7.38	1.2	<0.01	18.6	31.0	8.07	4.8	0.12	18.4	31.5	8.04	4.3	<0.10	19.1	32.4	8.07	4.9	<0.10	21.0	33.4
Max		8.06	5.4	7.14	20.2	32.0	8.16	5.2	4.43	19.9	32.0	8.17	5.5	1.10	20.2	35.4	8.19	4.6	1.20	21.7	39.0	8.23	5.1	1.16	21.1	39.7

Note: — = All animals dead.

APPENDIX TABLE 7

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	**1**	10	10	10	9	10	100	
	2	10	10	10	10	9	90	
	3	10	10	10	9	9	90	
	4	10	10	10	10	9	90	
	5	10	10	10	10	9	90	92.0
0.05	**1**	10	9	9	9	9	90	
	2	10	10	10	9	8	80	
	3	10	10	8	8	7	70	
	4	10	9	7	7	6	60	
	5	10	10	9	8	9	90	78.0
0.1	**1**	10	6	5	2	6	60	
	2	10	10	9	5	8	80	
	3	10	8	8	7	6	60	
	4	10	8	6	7	8	80	
	5	10	9	8	8	6	60	68.0
0.2	**1**	10	9	8	4	7	70	
	2	10	8	7	5	7	70	
	3	10	9	7	7	8	80	
	4	10	9	8	7	8	80	
	5	10	10	9	8	8	80	76.0
0.4	**1**	10	8	7	5	6	60	
	2	10	8	7	6	6	60	
	3	10	8	8	6	6	60	
	4	10	8	7	7	8	80	
	5	10	10	9	8	7	70	66.0
0.8	**1**	10	5	*	*	3	30	
	2	10	4	*	*	3	30	
	3	10	6	*	*	3	30	
	4	10	4	*	*	3	30	
	5	10	3	*	*	0	0	24.0
1.6	**1**	10	3	*	*	0	0	
	2	10	2	*	*	0	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	1	*	*	0	0	0.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 7 (Cont'd)

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	**1**	10	10	10	9	10	100	
	2	10	10	10	10	9	90	
	3	10	10	10	9	9	90	
	4	10	10	10	10	9	90	
	5	10	10	10	10	9	90	92.0
0.05	**1**	10	10	10	10	9	90	
	2	10	9	9	8	6	60	
	3	10	10	9	8	7	70	
	4	10	8	8	8	5	50	
	5	10	9	8	8	6	60	66.0
0.1	**1**	10	7	7	7	6	60	
	2	10	8	7	5	4	40	
	3	10	7	6	4	7	70	
	4	10	8	7	4	4	40	
	5	10	7	7	6	3	30	48.0
0.2	**1**	10	6	4	2	2	20	
	2	10	5	5	4	2	20	
	3	10	6	6	3	5	50	
	4	10	6	6	4	6	60	
	5	10	5	4	2	4	40	38.0
0.4	**1**	10	5	*	*	1	10	
	2	10	3	*	*	2	20	
	3	10	4	*	*	1	10	
	4	10	3	*	*	0	0	
	5	10	3	*	*	0	0	8.0
0.8	**1**	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
1.6	**1**	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 8

Mysidopsis bahia
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1				Day 2				Day 3				Day 4			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal
Control	1	8.03	5.6	20.9	32.0	8.00	4.8	21.2	32.0	7.67	5.4	21.6	33.0	7.90	3.8	21.6	33.9	7.93	4.1	21.1	34.0
	2					8.02	4.8	21.2	32.0	7.72	5.4	21.5	33.0	7.91	3.7	21.6	30.9	7.94	4.0	21.1	34.1
	3					8.03	4.8	21.3	32.0	7.70	5.3	21.6	33.0	7.90	3.8	21.8	33.8	7.94	4.0	21.1	34.2
1.25	1	8.04	5.4	20.9	32.0	8.00	4.8	21.3	32.0	7.58	5.2	21.6	33.0	7.90	3.6	21.8	33.8	7.94	4.0	20.9	34.1
	2					8.02	4.8	21.2	32.0	7.54	5.1	21.6	33.0	7.93	3.5	21.8	33.7	7.93	4.0	21.0	34.3
	3					8.03	4.8	21.2	32.0	7.38	5.1	21.6	33.0	7.95	3.5	21.7	33.8	7.95	3.9	21.0	34.7
2.5	1	8.04	5.4	20.9	32.0	8.01	4.8	21.3	32.0	7.62	5.1	21.6	33.0	7.96	3.6	21.8	33.8	7.99	3.9	20.9	34.1
	2					8.02	4.8	21.1	32.0	7.42	5.1	21.6	33.0	7.93	3.6	21.8	33.6	7.92	3.8	20.9	34.0
	3					8.02	4.6	21.1	32.0	7.47	5.0	21.6	33.0	7.93	3.6	21.7	33.9	7.91	3.8	21.0	33.9
5	1	8.04	5.4	21.1	32.0	8.00	4.8	21.1	32.0	7.32	4.7	21.6	33.0	7.98	3.7	21.8	33.1	7.92	3.8	21.0	33.8
	2					8.00	4.7	21.1	32.0	7.38	4.8	21.6	33.0	7.92	3.5	21.8	33.0	7.92	3.9	21.0	33.7
	3					7.98	4.7	21.1	32.0	7.31	4.6	21.5	33.0	7.92	3.5	21.8	33.9	7.91	3.9	21.0	33.9
10	1	8.03	5.4	21.2	32.0	7.91	4.6	21.2	32.0	7.30	4.1	21.5	33.0	7.86	3.6	21.9	33.7	7.89	3.9	20.9	34.0
	2					7.91	4.5	21.2	32.0	7.31	4.2	21.5	33.0	7.88	3.6	21.9	33.8	7.89	3.9	20.9	33.9
	3					7.91	4.3	21.2	32.0	7.31	4.2	21.6	33.0	7.87	3.6	22.0	33.6	7.91	3.9	21.0	34.1
20	1	8.02	5.3	20.8	32.0	7.85	4.4	20.9	32.0	7.20	4.0	21.6	33.0	7.78	3.7	21.8	33.4	7.90	3.9	21.0	33.9
	2					7.85	4.4	20.9	32.0	7.21	4.0	21.6	33.0	7.75	3.8	21.8	33.4	7.88	3.8	21.0	33.4
	3					7.86	4.2	20.9	32.0	7.21	4.0	21.5	33.0	7.78	3.8	21.8	33.2	7.88	3.9	21.0	33.9
Min		8.02	5.3	20.8	32.0	7.85	4.2	20.9	32.0	7.20	4.0	21.5	33.0	7.75	3.5	21.6	30.9	7.88	3.8	20.9	33.4
Max		8.04	5.6	21.2	32.0	8.03	4.8	21.3	32.0	7.72	5.4	21.6	33.0	7.98	3.8	22.0	33.9	7.99	4.1	21.1	34.7

APPENDIX TABLE 9

Mysidopsis bahia
SURVIVAL DATA FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	**1**	10	10	10	9	9	90	
	2	10	10	10	10	9	90	
	3	10	10	10	9	9	90	90.0
1.25	**1**	10	9	9	8	7	70	
	2	10	10	9	6	6	60	
	3	10	9	8	8	8	80	70.0
2.5	**1**	10	9	8	6	5	50	
	2	10	10	8	6	6	60	
	3	10	10	8	6	6	60	56.7
5	**1**	10	11	9	5	5	50	
	2	10	9	7	5	4	40	
	3	10	10	9	7	5	50	46.7
10	**1**	10	10	9	7	5	50	
	2	10	9	9	4	4	40	
	3	10	9	7	5	5	50	46.7
20	**1**	10	7	5	3	2	20	
	2	10	10	8	7	5	50	
	3	10	10	8	5	4	40	36.7

APPENDIX TABLE 10

Strongylocentrotus purpuratus
WATER QUALITY MEASUREMENTS FOR THE EFFLUENT TEST
Test Dates: 4/7-4/11/94

Site	Concentration (%)	Day 0 °C	Day 0 DO	Day 0 pH	Day 0 Sal	Day 1 °C	Day 1 DO	Day 1 pH	Day 1 Sal	Day 2 °C	Day 2 DO	Day 2 pH	Day 2 Sal	Day 3 °C	Day 3 DO	Day 3 pH	Day 3 Sal	Day 4 °C	Day 4 DO	Day 4 pH	Day 4 Sal
Control		16.3	8.0	7.49	26	15.1	8.7	7.77	27	16.2	8.4	7.87	26	15.4	8.4	7.79	26	15.7	8.2	7.89	27
HSW-1	0.08	16.0	8.1	7.42	26	14.5	8.6	7.62	27	15.6	8.4	7.86	26	15.6	7.7	7.84	26	15.9	8.1	7.88	26
	0.15	16.0	8.0	7.43	27	14.5	6.6	7.51	27	15.5	7.4	7.80	27	15.6	6.5	7.80	27	15.7	8.1	7.85	27
	0.3	16.2	8.0	7.83	29	14.5	4.5	7.54	29	15.7	2.2	7.59	28	15.5	3.0	7.47	28	15.8	7.8	7.65	29
	0.6	16.2	8.0	7.51	26	14.5	4.1	7.51	27	15.9	2.3	7.56	26	15.6	2.7	7.49	26	15.7	7.4	7.93	27
	1.2	16.4	8.0	7.62	26	14.5	1.5	7.10	29	15.6	1.3	7.46	28	15.7	1.7	7.51	27	15.1	7.4	7.97	29
HSW-2	0.08	16.2	8.0	7.33	26	14.5	1.2	7.41	27	15.3	7.7	7.93	27	15.6	7.9	7.80	27	15.2	7.6	7.95	27
	0.15	16.4	8.0	7.34	27	14.5	1.6	7.42	27	15.5	7.7	7.96	27	15.7	7.3	7.77	27	15.0	7.8	7.95	27
	0.3	16.4	8.0	7.21	27	14.5	1.3	7.45	27	15.6	7.8	7.82	27	15.6	6.9	7.79	27	15.0	7.8	7.97	27
	0.6	16.0	8.0	7.21	26	15.7	1.3	7.42	27	16.2	3.0	7.52	27	15.7	2.7	7.47	27	16.2	6.6	7.71	27
	1.2	16.2	7.9	6.87	26	15.7	1.3	7.10	27	16.1	1.4	7.42	27	15.7	1.7	7.38	27	16.2	6.4	7.63	27
	Min	16.0	7.9	6.87	26	14.5	1.2	7.10	27	15.3	1.3	7.42	26	15.4	1.7	7.38	26	15.0	6.4	7.63	26
	Max	16.4	8.1	7.83	29	15.7	8.7	7.77	29	16.2	8.4	7.96	28	15.7	8.4	7.84	28	16.2	8.2	7.97	29

APPENDIX TABLE 11

Strongylocentrotus purpuratus

SUMMARY OF SURVIVAL AND DEVELOPMENT FOR THE ECHINODERM LARVAE EFFLUENT TEST

Test Dates: 4/7-4/11/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
Initial Counts	1	156		31.2			
	2	136		27.2			
	3	141		28.2			
	4	168		33.6			
	5	137		27.4			
	Mean			29.5			
Final Control	1	95	14	21.8		12.8	
	2	59	4	12.6		6.3	
	3	109	7	23.2		6.0	
	4	94	1	19.0		1.1	
	5	90	2	18.4		2.2	
	Mean			19.0	64.4	5.7	NA
HSW-1 0.08	1	45	32	15.4		41.6	
	2	63	53	23.2		45.7	
	3	66	43	21.8		39.4	
	4	76	38	22.8		33.3	
	5	78	40	23.6		33.9	
	Mean			21.4	72.4	38.8	0.0
0.15	1	0	79	15.8		100.0	
	2	0	48	9.6		100.0	
	3	0	44	8.8		100.0	
	4	0	89	17.8		100.0	
	5	0	99	19.8		100.0	
	Mean			14.4	48.7	100.0	24.4
0.3	1	0	50	10.0		100.0	
	2	0	53	10.6		100.0	
	3	0	57	11.4		100.0	
	4	0	84	16.8		100.0	
	5	0	58	11.6		100.0	
	Mean			12.1	40.9	100.0	36.4
0.6	1	0	66	13.2		100.0	
	2	0	85	17.0		100.0	
	3	0	74	14.8		100.0	
	4	0	112	22.4		100.0	
	5	0	57	11.4		100.0	
	Mean			15.8	53.4	100.0	17.1
1.2	1	0	106	21.2		100.0	
	2	0	115	23.0		100.0	
	3	0	92	18.4		100.0	
	4	0	60	12.0		100.0	
	5	0	114	22.8		100.0	
	Mean			19.5	66.0	100.0	100.0

APPENDIX TABLE 11 (Cont'd)

Strongylocentrotus purpuratus

SUMMARY OF SURVIVAL AND DEVELOPMENT FOR THE ECHINODERM LARVAE EFFLUENT TEST

Test Dates: 4/7-4/11/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
HSW-2							
0.08	1	0	63	12.6		100.0	
	2	0	61	12.2		100.0	
	3	0	39	7.8		100.0	
	4	0	36	7.2		100.0	
	5	0	58	11.6		100.0	
	Mean			10.3	34.8	100.0	45.9
0.15	1	0	101	20.2		100.0	
	2	0	112	22.4		100.0	
	3	0	129	25.8		100.0	
	4	0	122	24.4		100.0	
	5	0	130	26.0		100.0	
	Mean			23.8	80.5	100.0	0.0
0.3	1	0	89	17.8		100.0	
	2	0	128	25.6		100.0	
	3	0	119	23.8		100.0	
	4	0	119	23.8		100.0	
	5	0	91	18.2		100.0	
	Mean			21.8	74.0	100.0	0.0
0.6	1	0	116	23.2		100.0	
	2	0	119	23.8		100.0	
	3	0	113	22.6		100.0	
	4	0	79	15.8		100.0	
	5	0	104	20.8		100.0	
	Mean			21.2	72.0	100.0	0.0
1.2	1	0	76	15.2		100.0	
	2	0	87	17.4		100.0	
	3	0	92	18.4		100.0	
	4	0	88	17.6		100.0	
	5	0	76	15.2		100.0	
	Mean			16.8	56.8	100.0	11.8

APPENDIX TABLE 12

Strongylocentrotus purpuratus
WATER QUALITY MEASUREMENTS FOR THE REFERENCE TOXICANT (C0PPER) TEST
Test Dates: 4/7-4/11/94

Concentration	Day 0				Day 1				Day 2				Day 3				Day 4			
(µg/L)	°C	DO	pH	Sal	°C	DO	pH	Sal	°C	DO	pH	Sal	°C	DO	pH	Sal	°C	DO	pH	Sal
0.1	15.6	8.9	7.88	29	14.3	NT	NT	NT	14.2	8.1	7.97	29	14.4	8.4	8.01	29	15.0	7.6	7.98	29
0.32	15.8	8.9	7.90	29	14.3	NT	NT	NT	14.2	8.1	8.00	29	14.4	8.4	8.04	29	15.0	7.7	7.99	29
1.8	15.8	8.9	7.92	29	14.4	NT	NT	NT	14.3	8.3	8.02	29	14.5	8.3	8.06	29	14.9	7.9	8.00	29
18	15.8	9.1	7.80	28	14.3	NT	NT	NT	14.2	8.3	8.01	28	14.5	8.3	8.06	29	15.0	7.9	8.00	29
56	15.8	9.1	7.86	26	14.4	NT	NT	NT	14.2	8.6	8.02	25	14.5	8.3	8.06	29	15.0	8.0	8.01	25
Min	15.6	8.9	7.80	26	14.3				14.2	8.1	7.97	25	14.4	8.3	8.01	29	14.9	7.6	7.98	25
Max	15.8	9.1	7.92	29	14.4				14.3	8.6	8.02	29	14.5	8.4	8.06	29	15.0	8.0	8.01	29

Note: NT = Not taken.

APPENDIX TABLE 13

Strongylocentrotus purpuratus
SUMMARY OF SURVIVAL AND DEVELOPMENT FOR THE ECHINODERM LARVAE
REFERENCE TOXICANT (Copper) TEST
Test Dates: 4/7-4/11/94

Concentration (µg/L)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
Copper							
0.1	1	78	14	18.4		15.2	
	2	86	19	21.0		18.1	
	3	86	12	19.6		12.2	
	Mean			19.7	66.7	15.2	0.0
0.32	1	26	1	5.4		3.7	
	2	33	1	6.8		2.9	
	3	96	0	19.2		0.0	
	Mean			10.5	35.5	2.2	44.9
1.8	1	69	4	14.6		5.5	
	2	60	2	12.4		3.2	
	3	96	4	20.0		4.0	
	Mean			15.7	53.1	4.2	17.5
18	1	3	51	10.8		94.4	
	2	0	31	6.2		100.0	
	3	0	28	5.6		100.0	
	Mean			7.5	25.5	98.1	60.4
56	1	0	38	7.6		100.0	
	2	0	24	4.8		100.0	
	3	0	48	9.6		100.0	
	Mean			7.3	24.9	100.0	61.4

APPENDIX TABLE 14

Mytilus edulis

WATER QUALITY MEASUREMENTS FOR THE EFFLUENT TEST

Test Dates: 4/7-4/9/94

Concentration		Day 0				Day 1	Day 2			
(%)	Rep	°C	DO	pH	Sal	°C	°C	DO	pH	Sal
Control	1	16.3	8.0	7.49	26	14.8	16.0	7.2	7.79	26
	2					14.6	16.0	7.2	7.82	26
	3					14.5	16.0	7.5	7.82	26
	4					14.7	16.0	7.5	7.88	26
	5					14.8	16.0	7.6	7.96	26
HSW-1										
0.08	1	16.0	8.1	7.42	26	14.5	16.0	7.6	7.68	26
	2					14.5	16.0	7.5	7.65	26
	3					14.4	16.1	7.3	7.67	26
	4					14.5	16.0	7.2	7.66	26
	5					14.5	16.1	7.1	7.66	26
0.15	1	16.0	8.0	7.43	27	14.5	16.0	4.0	7.46	26
	2					14.4	16.0	4.0	7.40	26
	3					14.4	16.0	3.8	7.38	26
	4					14.4	16.0	3.8	7.38	26
	5					14.5	16.0	3.6	7.40	26
0.3	1	16.2	8.0	7.83	29	14.4	16.0	2.0	7.44	28
	2					14.5	16.0	2.0	7.52	28
	3					14.5	16.0	1.8	7.54	28
	4					14.4	16.0	1.8	7.56	28
	5					14.5	16.0	1.5	7.55	28
0.6	1	16.2	8.0	7.51	26	14.5	16.0	1.6	7.56	26
	2					14.5	16.0	1.7	7.58	26
	3					14.5	16.0	1.7	7.60	26
	4					14.6	16.1	2.1	7.61	26
	5					14.5	16.1	2.0	7.60	26
1.2	1	16.4	8.0	7.62	26	14.4	16.0	4.2	7.62	26
	2					14.5	16.0	4.4	7.67	26
	3					14.5	16.0	4.3	7.64	26
	4					14.5	16.1	4.5	7.67	26
	5					14.5	16.1	4.6	7.83	26
	Min	16.0	8.0	7.42	26	14.4	16.0	1.5	7.38	26
	Max	16.4	8.1	7.83	29	14.8	16.1	7.6	7.96	28

APPENDIX TABLE 14 (Cont'd)

Mytilus edulis

WATER QUALITY MEASUREMENTS FOR THE EFFLUENT TEST

Test Dates: 4/7-4/9/94

Concentration		Day 0				Day 1	Day 2			
(%)	Rep	°C	DO	pH	Sal	°C	°C	DO	pH	Sal
HSW-2										
0.08	1	16.2	8.0	7.33	26	14.5	16.0	7.4	7.93	26
	2					14.6	16.0	7.7	7.92	26
	3					14.5	16.0	7.5	7.95	26
	4					14.5	16.1	7.5	7.97	26
	5					14.5	16.1	7.6	7.98	27
0.15	1	16.4	8.0	7.34	27	14.5	16.0	7.8	7.91	26
	2					14.5	16.0	8.0	7.94	26
	3					14.4	16.1	8.0	7.94	26
	4					14.5	16.1	7.9	7.86	26
	5					14.5	16.1	7.7	7.85	26
0.3	1	16.4	8.0	7.21	27	14.5	16.0	7.7	7.83	26
	2					14.5	16.0	7.7	7.86	26
	3					14.5	16.0	7.7	7.77	26
	4					14.5	16.1	7.6	7.59	26
	5					14.5	16.1	7.2	7.62	26
0.6	1	16.0	8.0	7.21	26	14.5	16.0	1.7	7.56	26
	2					14.6	16.1	1.7	7.53	26
	3					14.5	16.1	1.8	7.51	26
	4					14.6	16.1	1.8	7.51	26
	5					14.5	16.1	1.8	7.50	26
1.2	1	16.2	7.9	6.87	26	14.5	16.0	2.0	7.47	26
	2					14.5	16.1	1.7	7.37	26
	3					14.5	16.1	1.6	7.39	26
	4					14.5	16.1	2.0	7.42	26
	5					14.5	16.1	2.0	7.45	26
	Min	16.0	7.9	6.87	26	14.4	16.0	1.6	7.37	26
	Max	16.4	8.0	7.34	27	14.6	16.1	8.0	7.98	27

APPENDIX TABLE 15

Mytilus edulis
SUMMARY OF RESULTS FOR BIVALVE LARVAE BIOASSAY
Test Dates: 4/7-4/9/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
Initial Counts	1	129		25.8			
	2	95		19.0			
	3	102		20.4			
	4	76		15.2			
	5	115		23.0			
	Mean			20.7			
Final Control	1	103	13	23.2		11.2	
	2	97	3	20.0		3.0	
	3	86	5	18.2		5.5	
	4	83	5	17.6		5.7	
	5	106	7	22.6		6.2	
	Mean			20.3	98.2	6.3	NA
HSW-1 0.08	1	22	61	16.6		73.5	
	2	2	78	16.0		97.5	
	3	0	72	14.4		100.0	
	4	0	77	15.4		100.0	
	5	5	67	14.4		93.1	
	Mean			15.4	74.2	92.8	24.3
0.15	1	0	74	14.8		100.0	
	2	0	76	15.2		100.0	
	3	0	64	12.8		100.0	
	4	0	86	17.2		100.0	
	5	0	61	12.2		100.0	
	Mean			14.4	69.8	100.0	28.9
0.3	1	0	139	27.8		100.0	
	2	0	120	24.0		100.0	
	3	0	133	26.6		100.0	
	4	0	91	18.2		100.0	
	5	0	82	16.4		100.0	
	Mean			22.6	100.0	100.0	0.0
0.6	1	0	73	14.6		100.0	
	2	0	133	26.6		100.0	
	3	0	90	18.0		100.0	
	4	0	96	19.2		100.0	
	5	0	93	18.6		100.0	
	Mean			19.4	93.7	100.0	4.4
1.2	1	0	90	18.0		100.0	
	2	0	75	15.0		100.0	
	3	0	87	17.4		100.0	
	4	0	80	16.0		100.0	
	5	0	91	18.2		100.0	
	Mean			16.9	81.7		16.7

APPENDIX TABLE 15 (Cont'd)

Mytilus edulis
SUMMARY OF RESULTS FOR BIVALVE LARVAE BIOASSAY
Test Dates: 4/7-4/9/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
HSW-2							
0.08	1	0	109	21.8		100.0	
	2	1	84	17.0		98.8	
	3	0	100	20.0		100.0	
	4	0	110	22.0		100.0	
	5	0	95	19.0		100.0	
	Mean			20.0	96.4	99.8	1.7
0.15	1	0	100	20.0		100.0	
	2	0	90	18.0		100.0	
	3	0	111	22.2		100.0	
	4	0	89	17.8		100.0	
	5	0	115	23.0		100.0	
	Mean			20.2	97.6	100.0	0.5
0.3	1	0	82	16.4		100.0	
	2	0	101	20.2		100.0	
	3	0	97	19.4		100.0	
	4	0	89	17.8		100.0	
	5	0	104	20.8		100.0	
	Mean			18.9	91.4	100.0	6.8
0.6	1	0	144	28.8		100.0	
	2	0	128	25.6		100.0	
	3	0	94	18.8		100.0	
	4	0	103	20.6		100.0	
	5	0	119	23.8		100.0	
	Mean			23.5	100.0	100.0	0.0
1.2	1	0	81	16.2		100.0	
	2	0	94	18.8		100.0	
	3	0	104	20.8		100.0	
	4	0	88	17.6		100.0	
	5	0	87	17.4		100.0	
	Mean			18.2	87.7	100.0	10.5

APPENDIX TABLE 16

Mytilus edulis
WATER QUALITY MEASUREMENTS
FOR THE REFERENCE TOXICANT (C0PPER) TEST
Test Dates: 4/7-4/9/94

Concentration		Day 0				Day 1	Day 2			
µg/L	Rep	°C	DO	pH	Sal	°C	°C	DO	pH	Sal
0.56	1	15.8	9.2	7.91	30	14.3	14.0	7.7	7.95	28
	2					14.3	14.0	7.8	7.96	29
	3					14.3	14.0	7.9	7.96	29
3.2	1	15.7	8.9	7.91	29	14.3	14.1	7.9	7.96	28
	2					14.3	14.0	7.9	7.96	29
	3					14.2	14.0	8.1	7.96	29
10	1	15.6	8.7	7.92	29	14.3	14.0	8.0	7.96	28
	2					14.4	14.1	8.0	7.97	28
	3					14.3	14.1	8.1	7.97	28
32	1	15.6	9.7	7.78	26	14.3	14.0	8.0	7.97	26
	2					14.3	14.1	8.1	7.96	26
	3					14.3	14.1	8.1	7.95	26
56	1	15.8	9.1	7.86	26	14.4	14.0	8.3	7.95	25
	2					14.3	14.0	8.1	7.96	25
	3					14.4	14.0	8.1	7.96	25
	Min	15.6	8.7	7.78	26	14.2	14.0	7.7	7.95	25
	Max	15.8	9.7	7.92	30	14.4	14.1	8.3	7.97	29

APPENDIX TABLE 17

Mytilus edulis
SUMMARY OF RESULTS FOR THE BIVALVE LARVAE
REFERENCE TOXICANT (COPPER) BIOASSAY
Test Dates: 4/7-4/9/94

Concentration (µg/L)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
0.56	1	92	5	19.4		5.2	
	2	76	3	15.8		3.8	
	3	86	6	18.4		6.5	
	Mean			17.9	86.3	5.2	12.0
3.2	1	99	24	24.6		19.5	
	2	95	22	23.4		18.8	
	3	89	17	21.2		16.0	
	Mean			23.1	100.0	18.1	0.0
10	1	88	16	20.8		15.4	
	2	11	91	20.4		89.2	
	3	29	45	14.8		60.8	
	Mean			18.7	90.2	55.1	8.0
32	1	0	34	6.8		100.0	
	2	0	12	2.4		100.0	
	3	0	50	10.0		100.0	
	Mean			6.4	30.9	100.0	68.5
56	1	0	0	0.0		100.0	
	2	0	6	1.2		100.0	
	3	0	13	2.6		100.0	
	Mean			1.3	6.1	100.0	93.8

Appendix 6
Laboratory Results Submitted by ABT - Second Test

RESULTS OF BIOASSAYS CONDUCTED ON TWO HIGH STRENGTH WASTE SAMPLES FROM THE VAN CAMP AND STARKIST TUNA CANNERIES IN AMERICAN SAMOA

Prepared for:

CH2M Hill California, Inc.
1111 Broadway
Oakland, CA 94607
Project # PDX 30702

Prepared by:

Advanced Biological Testing Inc.
98 Main St., # 419
Tiburon, Ca. 94920

November 21, 1994

Ref: 9309-3

1.0 INTRODUCTION

At the request of CH2M Hill (Project # PDX 30702), Advanced Biological Testing conducted acute effluent bioassay testing on *Mysidopsis bahia*, *Mytilus edulis*, and *Citharichthys stigmaeus* using high strength wastes (HSW) collected separately from the Starkist (HSW-1) and Van Camp (HSW-2) tuna canneries in American Samoa. The study was run using methods generally specified in EPA 1991 and in a Sampling and Testing Plan submitted to the EPA.

The study was conducted at the Advanced Biological Testing Laboratory in Tiburon, California, and was managed by Mr. Mark Fisler.

2.0 METHODS

2.1 EFFLUENT SAMPLING

The high strength wastes were sampled as composites on October 20, 1994 by personnel from the two canneries. Due to shipping and airline scheduling problems, frequently encountered in this region, the sample was received by the laboratory on October 24, 1994. A single gallon carboy was provided from each cannery and were labeled at ABT as HSW-1 (HSW-SKS Grab) and HSW-2 (Pipeline Sludge HS-W2, Van Camp). Samples were maintained in ice-filled coolers from the date of sampling until laboratory receipt. The samples were at 2-3°C upon receipt and were stored at 4°C until use.

2.2 SAMPLE PREPARATION AND TESTING METHODS

2.2.1 Testing on the speckled sanddab, *Citharichthys stigmaeus*

In agreement with the EPA regarding the proposed testing concentrations, the high strength wastes were tested at six concentrations starting from 2.0% and dropping using a 50% dilution factor. The final concentrations were 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% as vol:vol dilutions in seawater. The diluent was filtered seawater from San Francisco Bay. The dilutions were brought up to the test temperature (17 ± 2°C) and aerated continuously. These effluents have an extremely high biological oxygen demand, therefore aeration was carried out from the beginning of the test.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 25, 12.5, 6.25, 3.1, and 1.6 mg/L in 30 ppt seawater in a 24 hour test.

The bioassays were carried out on juvenile *Citharichthys stigmaeus*, supplied by J. Brezina and Associates in Dillon Beach, California. The animals were received at ABT on October 24, 1994. The test conditions are summarized in Table 1. Five replicates of each concentration were tested with ten juvenile fish per replicate. Water quality was monitored daily as initial quality on Day 0 and final water quality on Days 1-4. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature.

2.2.2 Testing on the mysid, *Mysidopsis bahia*

In agreement with the EPA regarding the proposed testing concentrations, the high strength wastes were tested at six concentrations starting from 2.0% and dropping using a 50% dilution factor. The final concentrations were 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% as vol:vol dilutions in seawater. The diluent was filtered seawater from San Francisco Bay The dilutions were brought up to the test temperature (16 ± 2°C) and aerated continuously.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 40, 20, 10, 5, 2.5 and 1.25 mg/L in 30 ppt seawater in a 96 hour test.

The first bioassay was carried out on 7-10 day old larval *Mysidopsis bahia*, supplied by Aquatox from Hot Springs, Arkansas. The animals were received at ABT on November 1, 1994. The test conditions for this test are summarized in Table 2. Five replicates of each concentration were tested with ten larval mysids per replicate. Water quality was monitored daily as initial quality on Day 0 and final water quality on Days 1-4. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature.

2.2.3 Bivalve Larval Bioassay

Test solutions used in the bioassays were prepared using San Francisco Bay seawater at 30 ppt in serial dilution (0.5) to create 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% test concentrations for the bioassays. The bivalve study was conducted under ASTM 1993 guidelines.

The reference toxicant for the bivalve larval bioassays was copper sulfate at test concentrations of 3.75, 7.5, 15, 30, and 60 µg/L.

The bivalve larvae survival and development test was run following methods in ASTM (1993). Bay mussels, *Mytilus edulis,* were obtained from A. K. Siewers, Santa Cruz, California. Adults were induced to spawn by heat shocking. Released gametes were placed in individual containers of filtered seawater and examined for viability. Gametes were mixed and allowed to fertilize for up to two hours, under gentle aeration. Fertilized eggs were then separated from sperm and debris by filtering the suspension at 20 µm. Egg stock density was estimated by counting an aliquot of dilute stock concentrate. Equal volumes of concentrate were added to each replicate to

an initial density of 15-30 embryos per mL. Initial stocking density was confirmed by counting a 5 mL aliquot from at least three control replicates.

Testing was conducted at 16 ± 2°C under a 14 hour light and 10 hour dark photoperiod. Temperature, pH, dissolved oxygen, and salinity were recorded at 0 and 48 hours; temperature was also recorded at 24 hours. Total ammonia in the 2% concentration was 3.6 mg/L at test initiation for HSW-1 and 6.1 mg/L for HSW-2. Ammonia was not measured on Day 2. At the end of the exposure period, a 5 mL sub-sample was taken from each test replicate and preserved with buffered formalin. Sub-samples were counted in a Sedgwick-Rafter cell, and the total number of normal and abnormal larvae were counted.

Gentle aeration was initiated on Day 0, and continued for the duration of the tests. To assess the effects of aeration, an aeration control was run simultaneously. No statistical differences were observed between aerated and unaerated controls.

2.3 STATISTICAL ANALYSIS

At the conclusion of the testing, the survival data were evaluated statistically using ToxCalc™ to determine ECp, NOEC, and LOEC values where appropriate. ToxCalc™ is a comprehensive statistical application that follows standard guidelines for acute and chronic toxicity data analysis. Data were evaluated statistically to estimate the LC50 and IC50 values for the tests using the Probit or Trimmed Spearman-Karber Method.

3.0 RESULTS

3.1 Initial Effluent Quality

The two High Strength Wastes were tested for basic water quality parameters upon receipt at the laboratory. HSW-1 had a dissolved oxygen level of 0.7 mg/L; a pH of 6.53; a salinity of 23.5 ppt; and a total ammonia level of 480 mg/L. HSW-2 had a dissolved oxygen level of 0.6 mg/L; a pH of 6.39; a salinity of 14.0 ppt; and a total ammonia level of 350 mg/L.

3.1 *Citharichthys stigmaeus*

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 17 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected after test initiation in all of the concentration even with supplemental aeration and aeration was maintained in all chambers for the duration of the test. Ammonia was measured in all replicates from each concentration daily and was a potentially significant toxic component of the test for the highest three concentrations.

The LC50 for HSW-1 was 0.35% based upon a Trimmed Spearman-Karber method. The majority of the observed toxicity again occurred in the first 24 hours. There was significant mortality at 2.0, 1.0, and 0.5% concentrations compared to the control at 96 hours. The NOEC was 0.25% and the LOEC was 0.5%

The LC50 for HSW-2 was 0.37% based upon a Trimmed Spearman-Karber method. The majority of the observed toxicity occurred in the first 24 hours. There was significant mortality at 2.0, 1.0, and 0.5% concentrations compared to the control at 96 hours. The NOEC was 0.25%, and the LOEC was 0.5%.

The reference toxicant test required the use of the Trimmed Spearman-Karber method and generated an LC50 of 3.9 mg/L, an NOEC of 3.1 mg/L, and an LOEC of 6.25 mg/L. This is the third reference toxicant test on *Citharichthys* at this laboratory, therefore no database has been established by this laboratory although the data has been consistent in the 3 - 4 mg/L range. The current laboratory mean is 3.92 mg/L.

3.2 *Mysidopsis bahia*

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 17 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected after test initiation in all of the concentration even with supplemental aeration and aeration was maintained in all chambers for the duration of the test. Ammonia was measured in all replicates from each concentration daily and was a potentially significant toxic component of the test for the highest three concentrations.

The LC50 for HSW-1 was 1.16%. At 96 hours, there was significant mortality at 2.0 and 1.0% concentrations compared to the control. The NOEC was 0.5% and the LOEC was 1.0%.

The LC50 for HSW-2 was 0.79%. again there was significant mortality at 96 hours in the 2.0 and 1.0% concentrations compared to the control. The NOEC was 0.5%, and the LOEC was 1.0%.

The reference toxicant test had an LC50 of 7.27 mg/L, with an NOEC of 1.25 mg/L and an LOEC of 2.5 mg/L. This is the third reference toxicant test on *Mysidopsis* at this laboratory, therefore no database has been established. The current mean is 13.5 mg/L.

3.3 BIVALVE LARVAL BIOASSAY

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 17 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected after test initiation in all of the concentration even with supplemental aeration and aeration was maintained in all chambers for the duration of the test. Ammonia was measured in all replicates from each concentration daily and was a potentially significant toxic component of the test for the highest three concentrations.

Control survival was acceptable at 100% with 1.4% abnormal development. The LC50 for HSW-1 was >2.0%, while the LC50 for HSW-2 was 0.2%. The IC50 for HSW-1 was 0.1% and the IC50 for HSW-2 was 0.18%.

The LC50 (6.1 µg/L) for the copper sulfate reference toxicant test was within two standard deviations of the laboratory mean of 15.9 µg/L indicating normal to higher sensitivity of the test organisms.

3.5 AMMONIA MEASUREMENTS

Ammonia in both of the HSW was very high. When measured in a 25% dilution in seawater, ammonia levels ranged from 88 to 120 mg/L. When converted to the 100% concentration, the ammonia level would be above 350 - 450 mg/L. The un-ionized fraction as NH_3 would range from 17 to 24 mg/L at 100% concentration.

TABLE 1

Bioassay Procedure And Organism Data For the Survival Bioassay Using *Citharichthys stigmaeus* (U.S. EPA 1991)

Parameter	Data
Test Species	*Citharichthys stigmaeus*
Supplier	J. Brezina and Associates
Collection location	Tomales Bay
Date Acquired	10/25/94
Acclimation Time	24 hours
Acclimation Water	30 ppt seawater
Acclimation Temperature	12 ± 2°C
Age group	Juveniles, 3-5 cm TL
Sample Identification	
Sample ID(s)	941024-19, -20
Date Sampled	10/20/94
Date Received at ABT	10/24/94
Volume Received	One gallon
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	96 hour static acute, renewal at 48 hours
Test Dates	10/26/94 to 10/30/94
Control Water	San Francisco Bay seawater
Test Temperature	17 ± 2°C
Test Photoperiod	16 L : 8 D
Initial Salinity	31 ± 2 ppt
Test Chamber	10 L polyethylene chamber
Animals/Replicate	10 animals/replicate
Exposure Volume	5 L
Replicates/Treatment	5
Feeding	None
Deviations from procedures	None

TABLE 2

Bioassay Procedure And Organism Data For the Survival Bioassay Using *Mysidopsis bahia* (U.S. EPA 1991)

Parameter	Data
Test Species	*Mysidopsis bahia*
Supplier	Aquatox, Arkansas
Date Acquired	11/1/94
Acclimation Time	None
Acclimation Water	Shipping water
Acclimation Temperature	20 ± 2°C
Age group	7-10 day larvae
Sample Identification	
Sample ID(s)	941024-19, -20
Date Sampled	10/20/94
Date Received at ABT	10/24/94
Volume Received	Five gallons
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute; static; renewal at 48 hours
Test Dates	11/1/94 to 11/5/94
Control Water	San Francisco Bay seawater
Test Temperature	18 ± 2°C
Test Photoperiod	14 L : 10 D
Initial Salinity	30 ppt
Test Chamber	1000 mL jars
Animals/Replicate	10 animal/replicate
Exposure Volume	500 mL
Replicates/Treatment	5
Feeding	Brine shrimp (24 hr old nauplii)
Deviations from procedures	None

TABLE 3

Bioassay Procedure And Organism Data For The 48 Hour Bioassay Using Larvae of *Mytilus edulis* (ASTM 1993)

Parameter	Data
Test Species	*Mytilus edulis*
Supplier	A.K. Siewers, Santa Cruz, CA
Date Acquired	10/25//94
Acclimation Time	None
Acclimation Water	Not applicable
Acclimation Temperature	Not applicable
Age group	Fertilized embryos, 2 hours
Sample Identification	
Sample ID(s)	941024-19, -20
Date Sampled	10/20/94
Date Received at ABT	10/24/94
Volume Received	One gallon
Sample Storage Conditions	4°C in the dark
Test Procedures	
Type; Duration	Acute; static; 48 hours
Test Dates	10/25/94 to 10/27/94
Control Water	San Francisco Bay seawater
Test Temperature	16 ± 2°C
Test Photoperiod	16 L : 8 D
Salinity	32 ± 2 ppt
Test Chamber	125 mL beakers
Animals/Replicate	Approximately 30 embryos per mL
Exposure Volume	100 mL
Replicates/Treatment	3
Feeding	None
Deviations from procedures	Chambers were gently aerated with low bubble aeration

TABLE 4

SUMMARY OF RESULTS FOR THE HIGH STRENGTH WASTE BIOASSAYS

Species	Test	Endpoint	HSW-1	HSW-2
Citharichthys stigmaeus	96 hr static	LC50	0.35%	0.37%
		NOEC	0.25%	0.25%
		LOEC	0.50%	0.50%
Mysidopsis bahia	96 hr static	LC50	1.16%	0.79%
		NOEC	0.50%	0.50%
		LOEC	1.00%	1.00%
Mytilus edulis	48 hr static	LC50	>2.0	0.20%
		IC50	0.10%	0.18%

Note:
HSW-1: Starkist
HSW-2: Van Camp

TABLE 5

SUMMARY OF RESULTS FOR THE REFERENCE TOXICANT TESTS

Citharichthys stigmaeus Concentration (mg/L)	SDS % Survival	LC50 (mg/L)	NOEC (mg/L)	LOEC (mg/L)
Control	100.0	3.9	3.1	6.25
1.6	100.0			
3.1	83.3			
6.25	0.0*			
12.5	0.0*			
25	0.0*			

Lab LC50 = 3.92.

Mysidopsis bahia Concentration (mg/L)	SDS % Survival	LC50 (mg/L)	NOEC (mg/L)	LOEC (mg/L)
Control	98.0	7.27	1.25	2.5
0.7	90.0			
1.25	90.0			
2.5	73.3*			
5	83.3*			
10	70.0*			
20	10.0*			
40	0.0*			

Lab LC50 = 13.52.

Bivalve larvae Concentration (µg/L)	Copper sulfate Mean Normal Larvae/mL	% Treatment Mortality	LC50 (µg/L)	(%) Abnormal
Initial Counts	23.5		6.1	
Control W/Air	23.5	NA		1.4
Control WO/Air	22.9	NA		3.8
3.75	19.0	6.4		1.8
7.5	2.3*	88.5		51.9
15	4.7*	76.7		100
30	0.0*	100.0		100
60	0.0*	100.0		100

* Statistically significant.

4.0 REFERENCES

U.S. EPA. 1991. Methods for measuring acute toxicity of effluents to freshwater and marine organisms, 4th ed. EPA 600/4-90/027, September, 1991.

ASTM. 1993. Annual Book of Standards. Vol. 11.04. Standard guide for conducting static acute toxicity tests starting with embryos of four species of saltwater bivalve mollusca. E-724-89.

APPENDIX A

ANALYTICAL DATA

APPENDIX TABLE 1

SAMPLE WATER QUALITY

Sample	pH (units)	DO (mg/L)	Total NH3 (mg/L)	Initial Salinity (ppt)
HSW-1	6.53	0.7	480	23.5
HSW-2	6.39	0.6	350	14

APPENDIX TABLE 2

Mytilus edulis

WATER QUALITY MEASUREMENTS FOR THE EFFLUENT TEST

Test Dates: 10/25-10/27/94

Concentration		Day 0				Day 1	Day 2			
(%)	Rep	pH	DO	°C	Sal	°C	pH	DO	°C	Sal
Control	1	8.06	8.8	16.7	32	16.2	8.00	8.8	16.9	32
W/Air	2					16.3	8.01	8.8	16.9	32
	3					16.2	8.02	8.6	16.9	32
Control	1	8.06	8.8	16.7	32	16.2	8.09	8.8	16.9	32
WO/Air	2					16.2	8.11	8.8	16.9	32
	3					16.2	8.13	8.8	16.9	32
HSW-1										
0.06	1	8.04	8.8	16.8	32	16.3	8.12	8.8	16.9	32
	2					16.2	8.09	8.7	16.9	32
	3					16.2	8.11	8.8	16.9	32
0.125	1	7.99	8.8	16.8	32	16.3	8.14	8.6	16.9	32
	2					16.2	8.08	8.6	16.9	33
	3					16.2	8.12	8.7	16.9	32
0.25	1	7.88	8.8	16.7	32	16.2	8.14	8.6	16.9	33
	2					16.2	8.12	8.6	16.9	32
	3					16.3	8.08	8.5	16.9	32
0.5	1	7.68	8.8	16.6	32	16.2	8.02	6.2	16.9	32
	2					16.2	7.75	6.0	16.9	32
	3					16.2	7.68	6.1	16.9	32
1	1	7.34	8.8	16.6	32	16.2	8.01	4.8	16.9	32
	2					16.3	8.00	4.9	16.9	32
	3					16.3	7.93	4.8	16.9	32
2	1	6.96	8.4	16.6	32	16.2	8.04	3.4	16.9	32
	2					16.2	7.99	3.2	16.9	32
	3					16.2	8.05	3.4	16.9	32
	Min	6.96	8.4	16.6	32	16.2	7.68	3.2	16.9	32
	Max	8.06	8.8	16.8	32	16.3	8.14	8.8	16.9	33

APPENDIX TABLE 2 (Cont'd)

Mytilus edulis

WATER QUALITY MEASUREMENTS FOR THE EFFLUENT TEST

Test Dates: 4/7-4/9/94

Concentration		Day 0				Day 1	Day 2			
(%)	Rep	pH	DO	°C	Sal	°C	pH	DO	°C	Sal
HSW-2										
0.06	1	8.06	8.8	16.7	32	16.3	8.12	8.6	16.9	32
	2					16.3	8.15	8.5	16.9	32
	3					16.3	8.16	8.6	16.9	32
0.125	1	8.04	8.9	16.6	32	16.2	8.17	8.5	16.9	32
	2					16.2	8.17	8.5	16.8	32
	3					16.2	8.19	8.5	16.9	32
0.25	1	7.94	8.8	16.7	32	16.2	8.20	8.4	17.0	32
	2					16.2	8.19	8.5	16.9	32
	3					16.3	8.14	8.2	16.9	32
0.5	1	7.77	8.7	16.7	32	16.3	7.73	3.4	16.9	32
	2					16.3	8.11	7.8	16.9	32
	3					16.3	8.15	7.8	16.9	32
1	1	7.40	8.7	16.8	32	16.2	8.09	7.4	17.0	32
	2					16.2	8.19	7.6	16.9	32
	3					16.2	8.20	7.6	16.9	32
2	1	6.92	8.6	16.6	32	16.2	8.03	3.8	16.9	32
	2					16.2	8.03	4.8	16.9	32
	3					16.2	7.98	4.6	16.9	32
	Min	6.92	8.6	16.6	32	16.2	7.73	3.4	16.8	32
	Max	8.06	8.9	16.8	32	16.3	8.20	8.6	17.0	32

APPENDIX TABLE 3

Mytilus edulis

SUMMARY OF RESULTS FOR BIVALVE LARVAE HIGH STRENGTH WASTE BIOASSAY

Test Dates: 10/25-10/27/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
Initial Counts	1	110		22.0			
	2	135		27.0			
	3	108		21.6			
	Mean			23.5			
Final Control W/Air	1	101	0	20.2		0.0	
	2	129	0	25.8		0.0	
	3	117	5	24.4		4.1	
	Mean			23.5	100.0	1.4	NA
Final Control WO/Air	1	104	5	21.8		4.6	
	2	109	3	22.4		2.7	
	3	118	5	24.6		4.1	
	Mean			22.9	100.0	3.8	NA
HSW-1 0.06	1	82	12	18.8		12.8	
	2	89	14	20.6		13.6	
	3	78	15	18.6		16.1	
	Mean			19.3	93.4	14.2	4.8
0.125	1	23	72	19.0		75.8	
	2	18	58	15.2		76.3	
	3	20	71	18.2		78.0	
	Mean			17.5	84.4	76.7	14.0
0.25	1	3	82	17.0		96.5	
	2	1	77	15.6		98.7	
	3	3	85	17.6		96.6	
	Mean			16.7	80.8	97.3	17.6
0.5	1	0	85	17.0		100.0	
	2	0	93	18.6		100.0	
	3	0	81	16.2		100.0	
	Mean			17.3	83.4	100.0	14.9
1	1	0	89	17.8		100.0	
	2	0	94	18.8		100.0	
	3	0	97	19.4		100.0	
	Mean			18.7	90.2	100.0	8.0
2	1	0	95	19.0		100.0	
	2	0	96	19.2		100.0	
	3	0	87	17.4		100.0	
	Mean			18.5	89.5		8.7

APPENDIX TABLE 3 (Cont'd)

Mytilus edulis

SUMMARY OF RESULTS FOR BIVALVE LARVAE HIGH STRENGTH WASTE BIOASSAY

Test Dates: 10/25-10/27/94

Concentration (%)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
HSW-2							
0.06	1	102	3	21.0		2.9	
	2	87	2	17.8		2.2	
	3	117	3	24.0		2.5	
	Mean			20.9	100.0	2.5	0.0
0.125	1	67	13	16.0		16.3	
	2	61	12	14.6		16.4	
	3	52	12	12.8		18.8	
	Mean			14.5	69.9	17.1	28.7
0.25	1	0	38	7.6		100.0	
	2	0	27	5.4		100.0	
	3	0	33	6.6		100.0	
	Mean			6.5	31.6	100.0	67.8
0.5	1	0	27	5.4		100.0	
	2	0	27	5.4		100.0	
	3	0	27	5.4		100.0	
	Mean			5.4	26.1	100.0	73.4
1	1	0	36	7.2		100.0	
	2	0	39	7.8		100.0	
	3	0	31	6.2		100.0	
	Mean			7.1	34.1	100.0	65.2
2	1	0	37	7.4		100.0	
	2	0	31	6.2		100.0	
	3	0	36	7.2		100.0	
	Mean			6.9	33.5	100.0	65.8

APPENDIX TABLE 4

Mytilus edulis
WATER QUALITY MEASUREMENTS
FOR THE REFERENCE TOXICANT (C0PPER) TEST

Concentration		Day 0				Day 1	Day 2			
µg/L	Rep	pH	DO	°C	Sal	°C	pH	DO	°C	Sal
3.75	1	8.08	8.8	16.7	32	16.4	8.15	8.4	17.0	32
	2					16.4	8.13	8.5	16.9	32
	3					16.4	8.15	8.6	16.9	32
7.5	1	8.09	8.8	16.7	32	16.5	8.18	8.6	16.9	32
	2					16.4	8.18	8.4	16.9	32
	3					16.5	8.16	8.4	16.9	32
15	1	8.10	8.7	16.7	32	16.5	8.17	8.5	16.9	32
	2					16.5	8.18	8.5	17.0	32
	3					16.5	8.18	8.4	17.0	32
30	1	8.10	8.7	16.8	31	16.5	8.17	8.4	16.9	32
	2					16.5	8.17	8.4	16.9	32
	3					16.5	8.16	8.5	16.9	32
60	1	8.11	8.7	16.7	30	16.5	8.16	8.5	16.9	32
	2					16.4	8.17	8.6	16.9	32
	3					16.5	8.16	8.6	17.0	32
	Min	8.08	8.7	16.7	30	16.4	8.13	8.4	16.9	32
	Max	8.11	8.8	16.8	32	16.5	8.18	8.6	17.0	32

APPENDIX TABLE 5

Mytilus edulis
SUMMARY OF RESULTS FOR THE BIVALVE LARVAE
REFERENCE TOXICANT (COPPER) BIOASSAY

Concentration (µg/L)	Rep	Total Normal	Total Abnormal	Total Larvae/mL	% Survival	% Abnormal	Treatment Mortality (%)
3.75	1	90	2	18.4		2.2	
	2	97	1	19.6		1.0	
	3	93	2	19.0		2.1	
	Mean			19.0	91.8	1.8	6.4
7.5	1	4	5	1.8		55.6	
	2	6	7	2.6		53.8	
	3	7	6	2.6		46.2	
	Mean			2.3	11.3	51.9	88.5
15	1	0	27	5.4		100.0	
	2	0	21	4.2		100.0	
	3	0	23	4.6		100.0	
	Mean			4.7	22.9	100.0	76.7
30	1	0	0	0.0		100.0	
	2	0	0	0.0		100.0	
	3	0	0	0.0		100.0	
	Mean			0.0	0.0	100.0	100.0
60	1	0	0	0.0		100.0	
	2	0	0	0.0		100.0	
	3	0	0	0.0		100.0	
	Mean			0.0	0.0	100.0	100.0

APPENDIX TABLE 6

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	7.98	7.9	0.03	17.1	32	8.18	8.2		17.2	33	8.16	7.2	0.02	17.1	33	8.17	7.3	0.03	17.4	33	8.05	8.0	0.03	17.9	34
	2						8.23	8.1	0.03	17.0	33	8.23	7.2		16.5	33	8.22	7.2		17.1	33	8.14	8.0		17.7	34
	3						8.22	8.1		16.9	32	8.24	7.2		16.3	33	8.24	7.3		16.9	33	8.17	8.0		17.6	34
	4						8.22	8.4		16.6	33	8.24	7.2		16.2	33	8.24	7.4		16.8	33	8.18	8.1		17.5	34
	5						8.22	8.5		16.5	33	8.24	7.4		16.0	33	8.25	7.4		16.6	33	8.20	8.2		17.2	34
0.06	1	7.93	8.0	0.14	17.3	32	8.17	8.5		17.2	33	8.24	7.6	0.11	16.6	33	8.23	7.6	0.11	17.2	34	8.18	8.2	0.10	17.7	34
	2						8.15	8.5	0.10	17.0	32	8.25	7.5		16.5	33	8.20	7.4		17.0	33	8.13	8.2		17.6	34
	3						8.13	8.3		16.8	32	8.23	7.4		16.4	33	8.20	7.4		16.9	33	8.14	8.1		17.6	34
	4						8.20	8.2		16.5	33	8.19	7.4		16.2	33	8.13	7.4		16.6	34	7.98	8.0		17.3	34
	5						8.21	8.2		16.4	31	8.21	7.4		16.0	33	8.16	7.4		16.5	34	8.09	7.8		17.0	34
0.125	1	7.87	8.0	0.27	17.2	32	8.09	8.4		17.2	33	8.22	7.6	0.19	16.6	33	8.21	7.5	0.21	17.2	34	8.15	8.0	0.20	17.6	34
	2						8.02	8.4	0.22	17.0	33	8.24	7.5		16.5	33	8.21	7.4		17.1	33	8.16	8.0		17.6	34
	3						8.01	8.5		16.8	32	8.21	7.4		16.2	33	8.21	7.4		16.8	33	8.14	8.0		17.4	34
	4						8.03	8.3		16.5	33	8.25	7.4		16.0	33	8.25	7.4		16.5	34	8.21	8.0		17.0	34
	5						8.14	8.4		15.9	33	8.25	7.4		16.0	33	8.26	7.4		16.5	34	8.22	8.0		16.9	34
0.25	1	7.72	8.1	0.51	17.2	32	8.01	8.2		17.2	33	8.27	7.6	0.38	16.7	33	8.26	7.6	0.40	17.1	34	8.21	8.2	0.39	17.5	34
	2						8.01	8.2	0.70	17.0	33	8.26	7.6		16.5	33	8.27	7.6		17.0	34	8.20	8.0		17.5	34
	3						7.85	7.7		16.9	32	8.17	7.4		16.4	33	8.21	7.5		16.9	33	8.12	8.0		17.4	34
	4						8.02	7.8		16.5	33	8.23	7.4		16.0	33	8.22	7.4		16.6	34	8.15	7.8		17.0	34
	5						8.09	8.6		16.0	33	8.24	7.4		16.0	33	8.25	7.4		16.4	34	8.19	7.8		16.9	34
0.5	1	7.55	8.1	0.93	17.2	32	7.97	6.6		17.2	33	8.10	7.6	0.70	16.6	33	8.28	7.6	0.60	17.2	33	8.27	8.0	0.74	17.6	34
	2						7.84	7.7	0.40	17.0	32	8.20	7.4		16.5	33	8.23	7.5		17.0	33	8.19	8.0		17.6	34
	3						7.73	6.8		16.9	32	8.16	7.3		16.5	33	8.21	7.4		16.9	33	8.24	7.9		17.4	34
	4						7.78	7.6		16.6	33	8.13	7.2		16.3	33	8.21	7.4		16.6	34	8.18	7.8		17.2	34
	5						7.77	7.9		16.2	33	8.13	7.2		16.0	33	8.20	7.4		16.5	34	8.13	7.8		16.9	34
1	1	7.18	7.8	1.80	17.2	32	7.66	6.9		17.2	32	8.18	7.4	1.44	16.9	33	8.23	7.6	1.26	17.2	33	8.20	7.8	1.18	17.7	34
	2						7.81	7.1	1.50	17.0	32	8.23	7.3		16.6	33	8.28	7.4		17.1	33	8.26	7.8		17.7	34
	3						7.65	6.3		17.0	32	8.18	7.2		16.5	33	8.27	7.4		17.1	33	8.12	7.6		17.6	34
	4						7.60	5.9		16.7	33	8.14	7.2		16.2	33	8.23	7.3		16.7	32	8.17	7.6		17.3	34
	5						7.51	5.2		16.5	33	8.07	7.2		16.0	33	8.16	7.3		16.3	34	8.14	7.4		17.0	34
2.0	1	6.84	7.7	3.60	17.2	32	7.56	3.5		15.9	33	8.22	7.2	2.82	16.0	33	8.30	7.3	2.16	16.3	34	8.31	7.4	2.07	16.8	34
	2						7.47	2.0	3.70	15.7	33	8.09	7.2		16.0	34	—	—	—	—	—	—	—	—	—	—
	3						7.49	2.0		15.6	33	8.05	6.7		16.0	34	—	—	—	—	—	—	—	—	—	—
	4						7.38	0.6		15.8	33	8.14	6.7		16.0	34	—	—	—	—	—	—	—	—	—	—
	5						7.66	3.8		15.9	34	8.18	6.9		16.0	34	8.30	7.4		16.2	34	8.31	7.6		16.7	34
Min		6.84	7.7	0.03	17.1	32	7.38	0.6	0.03	15.6	31	8.05	6.7	0.02	16.0	33	8.13	7.2	0.03	16.2	32	7.98	7.4	0.03	16.7	34
Max		7.98	8.1	3.60	17.3	32	8.23	8.6	3.70	17.2	34	8.27	7.6	2.82	17.1	34	8.30	7.6	2.16	17.4	34	8.31	8.2	2.07	17.9	34

Note: — = All animals dead.

APPENDIX TABLE 6 (Cont'd)

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
0.06	1	7.84	8.1	0.24	17.6	32	8.15	8.1		17.2	33	8.26	7.2	0.16	16.6	33	8.28	7.6	0.20	17.1	34	8.27	8.2	0.18	17.6	34
	2						8.02	8.0	0.28	16.9	33	8.19	7.2		16.4	33	8.20	7.5		16.9	34	8.18	8.1		17.4	34
	3						8.18	8.0		16.5	33	8.24	7.2		16.0	33	8.26	7.4		16.7	34	8.24	8.1		17.2	34
	4						8.20	8.1		16.3	33	8.26	7.4		16.0	33	8.26	7.4		16.5	34	8.26	8.0		17.0	34
	5						8.20	8.0		16.2	34	8.25	7.4		16.0	33	8.15	7.5		16.5	34	8.27	8.0		17.0	34
0.125	1	7.79	8.1	0.47	17.7	32	8.12	8.1		17.2	33	8.25	7.5	0.27	16.5	34	8.28	7.4	0.32	17.0	34	8.27	8.2	0.28	17.4	34
	2						8.11	8.0	0.32	16.9	33	8.25	7.4		16.4	33	8.27	7.4		16.8	34	8.26	8.2		17.4	34
	3						8.05	8.0		16.6	33	8.21	7.4		16.2	33	8.26	7.4		16.6	34	8.12	8.0		17.2	34
	4						8.15	8.0		16.2	33	8.23	7.3		16.1	33	8.26	7.4		16.5	34	8.21	7.6		17.0	34
	5						8.17	8.1		16.2	33	8.27	7.4		16.0	34	8.27	7.6		16.5	34	8.26	7.6		16.9	34
0.25	1	7.66	8.0	0.84	17.6	32	7.95	7.8		17.1	33	8.24	7.4	0.54	16.4	33	8.26	7.6	0.51	16.9	34	8.25	8.0	0.47	17.4	34
	2						7.89	7.8	0.60	16.9	33	8.18	7.4		16.3	33	8.24	7.4		16.9	34	8.20	8.0		17.4	34
	3						7.93	7.8		16.6	33	8.20	7.2		16.2	33	8.24	7.4		16.6	34	8.21	7.9		17.2	34
	4						7.92	7.8		16.5	33	8.20	7.2		16.1	33	8.22	7.4		16.5	34	8.19	7.8		17.0	34
	5						8.01	7.8		16.2	33	8.20	7.2		16.0	34	8.25	7.4		16.5	34	8.23	7.8		16.9	34
0.5	1	7.43	7.9	1.60	17.6	32	7.89	7.8		17.1	33	8.25	7.4	1.10	16.2	33	8.27	7.5	1.05	16.8	34	8.26	8.0	0.98	17.2	34
	2						7.83	7.8	1.21	16.9	33	8.21	7.4		16.2	33	8.27	7.4		16.7	34	8.27	7.9		17.2	34
	3						7.79	7.4		16.7	33	8.20	7.2		16.1	33	8.27	7.4		16.6	34	8.23	7.8		17.2	34
	4						7.77	7.4		16.5	33	8.16	7.2		16.0	33	8.25	7.4		16.5	34	8.21	7.6		17.0	34
	5						7.94	7.8		16.2	33	8.24	7.2		16.0	34	8.30	7.4		16.5	34	8.28	7.6		16.9	34
1	1	7.10	7.8	3.20	17.6	32	7.64	5.8		16.9	33	8.25	7.3	2.21	16.0	34	—	—	—	—	—	—	—	—	—	—
	2						7.50	0.8	2.57	16.9	33	8.15	7.3		16.0	33	—	—	—	—	—	—	—	—	—	—
	3						7.62	5.2		16.6	33	8.20	7.2		16.0	33	8.24	7.4	2.05	16.5	34	8.28	7.8	2.01	17.0	34
	4						7.62	5.0		16.4	33	8.21	7.2		16.1	33	8.29	7.4		16.5	34	8.31	7.6		16.9	34
	5						7.67	4.8		16.2	33	8.17	7.2		16.0	34	8.25	7.3		16.5	34	8.22	7.6		16.9	34
2.0	1	6.82	7.2	6.10	17.9	32	7.45	0.8		17.0	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.49	0.4	5.28	16.7	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.40	0.6		16.5	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.57	1.8		16.3	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.47	0.6		16.2	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		6.82	7.2	0.24	17.6	32	7.40	0.4	0.28	16.2	33	8.15	7.2	0.16	16.0	33	8.15	7.3	0.20	16.5	34	8.12	7.6	0.18	16.9	34
Max		7.84	8.1	6.10	17.9	32	8.20	8.1	5.28	17.2	34	8.27	7.5	2.21	16.6	34	8.30	7.6	2.05	17.1	34	8.31	8.2	2.01	17.6	34

Note: — = All animals dead.

APPENDIX TABLE 7

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	9	9	9	90	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.06	1	10	10	9	9	9	90	
	2	10	10	9	10	10	100	
	3	10	10	10	9	9	90	
	4	10	9	9	8	8	80	
	5	10	9	9	9	9	90	90.0
0.125	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.25	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.5	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	9	9	90	98.0
1	1	10	10	10	10	9	90	
	2	10	10	10	10	6	60	
	3	10	10	10	10	7	70	
	4	10	10	10	10	6	60	
	5	10	10	8	6	5	50	66.0
2	1	10	*	3	3	1	10	
	2	10	*	0	—	—	0	
	3	10	*	0	—	—	0	
	4	10	*	0	—	—	0	
	5	10	*	2	2	1	10	4.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 7 (Cont'd)

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.06	1	10	10	10	10	10	100	
	2	10	10	7	6	5	50	
	3	10	10	10	10	10	100	
	4	10	10	7	7	6	60	
	5	10	10	9	9	9	90	80.0
0.125	1	10	10	10	10	10	100	
	2	10	10	9	9	8	80	
	3	10	10	10	10	9	90	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	94.0
0.25	1	10	10	10	10	9	90	
	2	10	10	10	10	9	90	
	3	10	10	10	9	9	90	
	4	10	10	10	9	9	90	
	5	10	10	8	8	7	70	86.0
0.5	1	10	10	9	9	9	90	
	2	10	10	10	9	9	90	
	3	10	10	10	9	9	90	
	4	10	10	10	10	9	90	
	5	10	10	9	9	8	80	88.0
1	1	10	*	0	—	—	0	
	2	10	*	0	—	—	0	
	3	10	*	2	2	3	30	
	4	10	*	2	2	2	20	
	5	10	*	2	2	2	20	14.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 8

Mysidopsis bahia
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1				Day 2				Day 3				Day 4			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal
0.7	1	8.06	8.2	15.9	33	8.16	7.2	17.4	33	8.16	7.2	17.4	33	8.03	7.4	17.6	33	7.88	6.8	18.2	33
	2					8.19	7.1	17.2	33	8.16	7.2	17.3	33	8.07	7.4	17.6	33	7.91	6.7	18.2	33
	3					8.20	7.1	17.3	33	8.16	7.1	17.3	33	8.06	7.2	17.6	33	7.88	6.6	18.2	33
1.25	1	8.07	8.1	15.9	32	8.19	7.0	17.2	33	8.17	7.0	17.3	33	8.08	7.2	17.6	33	7.93	6.5	18.2	33
	2					8.19	7.0	17.0	33	8.16	7.0	17.2	33	8.07	7.2	17.6	33	7.93	6.6	18.0	33
	3					8.19	7.0	17.1	33	8.15	7.1	17.2	33	8.07	7.2	17.5	33	7.93	6.6	18.0	33
2.5	1	8.07	8.1	15.8	32	8.16	6.9	17.2	33	8.13	7.0	17.3	33	8.05	7.2	17.6	33	7.93	6.7	18.2	33
	2					8.15	6.5	17.0	33	8.12	7.0	17.0	33	8.05	7.2	17.5	33	7.96	6.6	18.0	33
	3					8.14	6.4	17.0	33	8.12	7.0	17.1	33	8.03	7.2	17.6	33	7.89	6.7	18.0	33
5	1	8.08	8.1	15.9	32	8.11	6.4	17.2	33	8.08	7.0	17.4	33	8.02	7.2	17.6	33	7.90	6.5	18.3	33
	2					8.11	6.0	17.0	33	8.08	6.8	17.3	33	8.01	7.0	17.6	33	7.91	6.5	18.1	33
	3					8.10	5.8	17.0	33	8.09	6.8	17.2	33	8.00	7.0	17.6	33	7.89	6.4	18.2	33
10	1	8.08	8.0	15.8	32	8.05	5.8	17.3	33	8.01	6.4	17.5	33	7.98	7.0	17.9	33	7.89	6.4	18.6	33
	2					8.07	5.8	17.1	33	7.99	6.4	17.3	33	7.98	7.0	17.8	33	7.89	6.4	18.3	33
	3					8.08	5.1	17.2	33	7.98	6.4	17.3	33	7.98	7.0	17.6	33	7.87	6.4	18.3	33
20	1	8.09	8.0	15.8	32	8.05	4.8	17.5	33	7.80	4.5	17.7	33	—	—	—	—	—	—	—	—
	2					8.06	4.7	17.3	33	7.77	4.4	17.6	33	7.83	7.1	18.0	33	7.85	6.4	18.7	33
	3					8.05	4.7	17.2	33	7.78	4.4	17.4	33	7.81	6.4	17.8	33	7.92	6.7	18.6	34
40	1	8.09	8.1	15.7	32	8.12	6.0	17.8	33	—	—	—	—	—	—	—	—	—	—	—	—
	2					8.17	6.2	17.8	33	—	—	—	—	—	—	—	—	—	—	—	—
	3					8.17	6.2	17.8	33	—	—	—	—	—	—	—	—	—	—	—	—
Min		8.06	8.0	15.7	32	8.05	4.7	17.0	33.0	7.77	4.4	17.0	33.0	7.81	6.4	17.5	33.0	7.85	6.4	18.0	33.0
Max		8.09	8.2	15.9	33	8.20	7.2	17.8	33.0	8.17	7.2	17.7	33.0	8.08	7.4	18.0	33.0	7.96	6.8	18.7	34.0

Note: — = All animals dead.

APPENDIX TABLE 9

Mysidopsis bahia
SURVIVAL DATA FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.7	1	10	10	9	8	8	80	
	2	10	10	10	10	10	100	
	3	10	10	9	9	9	90	90.0
1.25	1	10	10	9	9	9	90	
	2	10	10	9	9	9	90	
	3	10	10	10	10	9	90	90.0
2.5	1	10	10	8	8	8	80	
	2	10	10	7	7	7	70	
	3	10	9	8	8	7	70	73.3
5	1	10	10	10	10	10	100	
	2	10	10	7	7	6	60	
	3	10	9	9	9	9	90	83.3
10	1	10	10	9	8	8	80	
	2	10	8	7	7	7	70	
	3	10	8	7	6	6	60	70.0
20	1	10	2	0	—	—	0	
	2	10	2	2	2	2	20	
	3	10	1	1	1	1	10	10.0
40	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	0.0

Note: — = All animals dead.

APPENDIX TABLE 10

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 10/26-10/30/94
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.02	8.6	<0.01	16.5	32	8.05	8.2	0.08	16.8	32	8.03	8.8	0.08	14.6	33	7.94	6.8	0.08	15.4	33	7.95	8.2	0.09	15.7	33
	2						7.92	8.3	0.08	16.9	32	7.82	8.8	0.09	14.7	33	7.78	7.0	0.09	15.5	33	7.81	8.2	0.14	15.7	33
	3						7.91	7.8	0.07	16.9	32	7.84	9.0	0.09	14.6	33	7.79	6.8	0.07	15.5	33	7.81	7.2	0.19	15.7	33
	4						8.04	8.1	0.07	16.8	32	7.99	8.7	0.08	14.5	33	8.00	6.6	0.07	15.4	33	7.99	8.1	0.18	15.6	33
	5						8.00	8.2	0.07	16.8	32	7.99	8.8	0.09	14.6	33	7.94	6.6	0.08	15.4	33	7.97	8.1	0.17	15.6	33
0.06	1	7.95	8.6	0.16	16.4	32	7.90	8.1	0.14	16.7	32	8.00	9.0	0.17	14.6	33	7.99	7.2	0.16	15.4	33	8.00	8.1	0.29	15.7	33
	2						7.89	8.0	0.14	16.6	32	8.01	9.0	0.17	14.5	33	8.00	7.2	0.18	15.5	33	8.03	8.1	0.26	15.6	34
	3						7.95	8.0	0.14	16.5	32	8.04	9.0	0.17	14.5	33	8.04	7.0	0.14	15.4	33	8.06	8.3	0.29	15.5	34
	4						7.83	7.6	0.15	16.3	32	8.02	9.0	0.18	14.2	33	7.94	7.2	0.18	15.3	33	7.95	8.2	0.30	15.2	34
	5						7.82	7.8	0.15	16.2	32	7.97	8.9	0.18	14.2	33	7.93	7.2	0.17	15.4	33	7.96	7.9	0.31	15.0	33
0.125	1	7.93	8.6	0.23	16.4	32	7.61	5.1	0.21	16.3	32	7.99	8.9	0.21	14.2	33	7.98	7.4	0.20	15.4	33	8.01	8.1	0.35	15.3	34
	2						7.59	5.0	0.22	16.2	32	7.99	9.0	0.24	14.2	33	7.95	7.2	0.24	15.2	33	8.01	8.1	0.40	15.2	34
	3						7.76	7.2	0.22	16.0	32	8.01	9.1	0.23	14.2	33	7.97	7.2	0.20	15.4	33	8.03	8.2	0.48	15.4	34
	4						7.64	5.6	0.19	16.2	32	8.01	9.1	0.23	14.3	33	7.97	7.0	0.19	15.2	33	8.00	8.1	0.53	15.3	34
	5						7.86	7.3	0.19	16.2	32	8.03	9.1	0.23	14.2	33	8.04	7.0	0.21	15.3	33	8.08	8.0	0.51	15.2	34
0.25	1	7.83	8.6	0.47	16.5	32	7.58	4.6	0.35	16.0	32	7.94	9.0	0.37	13.9	34	7.90	7.2	0.34	15.3	33	7.97	8.1	0.53	14.5	36
	2						7.65	4.7	0.36	16.0	32	8.04	8.8	0.37	14.0	33	8.01	7.3	0.33	15.3	33	8.10	8.0	0.62	14.7	35
	3						7.62	4.6	0.35	16.0	32	8.07	8.9	0.36	14.3	33	8.03	7.3	0.37	15.4	33	8.10	8.2	0.57	14.9	34
	4						7.67	4.7	0.34	15.9	32	8.03	9.0	0.36	14.4	33	7.92	7.3	0.36	15.4	33	8.03	8.2	0.66	15.1	34
	5						7.67	4.8	0.34	16.0	32	8.08	9.1	0.36	14.3	33	8.05	7.2	0.37	15.3	33	8.11	8.3	0.61	14.9	35
0.5	1	7.63	8.5	0.92	16.4	32	7.50	1.2	0.74	16.5	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.50	0.9	0.67	16.6	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.52	0.8	0.76	16.6	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.51	1.3	0.75	16.6	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.57	1.0	0.66	16.6	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	1	7.33	8.5	1.98	16.4	31	7.45	0.8	1.58	16.5	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.46	0.9	1.62	16.5	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.47	0.6	1.59	16.5	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.48	0.8	1.54	16.4	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.46	0.8	1.63	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	1	6.99	8.1	3.95	16.5	31	7.41	0.6	3.18	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.40	0.4	3.20	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.48	0.6	3.12	16.0	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.41	0.8	3.15	16.1	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.45	0.8	3.19	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		6.99	8.1	<0.10	16.4	31	7.40	0.4	0.07	15.9	32	7.82	8.7	0.08	13.9	33	7.78	6.6	<0.10	15.2	33	7.81	7.2	0.09	14.5	33
Max		8.02	8.6	3.95	16.5	32	8.05	8.3	3.20	16.9	32	8.08	9.1	0.37	14.7	34	8.05	7.4	0.37	15.5	33	8.11	8.3	0.66	15.7	36

Note: — = All animals dead.

APPENDIX TABLE 10 (Cont'd)

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 10/26-10/30/94
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
0.06	1	8.00	8.5	0.19	16.5	32	7.76	7.0	0.20	16.5	32	8.03	9.2	0.17	14.8	32	8.07	7.4	0.17	15.5	33	8.09	8.2	0.17	15.5	33
	2						7.84	7.2	0.17	16.4	32	8.03	9.1	0.17	14.4	33	8.04	7.2	0.16	15.4	33	8.08	8.3	0.20	15.5	33
	3						7.84	7.2	0.18	16.3	32	8.02	9.1	0.18	14.2	33	8.05	7.2	0.18	15.5	33	8.08	8.3	0.21	15.3	34
	4						7.75	6.2	0.17	16.4	32	8.00	9.0	0.18	14.2	33	8.01	7.0	0.17	15.5	33	8.06	8.2	0.19	15.2	34
	5						7.79	6.6	0.18	15.9	32	8.04	8.9	0.18	14.5	33	8.05	7.1	0.19	15.4	33	8.10	8.2	0.23	14.4	36
0.125	1	7.94	8.6	0.30	16.5	32	7.70	6.4	0.27	16.2	32	7.99	8.9	0.26	14.2	33	8.02	7.5	0.21	15.4	33	8.06	8.3	0.31	15.3	34
	2						7.81	6.2	0.27	16.3	32	8.03	9.1	0.27	14.3	33	8.04	7.3	0.25	15.4	33	8.09	8.1	0.34	15.3	34
	3						7.81	6.0	0.27	16.4	32	8.04	9.2	0.26	14.3	33	8.05	7.2	0.25	15.5	33	8.10	8.3	0.29	15.3	34
	4						7.58	6.1	0.29	15.9	32	8.04	9.2	0.26	13.8	33	8.06	7.2	0.27	15.3	33	8.11	8.3	0.31	14.8	35
	5						7.76	6.2	0.29	15.9	32	8.06	9.2	0.25	13.8	33	8.07	7.2	0.27	15.3	33	8.13	8.3	0.34	14.8	34
0.25	1	7.79	8.6	0.62	16.4	32	7.70	4.2	0.57	15.9	32	7.94	9.2	0.47	13.9	33	8.00	7.4	0.44	15.2	33	8.05	8.3	0.47	14.9	34
	2						7.70	4.5	0.58	15.9	32	7.91	8.9	0.47	13.8	33	7.96	7.2	0.41	15.3	33	8.02	8.2	0.49	14.9	34
	3						7.64	4.6	0.55	15.9	32	7.98	8.8	0.47	13.8	33	7.99	7.2	0.41	15.3	33	8.07	8.0	0.41	14.8	34
	4						7.61	4.6	0.53	16.1	32	7.89	8.8	0.46	14.0	33	7.92	7.3	0.40	15.3	33	8.00	8.1	0.47	15.2	34
	5						7.59	4.6	0.52	16.2	32	7.92	8.8	0.47	14.2	33	7.91	7.2	0.43	15.3	33	7.98	7.9	0.49	15.2	34
0.5	1	7.54	8.7	1.24	16.5	32	7.57	1.6	1.07	16.2	32	7.97	8.7	0.87	14.0	33	8.04	7.0	0.79	15.4	33	8.08	8.2	0.74	14.9	34
	2						7.49	1.8	1.16	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.54	1.8	1.09	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.56	1.8	1.08	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.57	1.9	1.03	16.3	32	8.05	8.8	0.86	14.2	33	8.09	7.0	0.83	15.4	33	8.15	8.2	0.69	15.0	35
1	1	7.23	8.6	2.41	16.5	32	7.61	0.9	2.10	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.62	0.9	2.24	16.3	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.54	1.0	2.22	16.4	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.54	0.8	2.31	15.8	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.51	0.8	2.31	15.7	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2.0	1	6.86	8.3	5.15	16.5	31	7.80	0.6	4.88	15.8	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.56	0.6	4.47	15.9	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.60	0.8	4.65	15.9	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.60	0.8	4.40	16.0	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.56	0.6	4.32	16.2	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		6.86	8.3	0.19	16.4	31	7.49	0.6	0.17	15.7	32	7.89	8.7	0.17	13.8	32	7.91	7.0	<0.10	15.2	33	7.98	7.9	0.19	14.4	33
Max		8.00	8.7	5.15	16.5	32	7.84	7.2	4.88	16.5	32	8.06	9.2	0.87	14.8	33	8.09	7.5	0.83	15.5	33	8.15	8.3	0.74	15.5	36

Note: — = All animals dead.

APPENDIX TABLE 11

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.06	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.125	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.25	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.5	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
1	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Note: — = All animals dead.

APPENDIX TABLE 11 (Cont'd)

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.06	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.125	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	9	10	10	100	100.0
0.25	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.5	1	10	4	2	2	2	20	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	2	2	2	2	20	8.0
1	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Note: — = All animals dead.

APPENDIX TABLE 12

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal
Control	**1**	7.93	9.4	15.4	31	7.75	5.0	NT	NT
	2					7.73	4.8	NT	NT
	3					7.69	4.8	NT	NT
1.6	**1**	7.94	9.4	15.2	31	7.62	4.0	NT	NT
	2					7.68	4.4	NT	NT
	3					7.70	4.4	NT	NT
3.1	**1**	7.95	9.4	15.2	31	7.59	4.1	NT	NT
	2					7.61	4.3	NT	NT
	3					7.64	4.4	NT	NT
6.25	**1**	7.95	9.4	15.2	31	7.42	2.1	NT	NT
	2					7.72	2.1	NT	NT
	3					7.75	2.2	NT	NT
12.5	**1**	7.96	9.4	15.2	31	7.42	2.0	NT	NT
	2					7.59	2.1	NT	NT
	3					7.56	2.1	NT	NT
25	**1**	7.96	9.4	15.2	31	7.40	2.0	NT	NT
	2					7.43	2.0	NT	NT
	3					7.48	2.0	NT	NT
Min		7.93	9.4	15.2	31	7.40	2.0		
Max		7.96	9.4	15.4	31	7.75	5.0		

Note: NT = Not taken.

APPENDIX TABLE 13

Citharichthys stigmaeus
SURVIVAL DATA
FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	% Survival	Average % Survival
Control	1	6	6	100	
	2	6	6	100	
	3	6	6	100	100.0
1.6	1	6	6	100	
	2	6	6	100	
	3	6	6	100	100.0
3.1	1	6	5	83	
	2	6	5	83	
	3	6	5	83	83.3
6.25	1	6	0	0	
	2	6	0	0	
	3	6	0	0	0.0
12.5	1	6	0	0	
	2	6	0	0	
	3	6	0	0	0.0
25	1	6	0	0	
	2	6	0	0	
	3	6	0	0	0.0

Appendix 7
Laboratory Results Submitted by ABT - Third Test

RESULTS OF BIOASSAYS CONDUCTED ON TWO HIGH-STRENGTH WASTE SAMPLES FROM THE VAN CAMP AND STARKIST TUNA CANNERIES IN AMERICAN SAMOA

Prepared for:

CH2M Hill California, Inc.
1111 Broadway
Oakland, CA 94607
Project # PDX 30702

Prepared by:

Advanced Biological Testing Inc.
98 Main St., # 419
Tiburon, Ca. 94920

July 10, 1995

Ref: 9309-8

1.0 INTRODUCTION

At the request of CH2M Hill (Project # PDX 30702), Advanced Biological Testing conducted acute effluent bioassay testing on *Mysidopsis bahia* and *Citharichthys stigmaeus* using high strength wastes (HSW) collected separately from the Starkist (HSW-1) and Van Camp (HSW-2) tuna canneries in American Samoa. The study was run using methods generally specified in EPA 1991 and in a Sampling and Testing Plan submitted to the EPA.

The study was conducted at the Advanced Biological Testing Laboratory in Tiburon, California, and was managed by Mr. Mark Fisler.

2.0 METHODS

2.1 EFFLUENT SAMPLING

The high strength wastes were sampled as composites on June 23, 1995 by personnel from the two canneries. Due to shipping and airline scheduling problems, frequently encountered in this region, the sample was received by the laboratory on June 26, 1995. A single gallon carboy was provided from each cannery and were labeled at ABT as HSW-1 (HSW-SKS Grab) and HSW-2 (Pipeline Sludge HS-W2, Van Camp). Samples were maintained in ice-filled coolers from the date of sampling until laboratory receipt. The samples were at 2-3°C upon receipt and were stored at 4°C until use.

2.2 SAMPLE PREPARATION AND TESTING METHODS

2.2.1 Testing on the speckled sanddab, *Citharichthys stigmaeus*

The bioassays were carried out on juvenile *Citharichthys stigmaeus*, supplied by J. Brezina and Associates in Dillon Beach, California. The animals were received at ABT on June 25, 1995. The test conditions are summarized in Table 1. Five replicates of each concentration were tested with ten juvenile fish per replicate. Water quality was monitored daily. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature. In agreement with the EPA regarding the proposed testing concentrations, the high strength wastes were tested at six concentrations starting from 2.0% and dropping using a 50% dilution factor. The final concentrations were 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% as vol:vol dilutions in seawater. The diluent was filtered seawater from San Francisco Bay. The dilutions were brought up to the test temperature (17 ± 2°C) and aerated continuously. These effluents have an extremely high biological oxygen demand, therefore aeration was carried out from the beginning of the test.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 25, 12.5, 6.25, 3.1, and 1.6 mg/L in 30 ppt seawater in a 24 hour test.

2.2.2 Testing on the mysid, *Mysidopsis bahia*

The bioassay was carried out on 3-5 day old larval *Mysidopsis bahia*, supplied by Aquatox from Hot Springs, Arkansas. The animals were received at ABT on June 27, 1994. The test conditions for this test are summarized in Table 2. Five replicates of each concentration were tested with ten larval mysids per replicate. Water quality was monitored daily as initial quality on Day 0 and final water quality on Days 1-4. Parameters measured included dissolved oxygen, pH, salinity, total ammonia, and temperature. In agreement with the EPA regarding the proposed testing concentrations, the high strength wastes were tested at six concentrations starting from 2.0% and dropping using a 50% dilution factor. The final concentrations were 2.0, 1.0, 0.5, 0.25, 0.125, and 0.06% as vol:vol dilutions in seawater. The diluent was filtered seawater from San Francisco Bay The dilutions were brought up to the test temperature (16 ± 2°C) and aerated continuously.

A reference toxicant was run using concentrations of the toxicant Sodium Dodecyl Sulfonate (SDS) made up as a 2 grams per liter stock solution in distilled water. The tested concentrations were set at 40, 20, 10, 5, 2.5 and 1.25 mg/L in 30 ppt seawater in a 96 hour test.

2.3 STATISTICAL ANALYSIS

At the conclusion of the testing, the survival data were evaluated statistically using ToxCalc™ to determine ECp, NOEC, and LOEC values where appropriate. ToxCalc™ is a comprehensive statistical application that follows standard guidelines for acute and chronic toxicity data analysis. Data were evaluated statistically to estimate the LC50 values for the tests using the Linear Interpolation (Bootstrap) or Trimmed Spearman-Karber methods.

3.0 RESULTS

3.1 Initial Effluent Quality

The two High Strength Wastes were tested for basic water quality parameters upon receipt at the laboratory. HSW-1 had a dissolved oxygen level of 0.8 mg/L; a pH of 6.49; a salinity of 23 ppt; and a total ammonia level of 380 mg/L. HSW-2 had a dissolved oxygen level of 1.4 mg/L; a pH of 6.71; a salinity of 17.0 ppt; and a total ammonia level of 220 mg/L.

3.2 *Citharichthys stigmaeus*

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 17 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected after test initiation in all of the concentration even with supplemental aeration and aeration was maintained in all chambers for the duration of the test. Ammonia was measured in all replicates from each concentration daily and was a potentially significant toxic component of the test for the highest three concentrations.

The LC50 for HSW-1 was 0.396% based upon a Trimmed Spearman-Karber method. The majority of the observed toxicity again occurred in the first 24 hours. There was significant mortality at 2.0, 1.0, and 0.5% concentrations compared to the control at 96 hours. The NOEC was 0.25% and the LOEC was 0.5%.

The LC50 for HSW-2 was 0.626% based upon a Trimmed Spearman-Karber method. The majority of the observed toxicity occurred in the first 24 hours. There was significant mortality at 2.0, 1.0, and 0.5% concentrations compared to the control at 96 hours. The NOEC was 0.25%, and the LOEC was 0.5%.

The reference toxicant test required the use of the Trimmed Spearman-Karber method and generated an LC50 of 4.05 mg/L, an NOEC of 3.2 mg/L, and an LOEC of 6.25 mg/L. This is the fifth reference toxicant test on *Citharichthys* at this laboratory, and the current laboratory mean is 3.95 mg/L (SD = 0.26 mg/L). The results are within one standard deviation of the laboratory mean, indicating a normally sensitive population.

3.3 *Mysidopsis bahia*

Water quality measurements were within the acceptable limits provided in EPA 1991. Temperature was maintained at 17 ± 2°C; pH remained relatively stable, and the salinity increased slightly as would be expected in a static test. The dissolved oxygen did drop as projected after test initiation in all of the concentration even with supplemental aeration and aeration was maintained in all chambers for the duration of the test. Ammonia was measured in all replicates from each concentration daily and was a potentially significant toxic component of the test for the highest three concentrations.

The LC50 for HSW-1 was 0.675%. At 96 hours, there was significant mortality at concentrations to 0.25% compared to the control. The NOEC was 0.125% and the LOEC was 0.25%.

The LC50 for HSW-2 was 0.625%. again there was significant mortality at 96 hours in the 2.0, 1.0 and 0.5% concentrations compared to the control. The NOEC was 0.25%, and the LOEC was 0.5%.

The reference toxicant test had an LC50 of 17.18 mg/L, with an NOEC of 10 mg/L and an LOEC of 20 mg/L. This is the tenth reference toxicant test on *Mysidopsis* at this laboratory, and the current laboratory mean is 14.29 mg/L (SD = 4.11 mg/L). The results are within one standard deviation of the laboratory mean, indicating a normally sensitive population.

3.4 AMMONIA MEASUREMENTS

Total ammonia in both of the HSW samples was very high. When measured in a 25% dilution in seawater, ammonia levels ranged from 55 to 95 mg/L. When converted to the 100% concentration, the ammonia level would be from 220 - 380 mg/L. The measured amount of total ammonia in the 2.0% concentrations on Day 0 in HSW-1 was 6.61 mg/L, and in HSW-2, 4.3 mg/L. In the 1.0% concentrations the total values were 3.32 mg/L and 2.10 mg/L respectively. These levels would be consistent with observed toxicity.

TABLE 1

Bioassay Procedure And Organism Data
For the Acute Bioassay
Using *Citharichthys stigmaeus* (U.S. EPA 1991)

Parameter	Data
Sample Identification	
Sample ID(s)	950626-1(HSW-1), 950626-2 (HSW-2)
Date Sampled	6/23/95
Date Received at ABT	6/26/95
Volume Received	One gallon
Sample Storage Conditions	4°C in the dark
Test Species	*Citharichthys stigmaeus*
Supplier	J. Brezina and Associates
Collection location	Tomales Bay
Date Acquired	June 25, 1995
Acclimation Time	48 hours
Acclimation Water	34 ppt seawater
Acclimation Temperature	17 ± 2°C
Age group	Juveniles, 3-5 cm TL
Test Procedures	
Type; Duration	96 hour static acute, renewal at 48 hours
Test Dates	6/27/95 to 7/1/95
Control Water	Bodega Bay seawater
Test Temperature	17 ± 2°C
Test Photoperiod	16 L : 8 D
Initial Salinity	34 ± 2 ppt
Test Chamber	10 L polyethylene chamber
Animals/Replicate	10 animals/replicate
Exposure Volume	5 L
Replicates/Treatment	5
Feeding	None
Deviations from procedures	None

TABLE 2

Bioassay Procedure And Organism Data For the Acute Bioassay Using *Mysidopsis bahia* (U.S. EPA 1991)

Parameter	Data
Sample Identification	
Sample ID(s)	950626-1(HSW-1), 950626-2 (HSW-2)
Date Sampled	6/23/95
Date Received at ABT	6/26/95
Volume Received	One gallon
Sample Storage Conditions	4°C in the dark
Test Species	*Mysidopsis bahia*
Supplier	Aquatox, Arkansas
Date Acquired	6/27/95
Acclimation Time	None
Acclimation Water	Shipping water
Acclimation Temperature/Salinity	20 ± 2°C/30-32 ppt salinity
Age group	3-5 day old larvae
Test Procedures	
Type; Duration	Acute; static; renewal at 48 hours
Test Dates	6/27/95 to 7/1/95
Control Water	San Francisco Bay seawater
Test Temperature	17 ± 2°C
Test Photoperiod	14 L : 10 D
Salinity	34 ± 2 ppt
Test Chamber	1000 mL jars
Animals/Replicate	10 animal/replicate
Exposure Volume	500 mL
Replicates/Treatment	5
Feeding	Brine shrimp (24 hr old nauplii)
Deviations from procedures	None

TABLE 4

Summary Of Effluent Toxicity
and
Results of the Reference Toxicity Testing

Species	Sample	LC50	95% Confidence Limits
Citharichthys	HSW-1	0.3959%	0.368% -0.426%
	HSW-2	0.6262%	0.569% -0.689%
	Ref Tox (SDS)	4.057 mg/L (acceptable)	3.51-4.69 mg/L
Mysidopsis	HSW-1	0.675%	0.563% -0.764%
	HSW-2	0.625%	0.549% -0.692%
	Ref Tox (SDS)	17.18 mg/L (acceptable)	Not calculated

4.0 REFERENCES

U.S. EPA. 1991. Methods for measuring acute toxicity of effluents to freshwater and marine organisms, 4th ed. EPA 600/4-90/027, September, 1991.

APPENDIX A

ANALYTICAL DATA

APPENDIX TABLE 1

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 6/27 - 7/1/95
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.07	9.1		16.4	33	8.14	8.0	<0.01	15.8	34	8.15	7.3	0.14	18.0	34	8.15	8.6	0.24	17.9	34	8.18	7.6	0.31	18.3	35
	2						8.07	7.8	<0.01	15.7	34	8.08	7.2	0.13	17.9	34	8.08	8.4	0.22	17.8	34	8.13	7.6	0.31	18.3	35
	3						8.01	7.2	<0.01	15.7	34	7.98	6.6	0.14	17.9	34	7.96	7.6	0.22	17.8	34	7.97	6.8	0.32	18.2	35
	4						8.08	7.8	<0.01	15.6	34	8.09	7.2	0.14	17.8	34	8.11	8.4	0.22	17.7	34	8.12	7.5	0.32	18.2	36
	5						8.11	7.8	<0.01	15.6	34	8.12	7.2	0.14	17.9	34	8.12	8.4	0.21	17.9	34	8.14	7.5	0.31	18.3	35
0.06	1	8.03	9.0	0.25	16.3	34	7.88	7.2	0.17	15.7	34	7.99	6.8	0.21	17.9	34	7.92	7.6	0.32	18.0	34	7.96	7.0	0.45	18.4	37
	2						7.99	7.8	0.19	15.5	34	8.09	6.9	0.24	17.8	34	8.09	8.2	0.35	17.9	34	8.13	7.6	0.49	18.3	38
	3						7.95	7.8	0.17	15.6	34	8.08	7.1	0.20	17.9	34	8.03	8.2	0.33	18.2	34	8.06	7.3	0.50	18.6	37
	4						7.97	7.8	0.20	15.5	34	8.09	7.2	0.26	17.9	34	8.09	8.2	0.40	17.7	34	8.12	7.5	0.55	18.0	38
	5						7.92	7.4	0.18	15.5	34	8.04	7.2	0.22	17.8	34	8.02	8.2	0.32	17.7	34	8.05	7.4	0.48	18.0	37
0.125	1	7.99	9.1	0.48	16.2	34	7.80	6.6	0.29	15.5	34	8.02	6.8	0.30	17.8	34	8.04	8.2	0.41	17.8	34	8.06	7.4	0.61	18.6	37
	2						7.84	6.8	0.28	15.5	34	8.04	7.0	0.33	17.8	34	8.06	8.2	0.49	17.9	34	8.10	7.4	0.68	18.2	37
	3						7.80	6.6	0.28	15.6	34	8.02	7.0	0.31	17.9	34	8.04	8.2	0.45	17.9	34	8.07	7.5	0.63	18.4	36
	4						7.90	6.4	0.29	15.4	34	8.09	7.2	0.32	17.6	34	8.13	8.2	0.44	17.8	34	8.15	7.4	0.64	18.2	38
	5						7.75	5.4	0.30	15.5	34	7.96	6.6	0.32	17.9	34	7.96	8.2	0.46	18.2	34	8.02	6.9	0.65	18.6	37
0.25	1	7.90	9.0	0.94	16.2	34	7.68	6.6	0.52	15.8	34	8.06	6.8	0.48	18.0	34	8.03	8.0	0.57	18.0	34	8.09	7.4	0.84	18.4	37
	2						7.62	5.8	0.52	15.7	34	8.03	6.8	0.48	18.0	34	8.01	8.0	0.59	18.0	34	8.07	7.3	0.84	18.4	36
	3						7.54	4.8	0.51	15.8	34	7.97	6.6	0.46	18.0	34	7.96	7.8	0.55	18.0	34	8.00	7.2	0.83	18.4	38
	4						7.55	4.8	0.52	15.7	34	7.95	6.6	0.56	18.0	34	7.95	7.6	0.55	17.9	34	7.99	7.0	0.92	18.4	36
	5						7.57	6.0	0.51	15.7	34	8.01	6.8	0.47	17.9	34	7.99	7.8	0.58	18.0	34	8.05	7.0	0.82	18.4	36
0.5	1	7.83	9.0	1.80	16.2	34	7.54	4.4	1.20	15.7	34	7.90	6.0	1.00	18.0	34	—	—	—	—	—	—	—	—	—	—
	2						7.48	4.3	1.19	15.7	34	7.85	5.9	1.08	18.0	34	—	—	—	—	—	—	—	—	—	—
	3						7.45	4.4	1.22	15.6	34	7.88	6.0	1.02	17.9	34	—	—	—	—	—	—	—	—	—	—
	4						7.52	4.1	1.18	15.7	34	7.86	5.6	1.02	18.0	34	—	—	—	—	—	—	—	—	—	—
	5						7.56	4.0	1.20	15.6	34	7.95	6.4	0.83	17.9	34	8.03	7.9	0.93	18.0	34	8.06	7.2	1.19	18.3	37
1	1	7.52	8.8	3.42	16.2	34	7.45	2.3	2.75	15.7	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.41	0.8	2.78	15.6	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.39	1.2	2.72	15.6	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.40	0.4	2.73	15.1	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.41	0.4	2.73	15.7	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	1	7.46	8.8	6.60	16.2	34	7.43	1.0	5.87	15.7	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.50	2.8	5.84	15.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.45	0.8	5.79	15.5	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.45	3.2	5.80	15.5	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.52	2.4	5.88	15.6	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		7.46	8.8	0.25	16.2	33	7.39	0.4	<0.01	15.1	34	7.85	5.6	0.13	17.6	34	7.92	7.6	0.21	17.7	34	7.96	6.8	0.31	18.0	35
Max		8.07	9.1	6.60	16.4	34	8.14	8.0	5.88	15.8	34	8.15	7.3	1.08	18.0	34	8.15	8.6	0.93	18.2	34	8.18	7.6	1.19	18.6	38

Note: — = All animals dead.

APPENDIX TABLE 1 (Cont'd)

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 6/27 - 7/1/95
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
0.06	1	8.02	9.0	0.17	16.3	34	7.98	7.6	0.20	15.5	34	8.06	7.0	0.19	17.9	34	7.99	8.2	0.34	17.8	34	8.08	7.3	0.47	18.8	37
	2						8.04	7.6	0.20	15.2	34	8.13	7.2	0.19	17.7	34	8.13	8.3	0.29	17.6	34	8.17	7.4	0.42	17.9	38
	3						8.05	7.8	0.20	15.2	34	8.14	7.3	0.19	17.7	34	8.13	8.4	0.29	17.6	34	8.15	7.6	0.41	18.0	37
	4						8.00	7.6.	0.19	15.4	34	8.06	7.1	0.19	17.9	34	8.06	8.4	0.29	17.8	34	8.07	7.3	0.41	18.2	37
	5						7.94	7.6	0.18	15.3	34	8.02	6.8	0.20	17.9	34	8.01	8.2	0.37	17.9	34	8.04	7.4	0.47	18.2	37
0.125	1	8.05	9.2	0.29	16.2	34	7.98	7.6	0.29	15.4	34	8.13	7.2	0.28	17.9	34	8.11	8.2	0.42	17.9	34	8.15	7.4	0.53	18.2	38
	2						7.93	7.5	0.19	15.4	34	8.08	7.1	0.25	18.0	34	8.07	8.4	0.36	18.0	34	8.09	7.5	0.48	18.5	37
	3						7.91	6.4	0.21	15.6	34	8.09	7.2	0.25	18.3	34	8.07	8.2	0.34	18.2	34	8.10	7.4	0.45	18.6	37
	4						7.78	7.4	0.22	15.5	34	7.99	6.6	0.25	18.1	34	7.94	7.6	0.35	18.0	34	7.94	6.6	0.45	18.3	37
	5						7.88	4.5	0.22	15.5	34	8.06	7.0	0.23	18.0	34	8.04	8.2	0.34	18.0	34	8.08	7.3	0.43	18.3	36
0.25	1	7.98	9.1	0.62	16.2	34	7.74	4.8	0.38	15.5	34	8.01	6.6	0.37	18.0	34	7.94	8.2	0.52	18.0	34	8.03	7.1	0.64	18.2	36
	2						7.78	5.8	0.38	15.3	34	8.07	7.0	0.34	18.0	34	8.03	8.0	0.48	17.9	34	8.11	7.2	0.58	18.2	37
	3						7.77	5.8	0.36	•15.3	34	8.05	7.0	0.35	18.0	34	8.01	8.2	0.49	17.9	34	8.06	7.2	0.60	18.2	37
	4						7.77	5.9	0.37	15.2	34	8.06	6.7	0.38	17.9	34	8.02	8.0	0.56	17.7	34	8.10	7.1	0.70	18.0	37
	5						7.83	6.6	0.38	15.2	34	8.10	7.0	0.36	17.8	34	8.07	8.2	0.55	17.6	34	8.14	7.5	0.62	17.9	37
0.5	1	7.91	9.0	1.18	16.0	34	7.79	5.6	0.78	15.2	34	8.09	7.0	0.58	17.9	34	8.07	8.2	0.74	17.7	34	8.13	7.5	0.89	18.0	38
	2						7.78	6.0	0.79	15.0	34	8.11	7.1	0.58	17.6	34	8.09	8.4	0.72	17.9	34	8.15	7.5	0.88	18.2	38
	3						7.59	6.0	0.84	15.5	34	8.06	7.0	0.61	18.1	34	8.08	8.2	0.74	18.0	34	8.12	7.4	0.88	18.3	36
	4						7.69	4.9	0.82	15.4	34	8.05	6.8	0.64	18.2	34	8.05	8.0	0.77	18.0	34	8.12	7.2	0.99	18.2	37
	5						7.73	5.3	0.81	15.3	34	8.09	6.8	0.57	18.2	34	8.07	8.0	0.75	18.0	34	8.14	7.2	0.86	18.3	37
1	1	7.63	9.0	2.21	16.0	34	7.64	1.0	1.39	15.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.59	1.1	1.37	15.5	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.52	0.8	1.79	15.5	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.48	0.6	1.70	15.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.47	1.0	1.71	15.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2.0	1	7.42	8.6	4.33	16.0	34	7.44	0.6	3.60	15.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.43	0.6	3.54	15.3	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.45	0.4	3.39	15.2	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.44	0.6	3.25	15.0	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.47	0.6	3.35	15.1	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		7.42	8.6	0.17	16.0	34	7.43	0.4	0.18	15.0	34	7.99	6.6	0.19	17.6	34	7.94	7.6	<0.10	17.6	34	7.94	6.6	0.41	17.9	36
Max		8.05	9.2	4.33	16.3	34	8.05	7.8	3.60	15.6	34	8.14	7.3	0.64	18.3	34	8.13	8.4	0.77	18.2	34	8.17	7.6	0.99	18.8	38

Note: — = All animals dead.

APPENDIX TABLE 2

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	**1**	10	10	9	9	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.06	**1**	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	9	90	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.125	**1**	10	10	10	10	10	100	
	2	10	10	10	9	9	90	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.25	**1**	10	10	10	10	10	100	
	2	10	9	9	9	9	90	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.5	**1**	10	9	0	—	—	0	
	2	10	10	0	—	—	0	
	3	10	8	0	—	—	0	
	4	10	10	0	—	—	0	
	5	10	8	8	8	8	80	16.0
1	**1**	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
2	**1**	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Note: — = All animals dead.

APPENDIX TABLE 2 (Cont'd)

Citharichthys stigmaeus
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.06	1	10	10	10	9	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	9	90	96.0
0.125	1	10	10	10	10	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	9	90	
	5	10	9	9	9	8	80	92.0
0.25	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	9	9	8	80	
	4	10	9	9	9	8	80	
	5	10	9	9	9	9	90	90.0
0.5	1	10	10	10	10	8	80	
	2	10	10	10	10	10	100	
	3	10	10	9	9	9	90	
	4	10	10	10	10	10	100	
	5	10	9	9	9	9	90	92.0
1	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Note: — = All animals dead.

APPENDIX TABLE 3

Citharichthys stigmaeus
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal
Control	1	8.03	9.0	16.8	34	7.55	5.0	16.2	34
	2					7.55	5.0	16.2	34
	3					7.55	5.0	16.2	34
1.6	1	8.03	9.0	16.9	34	7.53	4.9	16.1	34
	2					7.51	4.9	16.2	34
	3					7.53	4.8	16.2	34
3.1	1	8.03	8.9	17.0	34	7.49	4.8	16.2	34
	2					7.44	4.8	16.2	34
	3					7.49	4.7	16.2	34
6.25	1	8.04	8.8	16.7	34	7.49	4.7	16.2	34
	2					7.50	4.7	16.2	34
	3					7.57	4.7	16.2	34
12.5	1	8.05	8.8	16.7	34	7.44	4.5	16.2	34
	2					7.39	4.6	16.2	34
	3					7.36	4.7	16.2	34
25	1	8.05	8.8	16.6	34	7.33	4.8	16.2	34
	2					7.32	4.9	16.2	34
	3					7.30	4.9	16.3	34
Min		8.03	8.8	16.6	34	7.30	4.5	16.1	34
Max		8.05	9.0	17.0	34	7.57	5.0	16.3	34

APPENDIX TABLE 4

Citharichthys stigmaeus
SURVIVAL DATA
FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	% Survival	Average % Survival
Control	1	4	4	100	
	2	4	4	100	
	3	4	2	50	83.3
1.6	1	4	4	100	
	2	4	4	100	
	3	4	3	75	91.7
3.1	1	4	3	75	
	2	4	3	75	
	3	4	3	75	75.0
6.25	1	4	0	0	
	2	4	0	0	
	3	4	0	0	0.0
12.5	1	4	0	0	
	2	4	0	0	
	3	4	0	0	0.0
25	1	4	0	0	
	2	4	0	0	
	3	4	0	0	0.0

APPENDIX TABLE 5

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 6/27 - 7/1/95
HSW-1

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
Control	1	8.07	9.0		17.1	34	8.11	8.0	<0.01	16.5	34	8.25	7.4		18.2	34	8.17	8.4		18.0	34	8.20	7.7		18.3	36
	2						8.14	8.0		16.3	34	8.23	7.4	0.02	18.3	34	8.18	8.6		18.0	34	8.20	7.7		18.4	36
	3						8.13	8.0		16.3	34	8.17	7.4		18.3	34	8.09	8.6	0.03	18.1	34	8.13	7.7		18.4	35
	4						8.14	8.0		16.4	34	8.22	7.4		18.3	34	8.24	8.6		18.1	34	8.20	7.6	0.06	18.5	35
	5						8.16	8.0		16.4	34	8.24	7.4		18.2	34	8.28	8.6		18.0	34	8.26	7.7		18.3	36
0.06	1	8.02	9.0	0.25	17.9	34	7.98	7.8	0.11	16.2	34	8.10	7.2		18.3	34	8.14	8.6		18.0	34	8.11	7.4		18.4	35
	2						8.06	7.8		16.1	34	8.17	7.2	0.08	18.2	34	8.18	8.6		18.0	34	8.15	7.6		18.2	36
	3						8.04	7.8		16.0	34	8.13	7.2		18.2	34	8.12	8.6	0.11	17.9	34	8.11	7.5		18.2	35
	4						8.06	7.8		16.1	34	8.18	7.2		18.2	34	8.17	8.6		17.9	34	8.15	7.5	0.14	18.2	36
	5						8.12	8.0		16.1	34	8.22	7.3		18.2	34	8.22	8.7		17.9	34	8.20	7.6		18.2	36
0.125	1	7.96	8.8	0.48	18.0	34	7.78	6.2	0.22	16.2	34	8.16	7.2		18.2	34	8.13	8.6		18.0	34	8.13	7.6		18.4	35
	2						7.73	6.2		16.2	34	7.95	5.9	0.15	18.2	34	7.90	8.6		17.9	34	8.00	6.6		18.2	35
	3						7.98	7.8		16.1	34	8.10	7.0		18.1	34	8.14	8.4	0.22	17.9	34	8.10	7.5		18.2	35
	4						8.02	7.8		16.0	34	8.18	7.2		18.2	34	8.18	8.6		17.8	34	8.17	7.5	0.26	18.2	35
	5						7.94	7.6		16.2	34	8.14	7.2		18.3	34	8.16	8.6		17.9	34	8.14	7.6		18.3	35
0.25	1	7.90	8.8	0.94	18.0	34	7.75	7.1	0.41	16.2	34	8.04	7.0		18.2	34	8.10	8.5		18.0	34	8.08	7.5		18.4	35
	2						7.82	7.5		16.2	34	8.10	7.0	0.32	18.2	34	8.14	8.4		17.9	34	8.11	7.4		18.2	35
	3						7.86	7.4		16.1	34	8.13	7.2		18.1	34	8.13	8.6	0.47	17.8	34	8.12	7.4		18.2	35
	4						7.95	7.6		16.1	34	8.20	7.4		18.2	34	8.22	8.6		17.7	34	8.20	7.5	0.51	18.2	35
	5						7.90	7.4		16.2	34	8.12	7.2		18.3	34	8.14	8.6		17.9	34	8.14	7.6		18.3	35
0.5	1	7.92	8.8	1.80	17.9	34	7.80	6.9	0.81	16.3	34	8.20	7.2		18.2	34	8.25	8.6		18.0	34	8.23	7.4		18.4	35
	2						7.82	7.3		16.2	34	8.22	7.2	0.63	18.0	34	8.28	8.6		17.9	34	8.23	7.3		18.3	35
	3						7.74	6.2		16.2	34	8.17	7.1		18.0	34	8.23	8.6	0.83	17.9	34	8.26	7.4		18.2	35
	4						7.66	5.5		16.1	34	8.20	7.2		18.2	34	8.26	8.6		17.9	34	8.21	7.4	0.93	18.3	35
	5						7.71	6.2		16.2	34	8.20	7.2		18.3	34	8.30	8.6		17.9	34	8.25	7.4		18.3	36
1	1	7.74	8.6	3.41	17.9	34	7.64	2.8	1.91	16.3	34	8.12	6.6		18.4	34	—	—		—	—	—	—		—	—
	2						7.64	3.4		16.2	34	8.14	6.6	1.32	18.4	34	8.23	8.6		18.2	34	8.24	7.3		18.5	35
	3						7.65	3.6		16.2	34	8.15	6.7		18.3	34	8.26	8.6	1.54	18.0	34	8.29	7.4		18.4	35
	4						7.63	3.2		16.3	34	8.11	6.6		18.4	34	—	—		—	—	—	—		—	—
	5						7.64	3.6		16.2	34	8.13	6.6		18.5	34	8.29	8.6		18.1	34	8.31	7.3	1.61	18.4	35
2.0	1	7.63	8.8	6.60	17.6	34	7.46	1.2	3.51	16.5	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2						7.44	1.0		16.3	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3						7.45	2.0		16.2	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	4						7.50	2.7		16.2	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5						7.46	0.6		16.4	34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Min		7.63	8.6	0.25	17.1	34	7.44	0.6	<0.01	16.0	34	7.95	5.9	0.02	18.0	34	7.90	8.4	0.03	17.7	34	8.00	6.6	0.06	18.2	35
Max		8.07	9.0	6.60	18.0	34	8.16	8.0	3.51	16.5	34	8.25	7.4	1.32	18.5	34	8.30	8.7	1.54	18.2	34	8.31	7.7	1.61	18.5	36

Note: — = All animals dead.

APPENDIX TABLE 5 (Cont'd)

Mysidopsis bahia
WATER QUALITY MEASUREMENTS FOR EFFLUENT TEST
Study Dates: 6/27 - 7/1/95
HSW-2

Concentration		Day 0					Day 1					Day 2					Day 3					Day 4				
(%)	Rep	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal	pH	DO	NH3	°C	Sal
0.06	1	8.01	9.0	0.17	18.6	34	8.07	7.8	0.19	16.5	34	8.22	7.1		18.4	34	8.18	8.4		18.0	34	8.22	7.7		18.5	35
	2						8.07	7.6		16.4	34	8.18	7.2	0.09	18.4	34	8.15	8.6		18.0	34	8.16	7.6		18.4	35
	3						8.10	7.8		16.4	34	8.20	7.3		18.4	34	8.18	8.6	0.12	17.9	34	8.18	7.6		18.3	35
	4						8.12	7.8		16.3	34	8.22	7.4		18.3	34	8.20	8.6		17.9	34	8.20	7.7	0.15	18.2	35
	5						8.16	7.8		16.3	34	8.24	7.4		18.3	34	8.22	8.6		18.0	34	8.23	7.7		18.3	35
0.125	1	8.02	9.0	0.29	18.6	34	8.12	7.8	0.20	16.4	34	8.23	7.4		18.4	34	8.20	8.6		17.9	34	8.22	7.7		18.4	35
	2						8.14	7.8		16.4	34	8.25	7.3	0.12	18.3	34	8.20	8.6		17.9	34	8.25	7.8		18.3	35
	3						8.05	7.6		16.3	34	8.18	7.2		18.3	34	8.13	8.6	0.18	17.9	34	8.16	7.6		18.2	35
	4						8.09	7.8		16.2	34	8.20	7.3		18.2	34	8.20	8.6		17.9	34	8.22	7.6	0.20	18.2	35
	5						8.12	7.8		16.2	34	8.24	7.4		18.2	34	8.21	8.6		17.9	34	8.23	7.6		18.2	35
0.25	1	7.97	9.0	0.62	18.6	34	7.93	7.0	0.36	16.4	34	8.16	7.2		18.4	34	8.11	8.4		17.9	34	8.18	7.6		18.4	35
	2						7.92	7.4		16.3	34	8.17	7.2	0.25	18.3	34	8.14	8.4		17.9	34	8.22	7.6		18.2	35
	3						7.92	7.3		16.2	34	8.18	7.2		18.3	34	8.12	8.4	0.36	17.9	34	8.21	7.6		18.2	35
	4						8.02	7.4		16.2	34	8.22	7.4		18.2	34	8.12	8.5		17.9	34	8.25	7.6	0.41	18.2	35
	5						8.01	7.6		16.2	34	8.24	7.4		18.2	34	8.21	8.6		17.9	34	8.25	7.7		18.2	35
0.5	1	7.94	9.0	1.18	18.6	34	7.93	6.8	0.62	16.4	34	8.26	7.3		18.3	34	8.22	8.6		17.9	34	8.27	7.6		18.3	36
	2						7.90	6.4		16.3	34	8.25	7.3	0.51	18.3	34	8.20	8.4		17.9	34	8.27	7.6		18.2	35
	3						7.86	6.1		16.2	34	8.22	7.2		18.3	34	8.20	8.6	0.64	17.9	34	8.26	7.5		18.2	35
	4						7.80	4.8		16.3	34	8.22	7.2		18.2	34	8.18	8.5		17.9	34	8.26	7.6	0.73	18.2	35
	5						7.75	4.7		16.2	34	8.18	7.2		18.2	34	8.04	8.4		17.9	34	8.17	7.6		18.2	35
1	1	7.84	8.8	2.21	18.6	34	7.77	6.4	1.33	16.4	34	8.23	7.2		18.3	34	8.27	7.9		17.9	34	8.28	7.4		18.3	35
	2						7.66	5.0		16.3	34	8.15	7.0	1.06	18.3	34	8.26	8.3		17.9	34	8.27	7.4		18.3	35
	3						7.69	6.2		16.3	34	8.18	7.0		18.3	34	8.29	8.4	1.19	17.9	34	8.29	7.4		18.2	35
	4						7.70	5.4		16.2	34	8.20	7.0		18.2	34	8.26	8.6		17.9	34	8.24	7.2	1.36	18.2	35
	5						7.68	5.8		16.2	34	8.19	7.0		18.2	34	8.27	8.6		17.9	34	8.23	7.2		18.2	35
2.0	1	7.72	8.6	4.33	18.5	34	7.64	1.6	2.80	16.4	34	8.22	7.0		18.4	34	—	—	—	—	—	—	—	—	—	—
	2						7.60	0.6		16.3	34	8.16	6.1	2.26	18.3	34	—	—	—	—	—	—	—	—	—	—
	3						7.62	1.6		16.3	34	8.16	6.7		18.3	34	—	—	—	—	—	—	—	—	—	—
	4						7.58	0.4		16.3	34	8.12	6.4		18.3	34	—	—	—	—	—	—	—	—	—	—
	5						7.55	0.4		16.3	34	8.11	6.2		18.2	34	—	—	—	—	—	—	—	—	—	—
Min		7.72	8.6	0.17	18.5	34	7.55	0.4	0.19	16.2	34	8.11	6.1	0.09	18.2	34	8.04	7.9	0.12	17.9	34	8.16	7.2	0.15	18.2	35
Max		8.02	9.0	4.33	18.6	34	8.16	7.8	2.80	16.5	34	8.26	7.4	2.26	18.4	34	8.29	8.6	1.19	18.0	34	8.29	7.8	1.36	18.5	36

Note: — = All animals dead.

APPENDIX TABLE 6

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-1

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
Control	1	10	9	9	9	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.06	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	100.0
0.125	1	10	9	9	9	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	10	10	100	
	5	10	9	9	9	9	90	96.0
0.25	1	10	10	*	*	7	70	
	2	10	10	*	*	10	100	
	3	10	10	*	*	8	80	
	4	10	9	*	*	6	60	
	5	10	10	*	*	10	100	82.0
0.5	1	10	*	*	*	5	50	
	2	10	*	*	*	7	70	
	3	10	*	*	*	7	70	
	4	10	*	*	*	10	100	
	5	10	*	*	*	8	80	74.0
1	1	10	*	0	—	—	0	
	2	10	*	*	*	2	20	
	3	10	*	*	*	0	0	
	4	10	*	0	—	—	0	
	5	10	*	*	*	0	0	4.0
2	1	10	0	—	—	—	0	
	2	10	0	—	—	—	0	
	3	10	0	—	—	—	0	
	4	10	0	—	—	—	0	
	5	10	0	—	—	—	0	0.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 6 (Cont'd)

Mysidopsis bahia
SURVIVAL DATA FOR EFFLUENT TEST
HSW-2

Concentration (%)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.06	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	
	4	10	10	10	9	9	90	
	5	10	10	9	9	9	90	96.0
0.125	1	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	10	9	90	
	4	10	10	10	10	10	100	
	5	10	10	10	10	10	100	98.0
0.25	1	10	*	*	10	10	100	
	2	10	*	*	10	9	90	
	3	10	*	*	10	10	100	
	4	10	*	*	9	9	90	
	5	10	*	*	10	10	100	96.0
0.5	1	10	*	*	*	5	50	
	2	10	*	*	*	6	60	
	3	10	*	*	*	7	70	
	4	10	*	*	*	7	70	
	5	10	*	*	*	6	60	62.0
1	1	10	*	*	*	1	10	
	2	10	*	*	*	0	0	
	3	10	*	*	*	2	20	
	4	10	*	*	*	0	0	
	5	10	*	*	*	2	20	10.0
2	1	10	*	0	—	—	0	
	2	10	*	0	—	—	0	
	3	10	*	0	—	—	0	
	4	10	*	0	—	—	0	
	5	10	*	0	—	—	0	0.0

Notes: — = All animals dead.
* Sample too turbid to do counts.

APPENDIX TABLE 7

Mysidopsis bahia
WATER QUALITY MEASUREMENTS
FOR REFERENCE TOXICANT (S.D.S) TEST

Concentration		Day 0				Day 1				Day 2				Day 3				Day 4			
(mg/L)	Rep	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal	pH	DO	°C	Sal
0.7	1	8.07	9.0	17.5	34	8.11	7.8	16.5	34	8.09	6.8	18.6	34	7.98	7.8	18.4	34	7.77	6.3	18.7	35
	2					8.10	7.8	16.3	34	8.08	6.8	18.5	34	8.00	8.0	18.2	34	7.82	6.5	18.6	35
	3					8.10	7.7	16.2	34	8.07	6.6	18.4	34	8.00	8.0	18.0	34	7.84	6.4	18.5	35
1.25	1	8.08	9.0	17.6	34	8.07	7.3	16.4	34	8.04	6.4	18.5	34	7.97	8.0	18.2	34	7.84	6.5	18.6	35
	2					8.08	7.3	16.4	34	8.05	6.6	18.5	34	7.98	7.8	18.2	34	7.85	6.4	18.6	35
	3					8.08	7.3	16.2	34	8.06	6.6	18.4	34	7.98	7.8	18.1	34	7.85	6.4	18.6	35
2.5	1	8.08	9.2	17.6	34	8.05	7.0	16.4	34	8.03	6.6	18.5	34	7.96	7.8	18.2	34	7.86	6.2	18.5	35
	2					8.04	6.8	16.3	34	8.03	6.6	18.5	34	7.97	7.8	18.1	34	7.87	6.3	18.5	35
	3					8.04	6.8	16.2	34	8.04	6.6	18.5	34	7.98	7.8	18.1	34	7.87	6.3	18.5	35
5	1	8.08	9.2	17.6	34	7.99	6.0	16.5	34	7.96	6.0	18.5	34	7.89	7.0	18.2	34	7.84	5.8	18.6	35
	2					7.98	5.8	16.4	34	7.96	6.0	18.5	34	7.90	7.1	18.1	34	7.80	5.7	18.5	35
	3					7.98	5.8	16.2	34	7.98	6.2	18.5	34	7.92	7.3	18.1	34	7.81	5.8	18.5	35
10	1	8.08	9.2	17.6	34	7.93	5.0	16.5	34	7.87	5.2	18.6	34	7.87	7.3	18.2	34	7.82	6.0	18.6	35
	2					7.92	5.1	16.3	34	7.83	5.2	18.5	34	7.86	7.3	18.1	34	7.85	6.3	18.5	35
	3					7.92	4.9	16.2	34	7.83	5.1	18.5	34	7.87	7.4	18.1	34	7.86	6.5	18.5	34
20	1	8.09	9.2	17.6	34	7.92	4.9	16.4	34	7.73	4.8	18.6	34	7.75	5.8	18.3	34	7.79	6.1	18.6	34
	2					7.93	4.9	16.4	34	7.69	4.7	18.5	34	7.70	5.3	18.2	34	7.75	6.1	18.6	34
	3					7.93	5.0	16.2	34	7.68	4.8	18.5	34	7.68	5.1	18.2	34	7.74	6.0	18.5	34
Min		8.07	9.0	17.5	34	7.92	4.9	16.2	34	7.68	4.7	18.4	34	7.68	5.1	18.0	34	7.74	5.7	18.5	34
Max		8.09	9.2	17.6	34	8.11	7.8	16.5	34	8.09	6.8	18.6	34	8.00	8.0	18.4	34	7.87	6.5	18.7	35

Note: — = All animals dead.

APPENDIX TABLE 8

Mysidopsis bahia
SURVIVAL DATA FOR REFERENCE TOXICANT (S.D.S.) TEST

Concentration (mg/L)	Rep	Initial Added	Day 1	Day 2	Day 3	Day 4	% Survival	Average % Survival
0.7	**1**	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	10	9	9	90	96.7
1.25	**1**	10	10	10	10	10	100	
	2	10	10	10	9	9	90	
	3	10	10	10	10	10	100	96.7
2.5	**1**	10	10	10	10	9	90	
	2	10	10	10	10	10	100	
	3	10	10	10	10	10	100	96.7
5	**1**	10	10	10	10	10	100	
	2	10	10	10	10	10	100	
	3	10	10	9	9	9	90	96.7
10	**1**	10	10	10	9	8	80	
	2	10	10	10	10	10	100	
	3	10	10	10	8	8	80	86.7
20	**1**	10	2	1	1	1	10	
	2	10	7	6	6	6	60	
	3	10	8	3	3	3	30	33.3

Note: — = All animals dead.

Appendix 8
Calculation of Entrainment Adjustment

APPENDIX B

MATHEMATICAL MODELING

OF FISH WASTE DISPOSAL IN DEEP WATER

FINAL
ENVIRONMENTAL IMPACT STATEMENT

FOR THE DESIGNATION
OF AN OCEAN DISPOSAL SITE FOR FISH CANNERY WASTES
OFF TUTUILA ISLAND, AMERICAN SAMOA

1. INTRODUCTION

The purpose of this study is to predict the fate of fish processing wastes which are discharged at the present dumpsite off Tutuila Island, American Samoa in the South Pacific. The center point of the 1.5 nautical mile (n mi) diameter dumpsite is located at 170°40.87'W and 14°22.18'S. and is about 3.3 n mi due east of Sail Rock Point on Tutuila Island.

The preferred dumpsite selected in the FEIS is located at 170°38.30'W and 14°24.00'S, southeast of the present site. The model studies in this section were performed using the present site and known oceanographic conditions and waste characteristics, but the results are equally applicable to the preferred site under present waste loadings.

The waste is expected to undergo rapid initial mixing after discharge. Since the gross bulk density of the fish waste is between 0.72 and 0.99 gm/ml, the majority of the plume will remain near the ocean surface immediately after being discharged from the ship. Since the model developed by Koh and Chang (1973) was designed to simulate disposal of wastes that are heavier than the sea water, a new mathematical model has been formulated specifically for this study to predict the fate of the floating plume. This model can simulate the diffusion (lateral and vertical) and settling of the waste particles while the plume is advected in the direction of the ambient current. Most of the data used in the simulations were obtained from the reports published by Soule and Oguri (1983 and 1984) but subsequent monitoring data in 1987 and 1988 (See Appendix A) are consistent with the previously published data. The results of the simulations are presented in terms of dilution as a function of time after discharge, and/or distance and time from the discharge location. The simulations have been performed for two density

profiles (summer and winter), three ambient currents (0.2, 0.4, and 0.8 knots), and three particle settling velocities (1, 0.1, and 0.01 cm/sec). The waste plume is advected downstream by the ambient current. The direction of the ambient current varies with the season and the time of measurement. Some drogue studies by Soule and Oguri (1984) indicate movement toward the southwest direction while some 1987 current meter data indicate movement in the northwest direction. A close examination of the current direction based on the data published in the U.S. Navy Marine Climatic Atlas of the World (1979) for the region under study also indicates a SW direction. The prevailing south equatorial current indicates the direction is from SE toward NW. In order to cover several possible scenarios several current directions are used for simulation.

Since no data were ascertained for the settling velocity of the waste particles of the Samoa plant, velocities of 1, 0.1, and 0.01 cm/sec have been used in the calculations to cover the possible range of settling velocities. It is possible to distinguish the waste particles into three categories according to the density of the particles: (a) particles that are buoyant will form a thin layer floating at the ocean surface; (b) particles that are neutrally buoyant will be mixed and dispersed within the mixed layer (the mixed layer is the surface layer of the ocean extending from the ocean surface to the thermocline); (c) particles that are heavier than sea water will sink as the layer of waste particles is advected by the ambient current.

2. DEVELOPMENT OF MATHEMATICAL MODEL

Based on the data contained in Soule and Oguri (1983), the bulk densities of the fish processing wastes generated by Star-Kist Samoa and Samoa Packing are 0.72 to 0.96 gm/ml and 0.99 gm/ml, respectively. Recent

data on the specific gravity tests of the cannery waste provided to us on November 13, 1987 indicate a range of 0.99 to 1.023 gm/ml have been measured. Thus the possible settling velocity of the particulates in the plume is covered in our range of simulation. The tuna fish waste discharged from the ship is predominantly buoyant in sea water. Immediately after being discharged by the vessel pumps it undergoes rapid, near field, initial mixing similar to mixing in a jet. Because the discharge vessel circles around within the discharge zone, it is reasonable to assume that this nearfield mixing process, in combination with the ship's track and the prevailing current, would (1) establish an initial zone of width L and depth H within which the mean concentration is Co, and (2) the plume would drift downstream emanating from this initial zone. The dimension L would be expected to be approximately the turning diameter of the discharge ship. The concentration Co would correspond to the dilution obtained by the discharge jet as it is propelled downward and then returns towards the surface. The dimension H would be obtained such that where Q is the

$$U\ L\ H\ Co = Q \qquad (2.1)$$

discharge rate of the tuna fish waste and U is the magnitude of the prevailing current. It can be visualized that the initial plume to be advected by the ambient current has a concentration Co with the plume width L and the plume depth extending from the ocean surface downward by a value of H.

Each discharge episode would have a duration T. We shall assume that the prevailing current can be regarded as constant during that time. Then a plume of length UT would be generated as a result of the discharge episode.

Along the length of the plume, the concentration would decrease from

Co due to lateral mixing. Longitudinal diffusion will be probably small.

Diffusion of waste effluent in an ocean current was analyzed by Brooks (1960), taking into account the increase of the eddy diffusivity as the waste field spreads.

The basic differential equation, based on the principle of conservation of mass, for the substance being diffused is:

$$\frac{\partial}{\partial y}\left(-\mathcal{E}\frac{\partial C}{\partial y}\right) + U\frac{\partial C}{\partial x} + KC = 0 \qquad (2.2)$$

where the spatial coordinate x represents longitudinal direction (in the direction of ambient current) and y represents the lateral direction. The three terms in the above equation represents the rates of concentration decay per unit volume due to lateral diffusion, longitudinal advection and apparent dieoff respectively.

Incorporating an exponential decay term to take care of the dieoff term in Equation 2.2 such as

$$C = \phi e^{-Kx/U} \qquad (2.3)$$

would transform the equation into a simpler differential equation

$$\mathcal{E}\frac{\partial^2\phi}{\partial y} = U\frac{\partial\phi}{\partial x} \qquad (2.4)$$

The function ϕ is the concentration without any dieoff effect; it is a function of x and y.

An additional change of variable: $\mathcal{E} = \mathcal{E}_0 f(x)$ and $dx' = f(x)dx$ would allow one to transform Equation 2.4 to the classical heat equation as follows:

$$\mathcal{E}\frac{\partial^2\phi}{\partial y^2} = U\frac{\partial\phi}{\partial x} \qquad (2.5)$$

where $\mathcal{E}_o$ is the eddy diffusivity at x=0.

An exact solution to Equation 2.5, therefore, Equation 2.2 can easily be found as:

$$C(x,y) = \frac{Co\ e^{-Kx/U}}{2\sqrt{\pi \mathcal{E}_o t'}} \int_{-\frac{b}{2}}^{\frac{b}{2}} e^{-\frac{(y-y')^2}{4\mathcal{E}_o t'}}\ dy \qquad (2.6)$$

in which $t' = x'/U$ has been used, Co is the initial waste concentration at x=0, for $-b/2 < y < b/2$.

The integral in Equation 2.6 can be arranged to become the well known error function defined as

$$\text{erf } z = (2/\sqrt{\pi}) \int_0^z \exp(-\xi^2)\ d\xi \qquad (2.7)$$

We further introduce the concentration Cmax(x) as the concentration of the waste plume at y=0 and neglect the dieoff effect (i.e. set k=0.), this would yield a conservative estimation. We also assume that the lateral diffusivity can be expressed as

$$\mathcal{E} = A\ L^{4/3} \qquad (2.8)$$

where L is a length parameter proportional to the lateral width of the plume and A is a proportionality constant.

Thus, the maximum concentration at the center line of the plume can be simplified to be

$$\frac{Cmax}{Co} = \text{erf}\{ [\frac{1.5}{(1 + 8\ A\ t\ /\ L^{2/3})^3 - 1}]^{1/2} \} \qquad (2.9)$$

The error function in Equation 2.9 has been defined in Equation 2.7, and t is defined as x/U with x denoting the distance downstream from the initial dumping location.

For the waste with settling velocity Ws, it can be readily visualized that the combination of lateral diffusion, downstream advection by current, and settling can be schematised to a very good approximation by taking an x' coordinate inclined to the original downstream x coordinate by an angle $O = \tan^{-1}(Ws/U)$, as shown in Figure 2-1.

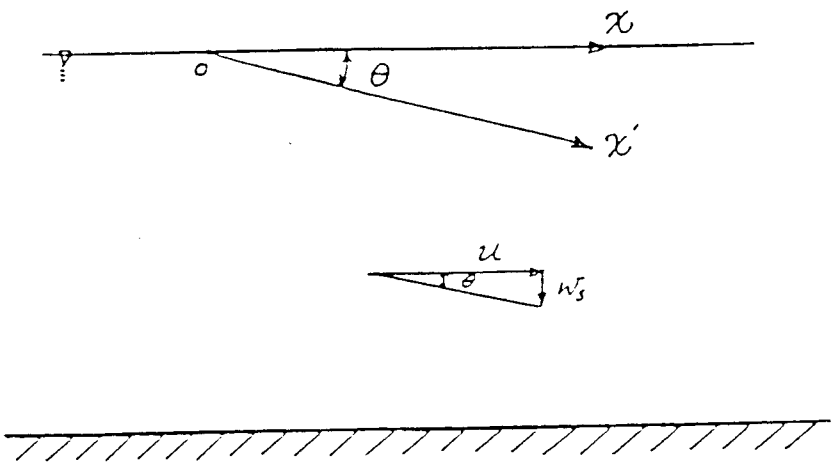


Figure 2-1. Definition sketch of the longitudinal direction with the effects of settling velocity.

Physically we are simply following the particles down with a velocity Ws while they are being advected downstream at speed U. The reduction in concentration still obeys the same formula as in Equation 2.9 except that the velocity along x' should be $U' = \sqrt{(U^2 + Ws^2)}$. But $t = x/U = x'/U'$ and hence the evaluation of Equation 2.9 needs only to be performed once for all Ws. Only the vertical location needs to be changed for each of the particle classes with differing fall velocities.

The effect of vertical diffusion can be incorporated approximately by deducing a concentration reduction factor based on vertical diffusion. For this purpose we assume Fickian diffusion with a diffusion coefficient Kv. Then it can be readily deduced that the concentration reduction factor due to vertical diffusion is approximately

$$\frac{H/4}{(2\ Kv\ t + H^2/16)^{1/2}} \tag{2.10}$$

The quantity in the denominater is simply the characteristic vertical dimension (standard deviation) of the plume whose initial dimension is H/4. Combining this with the reduction due to lateral diffusion gives

$$\frac{Cmax}{Co} = \frac{H/4}{(2Kvt+H^2/16)^{1/2}}\ \mathrm{erf}\left\{ \left[\frac{1.5}{(1 + 8At/L^{2/3})^3} - 1 \right]^{1/2} \right\} \tag{2.11}$$

where the vertical location of the centroid y is

$$y = Ws\ t = Ws\ x\ /\ U \tag{2.12}$$

The above formulation retains all the essence of the complicated diffusion process in an ocean current. It is believed that this model provides a good and valid estimate of the mixing, transport, and diffusion of the tuna fish waste.

3. RESULTS OF MATHEMATICAL MODELING

The mathematical model developed in Section 2 was used to simulate the fate of the discharged fish processing wastes with the available data. The data used in the simulations are first presented. Then the results are presented in terms of dilution as a function of time after discharge and distance from the discharge location. According to Fischer et al. (1979), dilution usually is defined as the ratio of the total volume of a sample to the volume of effluent contained in the sample. Thus the volume fraction of effluent in a sample is equal to the reciprocal of dilution.

3.1 Data used for Simulations

The following input data are obtained from Soule and Oguri (1983):

Ambient Current Velocity	0 to 0.8 knots	
Ambient Density Profiles	summer, winter	
Dumpsite Water Depth	1.46 km (800 fathoms)	
Discharge Rate	500 to 1400 gpm	
	(1.89 cu m/min to 5.30 cu m/min)	
Sludge Bulk Density	0.72 to 0.96 gm/ml	Star-Kist
	0.99 gm/ml	Van Camp
Sludge Tank Capacity	24000 gal (90.85 cu m)	
Dump Vessel Key Dimensions	Length = 49.0 m Beam = 8.1 m Draft = 3.35 m	

The radius of the dumping circle circumscribed by the dump vessel is 0.2 n mi. Also, the pumping rate of the sludge is 140 gpm per knot of vessel speed which can go up to 10 knots. Thus, for our simulation a range of discharge rates between 500 gpm and 1400 gpm is used. The discharge of the fish waste is completed within a time period during which the current direction does not change. For example, with the sludge tank capacity of 24,000 gallons and the discharge rate of 500 gpm the estimated discharge

period would be 48 minutes. It is reasonable to assume that the direction of the current would not be altered during this period.

Data of the ambient current velocity in the vicinity of the dumpsite are also available from the drogue and waste plume tracking studies conducted by Soule and Oguri (1984) and 1987 permit monitoring data. According to the drogue tracking studies, the speed of the surface current ranges from 0.39 to 0.94 knots. The waste plume was observed to move at an average speed of 0.67 knots. These values of the ambient current speed are in good agreement with the values (0.4 to 0.8 knots) published in the U.S. Navy Marine Climatic Atlas of the World (1979). The prevailing surface current patterns in the South Pacific Ocean for the summer and winter seasons are shown in Figures 3-1 and 3-2, respectively. Therefore, current speeds of 0.2, 0.4, and 0.8 knots have been used in the simulations.

Two ambient density profiles have been used in the simulations to account for the summer and winter seasons. Typical sea water temperature and salinity profiles for the summer and winter seasons are shown in Tables 3-1 and 3-2, respectively. These profiles were obtained from Soule and Oguri (1983) who conducted cruise studies in the vicinity of the dumpsite. As shown in Table 3-1, the temperature data were obtained to a water depth of 24.5 m. However, a thermocline would be present in the summer season. Hence, a thermocline is assumed to be present at a water depth of about 100 - 200 m based on the data available for the Southern Pacific Ocean. The sea water temperature profile for the summer season looks like this:

0 to 100 m	same as shown in Table 3-1
100 to 200 m	a temperature gradient of $8^{o}C$ / 50 m
below 200 m	a temperature gradient of $1.2^{o}C$ / 50 m

FIG. 3-1 PREVAILING SURFACE CURRENTS SUMMER, (DEC., JAN., FEB.)

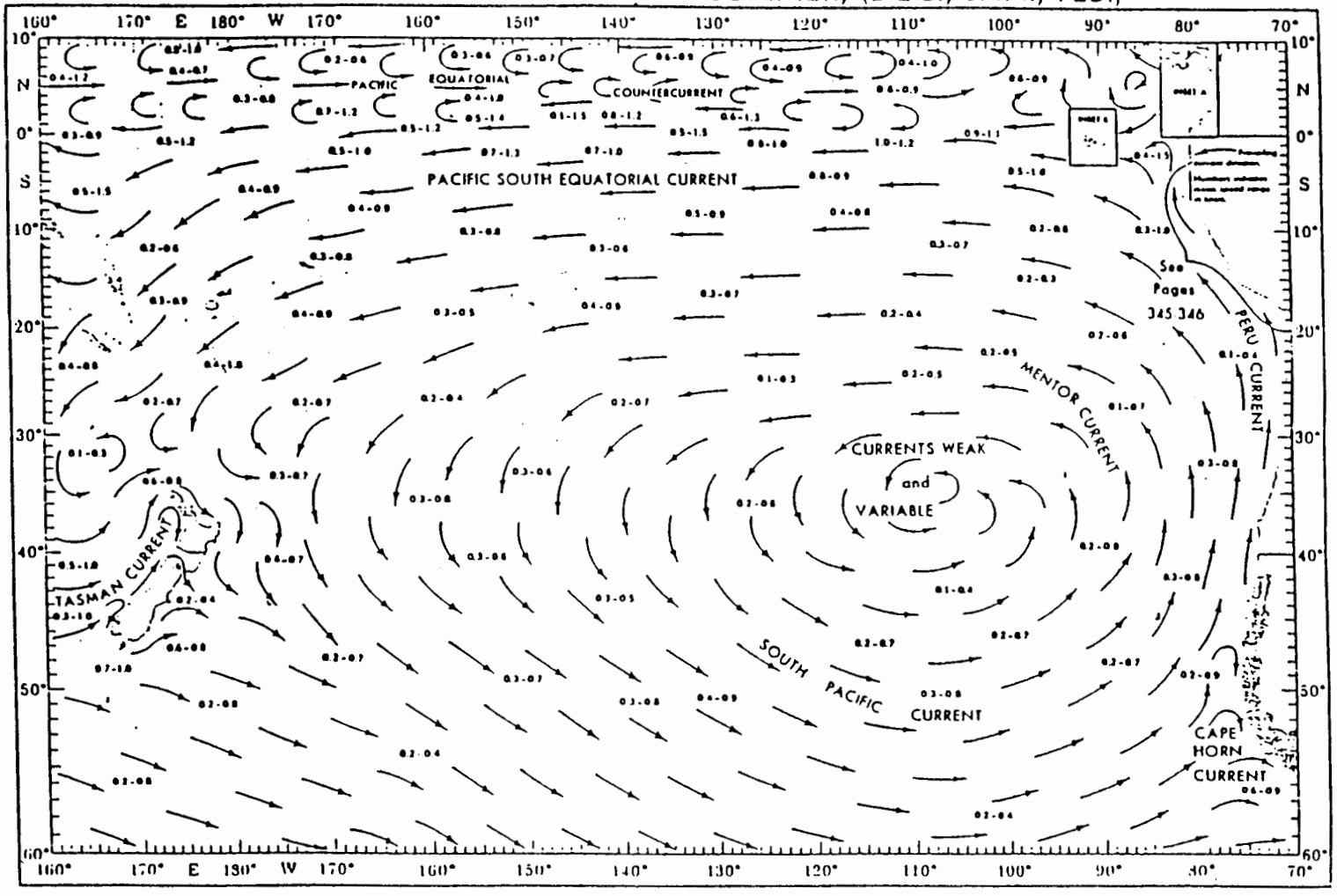


FIG. 3-2 PREVAILING SURFACE CURRENTS WINTER, (JUN., JUL., AUG.)

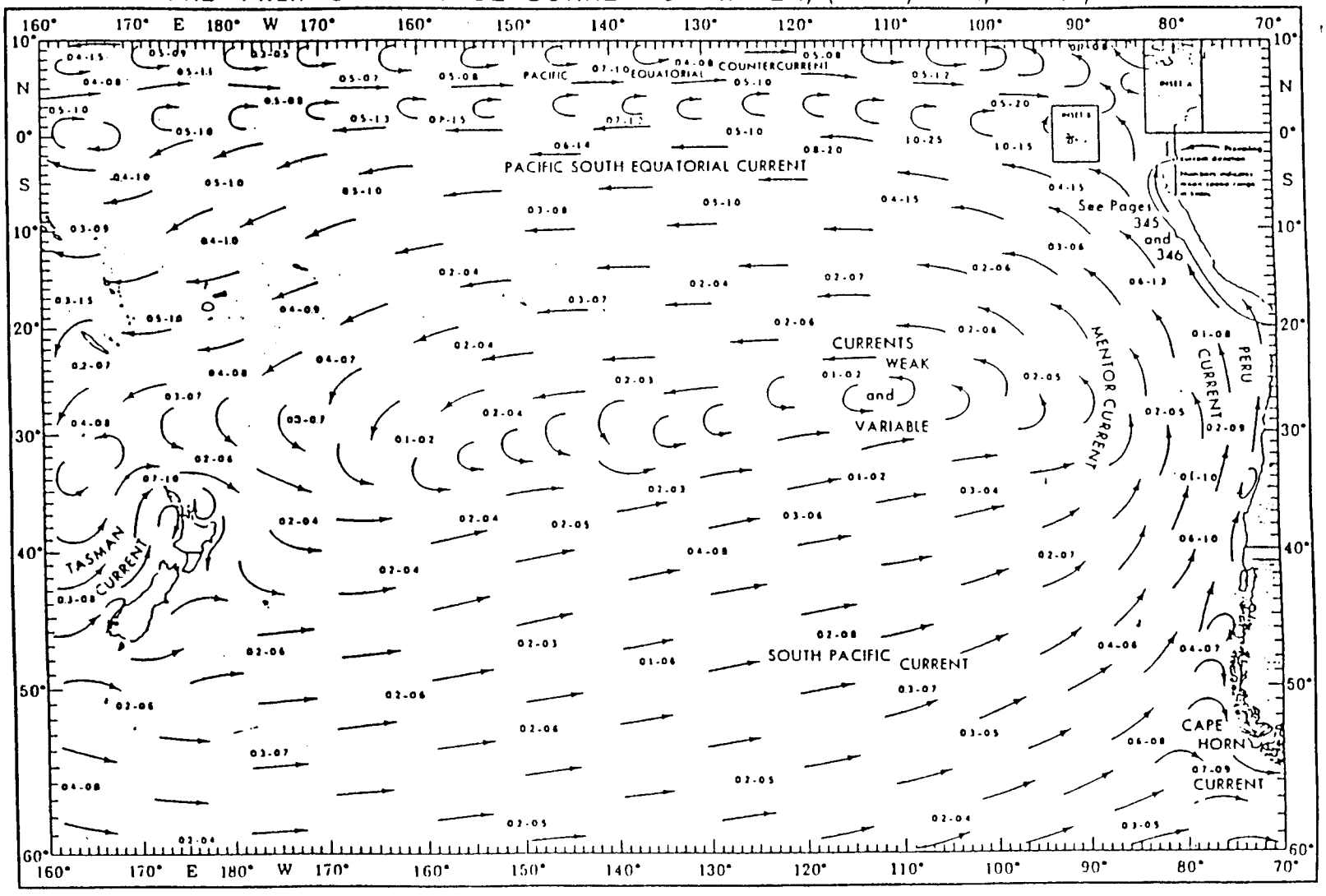


Table 3-1

CRUISE: Star-Kist - Van Camp NOAA-OMPA-AMERICAN SAMOA

VESSEL: AUTELE

DATE: 21 Jan. 1982

WEATHER: See Cruise Report

SEA STATE: See Cruise Report

TIDE: High; 1710, 2.6ft.

Station	Depth m	Time	Temp °C	Sal o/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l	DO Winkler
TP05	0	1045	29.8	36.3	5.9	8.4	55	3	6		4.5		5.4
	3		29.9	36.8	6.1	8.4	85				3.5		5.4
	6		29.5	37.0	6.1	8.4	90						5.6
	10		29.4	37.0	6.1	8.4	96				3		5.5
	15		29.4		6.0	8.5	98						
TS06	0	1115	29.5	36.1	5.7	8.4	87	4	4				5.4
	3		29.5	36.5	5.5	8.4	86						5.7
	6		29.4	36.5	5.8	8.4	91						5.8
	10		29.4	36.8	6.0	8.5	95						5.6
	15		29.4		5.8	8.5	96						
TS07	0	1135	29.4	36.6	5.7	8.4	90	7	3		7.5		5.6
	3		29.5	36.6	6.0	8.4	88				5		5.4
	6		29.5	36.7	5.7	8.4	91				6		5.6
	10		29.5	36.9	5.8	8.4	92				5.5		5.7
	15		29.5		5.8	8.5	94						
	20		29.4		5.8	8.5	93						
	24.5		29.4		5.8	8.5	93						

Table 3-2

CRUISE: NOAA-OMPA-Star-Kist Samoa VESSEL: Autele DATE: 23 July 1982

WEATHER: Hot, calm with gusts, 2-6k SEA STATE: Long swells, 8-10ft TIDE: Low 1530, -0.5ft

Station (Map/Site)	Depth m	Time	Temp °C	Sal o/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS E (6)	0	1141	28.37	34.28	6.68	8.27		3	6			
	3		28.33	34.30	6.64	8.26						
	6		28.25	34.32	6.68	8.26						
	10		28.24	34.32	6.65	8.26						
	15		28.24	34.33	6.66	8.27						
	20		28.23	34.35	6.63	8.27						
* (7)												
TS F (8)	0	1157	28.59	34.25	6.62	8.25		4	4			
	3		28.29	34.31	6.66	8.26						
	6		28.26	34.31	6.41	8.26						
	10		28.25	34.32	6.41	8.27						
	15		28.25	34.32	6.51	8.27						
	20		28.25	34.32	6.41	8.27						
TS G (9)	0	1206	28.44	34.27	6.62	8.25		14	3			
	3		28.31	34.30	6.65	8.26						
	6		28.26	34.30	6.66	8.27						
	10		28.24	34.31	6.53	8.27						
	15		28.24	24.32	6.42	8.27						
	20		28.24	34.31	6.41	8.27						

*7 1151 drogues only

For water depths below 100 m, the temperature gradients have been estimated from the data shown in Figure III.11, of this volume. A temperature profile as shown in Table 3-2 has been assumed for the winter season. The temperature gradient is about 0.5^{o}C per 30.5m.

3.2 Results of Simulations

Before the simulations were performed, parameters such as A, Co, Kv, and L in Equation 2.11 need to be calculated or chosen. The parameter A is a constant called the dissipation parameter. The constant A relates the lateral diffusivity to the plume width parameter as defined in Equation 2.8. The empirical value of A in the ocean environment is generally from 0.1 to 0.0001 $ft^{2/3}$ /sec. (See Koh & Fan 1970, page 129 for presentation of such data). For the study site the exact value of A is not known. Therefore, a median value in the range just cited can be assumed. The value of A chosen for this simulation is 0.001 $ft^{2/3}$ /sec Since the exact value varies from day to day and it also depends on the currents in the study site, this chosen value is believed to be reasonable. More precise value may be obtained by field experiments.

The initial mean concentration Co of the fish wastes discharged into the ocean water through the disposal ship must be estimated based on the discharge rate. This value corresponds to the dilution obtained at the wake of the discharge ship and it can be estimated by the formula developed by Koh and Chang (1973). In their analysis they first assumed that the pumping rate of the waste material is such that the waste material is completely mixed into the wake by the turbulence without altering the wake flow pattern. Secondly, the effect of surface waves can be disregarded so that the flow pattern can be approximated from the analysis of the jet and wake flows. Thirdly, they assumed that the flow

pattern approaches a similarity form at a certain distance from the discharge point. Based on the given information of the discharge vessel and the assumptions involved in deriving the Koh and Chang formula, the initial mean concentration, Co, can be estimated by the following formula:

$$Co = \frac{Q}{1.814\,\pi\,R^2\,V} \qquad (3.1)$$

where Q is the discharge rate of the fish waste from the discharge pipe.

R is a characteristic length of the body which is chosen as the geometric mean of the half beam and the draft of the discharge vessel (i.e. $[(\text{ship draft})\ (\text{half beam})]^{1/2}$.

V is the relative velocity between ship and ambient current.

It should be noted that based on Equation 3.1 the scale of the mixing zone in the wake is proportional to the characteristic dimension of the discharge vessel which is reasonable.

The vertical diffusion coefficient Kv can be evaluated by the formulation of Koh and Fan (1970)

$$Kv = 10^{-4} / E \qquad (\text{sq cm/sec}) \qquad (3.2)$$

and

$$E = \left| \frac{1}{\rho} \frac{d}{dy} \right| \qquad (3.3)$$

where E = sea water density gradient

ρ = sea water density

y = water depth (meters)

From the temperature profiles developed in Section 3.1, the values of Kv, as shown in Table 3-3, are calculated as a function of water depth for the summer and winter seasons.

The width L of the initial plume is expected to be approximately twice the turning radius of the discharge ship. Since the turning radius

Table 3-3. Vertical Diffusion Coefficient.

Depth (m)	Kv (sq cm/sec) Summer	Winter
0 - 100	7.8	17.3
100 - 200	1.2	17.3
> 200	7.3	17.3

of the disposal vessel is 0.2 n mi (370.5 m), L is taken to be 741 m.

The results of the simulations are presented in terms of dilution of the fish wastes as a function of time after discharge and distance from the discharge location. Dilution is reciprocal of the product of Co and Cmax/Co. This value gives an indication of the volume fraction of fish waste in the water sample after the waste plume has traveled for a certain distance from the discharge location. Since no data have been obtained for the settling velocity of the Samoa waste particles, velocities of 1, 0.1, and 0.01 cm/sec have been used in the calculations to cover the possible range of settling velocities which is a function of the density of the waste material relative to the sea water density. The group of results with settling velocities of 0.01, 0.1, and 1.0 cm/sec would correspond to the particles that are floating on the ocean surface, neutrally buoyant in sea water and heavier than sea water respectively. The behavior of the particles with a settling velocity of 0.1 cm/sec is similar to that of neutrally buoyant particles and thus they are advected by the ambient surface and near surface currents.

The settling tank experiments reported by Soule and Oguri (1983) indicate that 30% of the fish waste being studied had a fall velocity greater than zero, 7% of the wastes had a fall velocity greater than 0.059 cm/sec and only 0.5% of the waste had a fall velocity greater than 0.24 cm/sec. Therefore the range of fall velocity used for the present study is reasonable. In fact, the fall velocity of 0.01 cm/sec would be the most representative value; thus, when discussing the simulated results, attention is directed toward the fall velocity of 0.01 cm/sec.

The computer model results are presented in tabular form in Tables 3-4 to 3-7 using the dimensions given for the dump vessel. Tables 3-4 and

Table 3-4. Results of Summer Waste Dilution, Q = 500 gpm.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
				Vfall = 1 cm/s			Vfall = 0.1 cm/s			Vfall = 0.01 cm/s		
T(hr)	X(n mi)	U(kt)	Co	Y1(m)	Cmax/Co	Ratio	Y2(m)	Cmax/Co	Ratio	Y3(m)	Cmax/Co	Ratio
5.0	1.0	.2	.000222	180.0	.05423	.33	18.0	.04999	.36	1.8	.04999	.36
7.5	1.5	.2	.000222	270.0	.03242	.56	27.0	.03038	.59	2.7	.03038	.59
10.0	2.0	.2	.000222	360.0	.02172	.83	36.0	.02052	.88	3.6	.02052	.88
12.5	2.5	.2	.000222	450.0	.01562	1.15	45.0	.01482	1.22	4.5	.01482	1.22
15.0	3.0	.2	.000222	540.0	.01179	1.53	54.0	.01133	1.59	5.4	.01122	1.61
17.5	3.5	.2	.000222	630.0	.00922	1.95	63.0	.00947	1.90	6.3	.00880	2.05
20.0	4.0	.2	.000222	720.0	.00741	2.43	72.0	.00805	2.24	7.2	.00769	2.54
2.5	1.0	.4	.000222	90.0	.05794	.31	9.0	.05035	.36	.9	.05035	.36
3.7	1.5	.4	.000222	135.0	.03790	.47	13.5	.03430	.53	1.3	.03430	.53
5.0	2.0	.4	.000222	180.0	.02726	.66	18.0	.02507	.72	1.8	.02507	.72
6.3	2.5	.4	.000222	225.0	.02067	.87	22.5	.01920	.94	2.2	.01920	.94
7.5	3.0	.4	.000222	270.0	.01627	1.11	27.0	.01522	1.18	2.7	.01522	1.18
8.8	3.5	.4	.000222	315.0	.01317	1.37	31.5	.01238	1.46	3.1	.01238	1.46
10.0	4.0	.4	.000222	360.0	.01089	1.65	36.0	.01028	1.75	3.6	.01028	1.75
1.2	1.0	.8	.000222	45.0	.04207	.43	4.5	.04207	.43	.5	.04207	.43
1.9	1.5	.8	.000222	67.5	.03532	.51	6.8	.03183	.57	.7	.03183	.57
2.5	2.0	.8	.000222	90.0	.02859	.63	9.0	.02521	.71	.9	.02521	.71
3.1	2.5	.8	.000222	112.5	.02287	.79	11.3	.02058	.88	1.1	.02058	.88
3.7	3.0	.8	.000222	135.0	.01883	.96	13.5	.01717	1.05	1.3	.01717	1.05
4.4	3.5	.8	.000222	157.5	.01585	1.14	15.8	.01457	1.24	1.6	.01457	1.24
5.0	4.0	.8	.000222	180.0	.01355	1.33	18.0	.01254	1.44	1.8	.01254	1.44

Table 3-5. Results of Summer Waste Dilution, Q = 1400 gpm.

				Vfall = 1 cm/s			Vfall = 0.1 cm/s			Vfall = 0.01 cm/s		
T(hr)	X(n mi)	U(kt)	Co	Y1(m)	Cmax/Co	Ratio	Y2(m)	Cmax/Co	Ratio	Y3(m)	Cmax/Co	Ratio
5.0	1.0	.2	.000621	180.0	.05423	.12	18.0	.05060	.13	1.8	.05000	.13
7.5	1.5	.2	.000621	270.0	.03242	.20	27.0	.03039	.21	2.7	.03039	.21
10.0	2.0	.2	.000621	360.0	.02172	.30	36.0	.02052	.31	3.6	.02052	.31
12.5	2.5	.2	.000621	450.0	.01562	.41	45.0	.01483	.43	4.5	.01483	.43
15.0	3.0	.2	.000621	540.0	.01179	.55	54.0	.01133	.57	5.4	.01123	.57
17.5	3.5	.2	.000621	630.0	.00922	.70	63.0	.00947	.68	6.3	.00890	.73
20.0	4.0	.2	.000621	720.0	.00741	.87	72.0	.00805	.80	7.2	.00789	.91
2.5	1.0	.4	.000621	90.0	.05795	.11	9.0	.05036	.13	.9	.05036	.13
3.7	1.5	.4	.000621	135.0	.03799	.17	13.5	.03430	.19	1.3	.03430	.19
5.0	2.0	.4	.000621	180.0	.02727	.24	18.0	.02507	.26	1.8	.02507	.26
6.3	2.5	.4	.000621	225.0	.02067	.31	22.5	.01921	.34	2.2	.01921	.34
7.5	3.0	.4	.000621	270.0	.01627	.40	27.0	.01522	.42	2.7	.01522	.42
8.8	3.5	.4	.000621	315.0	.01317	.49	31.5	.01230	.52	3.1	.01230	.52
10.0	4.0	.4	.000621	360.0	.01089	.59	36.0	.01020	.63	3.6	.01020	.63
1.2	1.0	.8	.000621	45.0	.04208	.15	4.5	.04208	.15	.5	.04209	.15
1.9	1.5	.8	.000621	67.5	.03533	.18	6.8	.03184	.20	.7	.03184	.20
2.5	2.0	.8	.000621	90.0	.02859	.23	9.0	.02522	.26	.9	.02522	.26
3.1	2.5	.8	.000621	112.5	.02297	.28	11.3	.02058	.31	1.1	.02058	.31
3.7	3.0	.8	.000621	135.0	.01884	.34	13.5	.01717	.37	1.3	.01717	.37
4.4	3.5	.8	.000621	157.5	.01585	.41	15.8	.01457	.44	1.6	.01457	.44
5.0	4.0	.8	.000621	180.0	.01355	.47	18.0	.01254	.51	1.8	.01254	.51

Table 3-6. Results of Winter Waste Dilution, Q = 500 gpm.

				Vfall = 1 cm/s			Vfall = 0.1 cm/s			Vfall = 0.01 cm/s		
T(hr)	X(n mi)	U(kt)	Co	Y1(m)	Cmax/Co	Ratio	Y2(m)	Cmax/Co	Ratio	Y3(m)	Cmax/Co	Ratio
5.0	1.0	.2	.000222	180.0	.03364	.54	18.0	.03364	.54	1.8	.03364	.54
7.5	1.5	.2	.000222	270.0	.02043	.88	27.0	.02043	.88	2.7	.02043	.88
10.0	2.0	.2	.000222	360.0	.01379	1.31	36.0	.01379	1.31	3.6	.01379	1.31
12.5	2.5	.2	.000222	450.0	.00996	1.81	45.0	.00996	1.81	4.5	.00996	1.81
15.0	3.0	.2	.000222	540.0	.00754	2.39	54.0	.00754	2.39	5.4	.00754	2.39
17.5	3.5	.2	.000222	630.0	.00591	3.05	63.0	.00591	3.05	6.3	.00591	3.05
20.0	4.0	.2	.000222	720.0	.00476	3.78	72.0	.00476	3.78	7.2	.00476	3.78
2.5	1.0	.4	.000222	90.0	.03385	.53	9.0	.03385	.53	.9	.03385	.53
3.7	1.5	.4	.000222	135.0	.02305	.78	13.5	.02305	.78	1.3	.02305	.78
5.0	2.0	.4	.000222	180.0	.01684	1.07	18.0	.01684	1.07	1.8	.01684	1.07
6.3	2.5	.4	.000222	225.0	.01290	1.40	22.5	.01290	1.40	2.2	.01290	1.40
7.5	3.0	.4	.000222	270.0	.01022	1.76	27.0	.01022	1.76	2.7	.01022	1.76
8.8	3.5	.4	.000222	315.0	.00831	2.17	31.5	.00831	2.17	3.1	.00831	2.17
10.0	4.0	.4	.000222	360.0	.00690	2.61	36.0	.00690	2.61	3.6	.00690	2.61
1.2	1.0	.8	.000222	45.0	.02827	.64	4.5	.02827	.64	.5	.02827	.64
1.9	1.5	.8	.000222	67.5	.02138	.84	6.8	.02138	.84	.7	.02138	.84
2.5	2.0	.8	.000222	90.0	.01693	1.06	9.0	.01693	1.06	.9	.01693	1.06
3.1	2.5	.8	.000222	112.5	.01382	1.30	11.3	.01382	1.30	1.1	.01382	1.30
3.7	3.0	.8	.000222	135.0	.01153	1.56	13.5	.01153	1.56	1.3	.01153	1.56
4.4	3.5	.8	.000222	157.5	.00979	1.84	15.8	.00979	1.84	1.6	.00979	1.84
5.0	4.0	.8	.000222	180.0	.00842	2.14	18.0	.00842	2.14	1.8	.00842	2.14

Table 3-7. Results of Winter Waste Dilution, Q = 1400 gpm.

				Vfall = 1 cm/s			Vfall = 0.1 cm/s			Vfall = 0.01 cm/s		
T(hr)	X(n mi)	U(kt)	Co	Y1(m)	Cmax/Co	Ratio	Y2(m)	Cmax/Co	Ratio	Y3(m)	Cmax/Co	Ratio
5.0	1.0	.2	.000621	180.0	.03364	.19	18.0	.03364	.19	1.8	.03364	.19
7.5	1.5	.2	.000621	270.0	.02043	.32	27.0	.02043	.32	2.7	.02043	.32
10.0	2.0	.2	.000621	360.0	.01380	.47	36.0	.01380	.47	3.6	.01380	.47
12.5	2.5	.2	.000621	450.0	.00996	.65	45.0	.00996	.65	4.5	.00996	.65
15.0	3.0	.2	.000621	540.0	.00754	.85	54.0	.00754	.85	5.4	.00754	.85
17.5	3.5	.2	.000621	630.0	.00591	1.09	63.0	.00591	1.09	6.3	.00591	1.09
20.0	4.0	.2	.000621	720.0	.00476	1.35	72.0	.00476	1.35	7.2	.00476	1.35
2.5	1.0	.4	.000621	90.0	.03385	.19	9.0	.03385	.19	.9	.03385	.19
3.7	1.5	.4	.000621	135.0	.02305	.28	13.5	.02305	.28	1.3	.02305	.28
5.0	2.0	.4	.000621	180.0	.01684	.38	18.0	.01684	.38	1.8	.01684	.38
6.3	2.5	.4	.000621	225.0	.01290	.50	22.5	.01290	.50	2.2	.01290	.50
7.5	3.0	.4	.000621	270.0	.01022	.63	27.0	.01022	.63	2.7	.01022	.63
8.8	3.5	.4	.000621	315.0	.00832	.77	31.5	.00832	.77	3.1	.00832	.77
10.0	4.0	.4	.000621	360.0	.00690	.93	36.0	.00690	.93	3.6	.00690	.93
1.2	1.0	.8	.000621	45.0	.02827	.23	4.5	.02827	.23	.5	.02827	.23
1.9	1.5	.8	.000621	67.5	.02138	.30	6.8	.02138	.30	.7	.02138	.30
2.5	2.0	.8	.000621	90.0	.01694	.38	9.0	.01694	.38	.9	.01694	.38
3.1	2.5	.8	.000621	112.5	.01382	.47	11.3	.01382	.47	1.1	.01382	.47
3.7	3.0	.8	.000621	135.0	.01153	.56	13.5	.01153	.56	1.3	.01153	.56
4.4	3.5	.8	.000621	157.5	.00979	.66	15.8	.00979	.66	1.6	.00979	.66
5.0	4.0	.8	.000621	180.0	.00842	.76	18.0	.00842	.76	1.8	.00842	.76

3-5 show the results for the summer months, with discharge rates Q = 500 gpm and Q = 1400 gpm, respectively. To interpret the results, it is fruitful to note the various items shown in each of the tables. The first column in Table 3-4 is the time after the initial release of the waste material. The second column converts the time into distance from the discharge point. In the third column, three different current speeds, namely 0.2 knots, 0.4 knots, and 0.8 knots are included. Based on Equation (3.1) the initial mean concentration, Co, is computed. For a discharge rate of 500 gpm Co is computed to be 0.000222. The vertical location of the centerline of the plume at different times for a fall velocity of 1 cm/sec is shown in the fifth column. The concentration at the centerline of the plume Cmax normalized with respect to Co is shown in column 6. The dilution, which can be obtained as the reciprocal of (Co) (Cmax/Co), can easily be obtained by the inverse of the value in column 4 multiplied by that in column 6. According to Soule and Oguri (1983) and Section III.A.2.C.1 of this report, the limiting permissible concentration (LPC) of the waste being discharged is 0.0004 % concentration of the fish waste. This value of concentration corresponds to a dilution of 250,000. Therefore, for convenience the dilution ratio has been normalized with respect to 250,000 and such ratio is presented in column 7. For the fall velocity of 0.1 cm/sec the corresponding results are presented in columns 8 to 10. Similarly the results for 0.01 cm/sec fall velocity are shown in columns 11 to 13. Thus, when one reads the value at columns 7, 10, and 13, a value of 1.00 implies the dilution of 250,000. A value greater than 1.0 implies a dilution greater than 250,000.

The major difference between the summer months and winter months is for the value of vertical diffusion. For the winter months, larger

vertical diffusions were used causing more mixing and thus a larger dilution. It can be seen that a greater mixing, therefore larger dilution, is achieved in the winter months (Tables 3-6 and 3-7) in comparison with the corresponding results for that in the summer months (Tables 3-4 and 3-5).

The results presented in Tables 3-4 to 3-7 can be plotted to provide a better picture of the extent of the waste plume following a prescribed current direction. Based on the available data the two observed directions at the discharge site are SW and NW. The waste plume is therefore advected along these directions while experiencing a lateral mixing along the way.

3.3 Extent of the Plume at the Present Site

To show the extent of the plume. at the present site, curves containing a series of equi-dilution lines are presented in Figures 3-3 and 3-4 (based on the results presented in Tables 3-4 and 3-6 respectively). The dilution ratios shown are the dilutions normalized with respect to 250,000 (LPC) for both the summer and winter months and for current speeds of 0.2 knots, 0.4 knots. and 0.8 knots. The discharge rate for these figures is 500 gpm and the fall velocity is set at 0.01 cm/sec.

Figure 3-5 shows the equi-dilution lines in the summer months plotted on the map for a waste discharge of 500 gpm in a current of 0.2 knots towards the SW direction. Two different equi-dilution lines are drawn: the line for 0.5 represents a dilution of 125,000, while the line for 1.0 represents a dilution of 250,000. Such a favorable current direction would continue to carry the plume away in the SW direction. Thus, the plume would not reach the shore region while undergoing a significant mixing and diffusion.

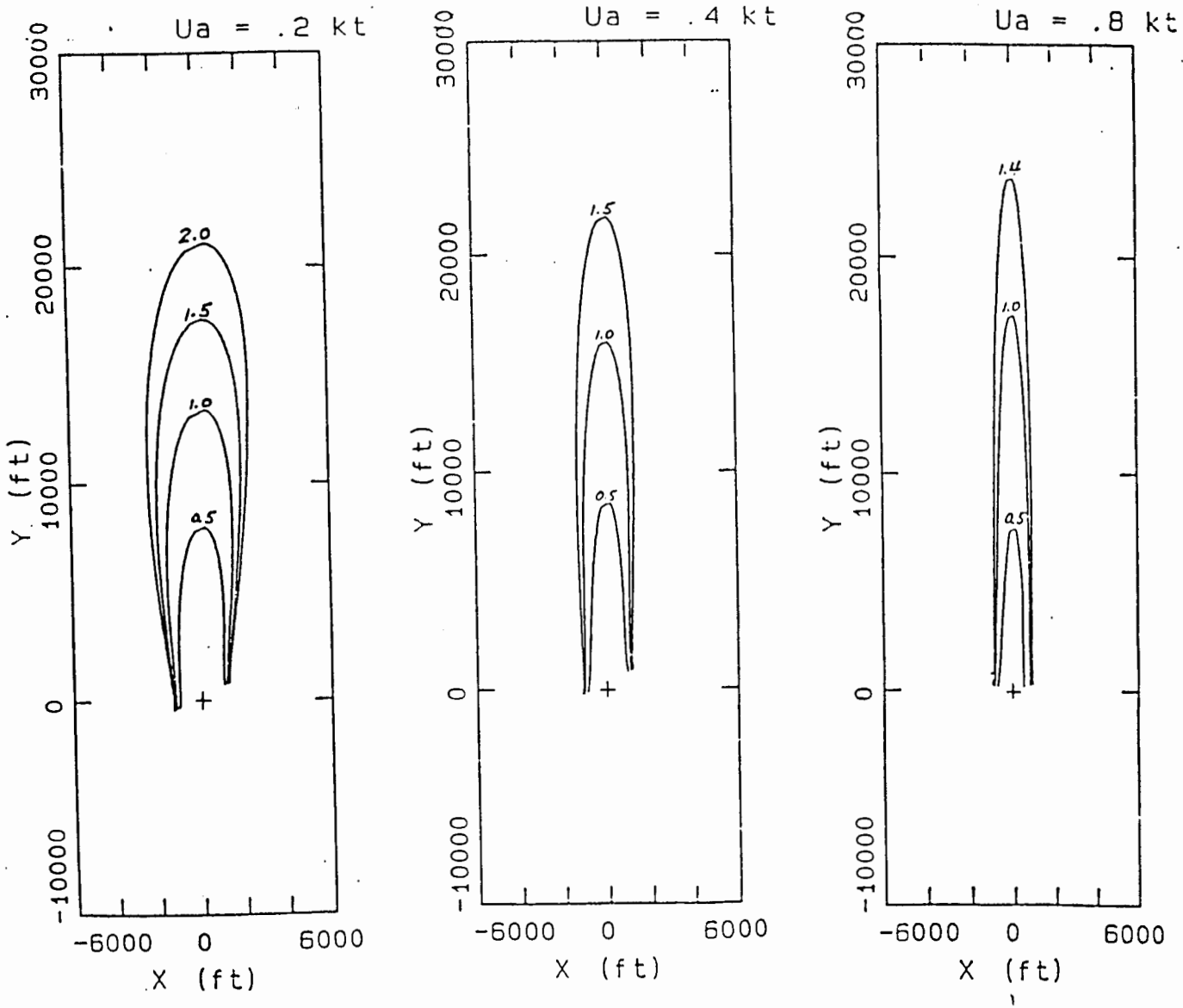


Figure 3-3. Equi-dilution lines of discharge waste plume, summer months. (Q = 500 gpm, Vfall = 0.01 cm/s, Ua = 0.2, 0.4, 0.8 kt).

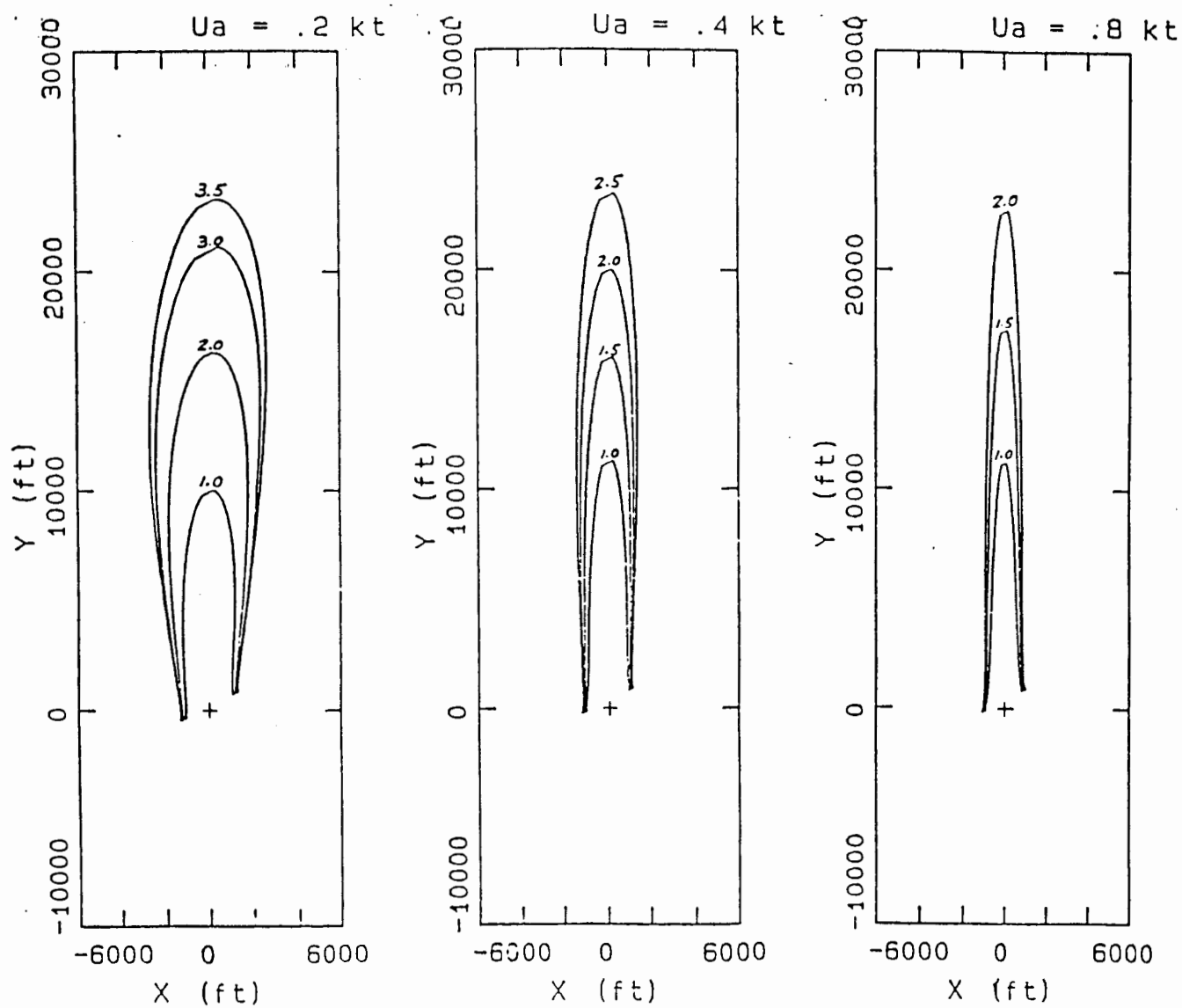


Figure 3-4. Equi-dilution lines of discharge waste plume, winter months. (Q = 500 gpm, Vfall = 0.01 cm/s, Ua = 0.2, 0.4, 0.8 kt).

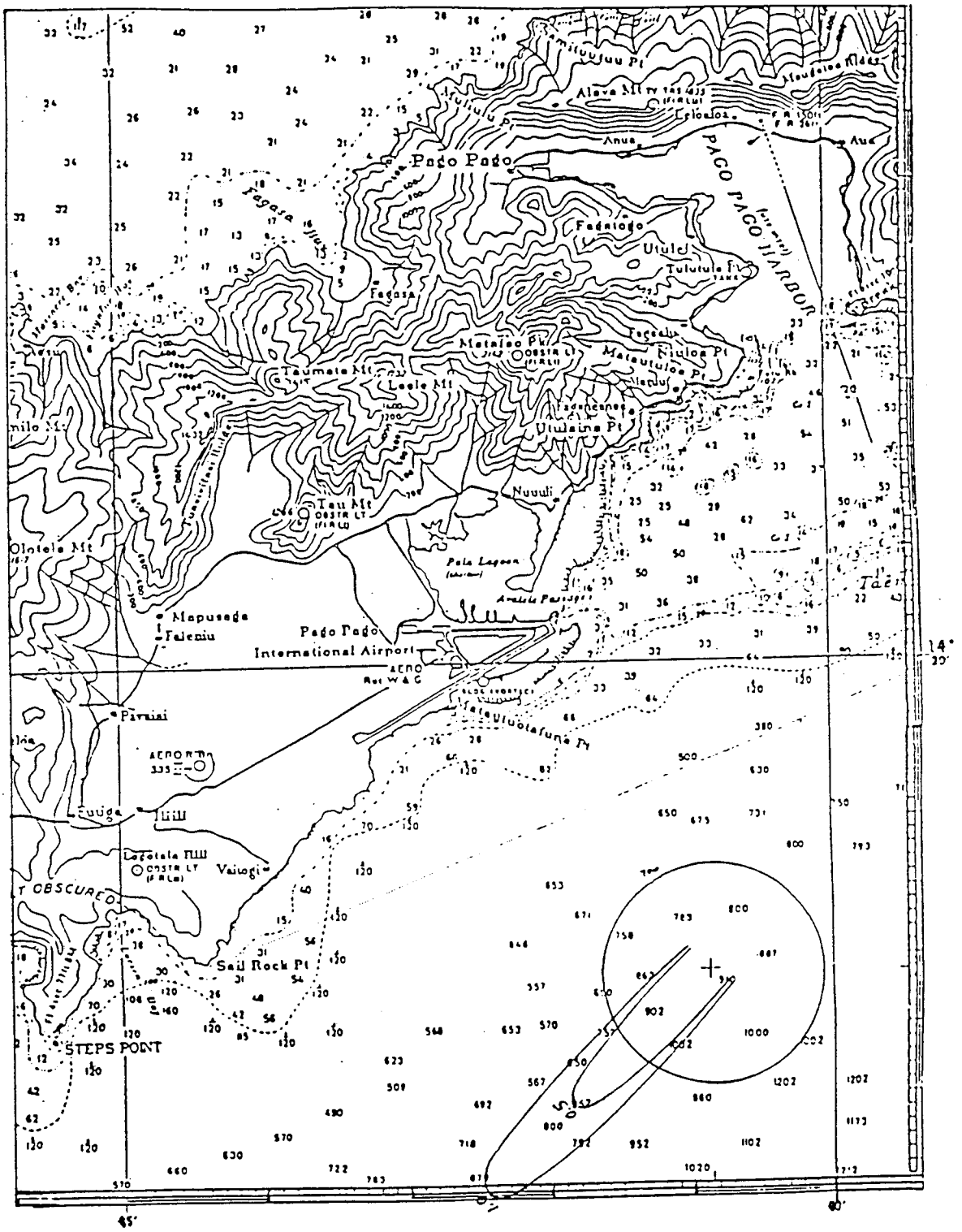


Figure 3-5. Equi-dilution lines of discharge waste plume, summer months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.2 kt).

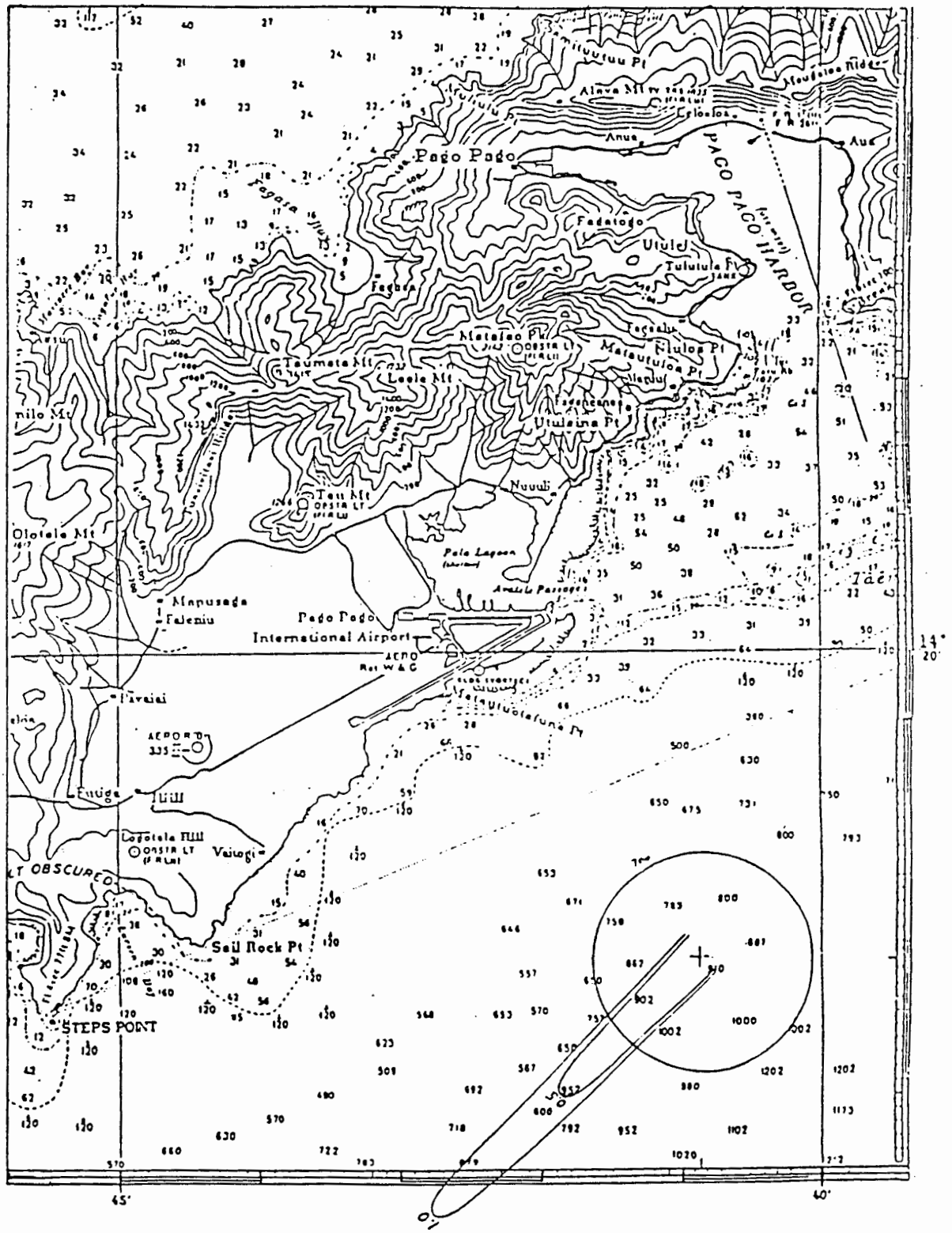


Figure 3-6. Equi-dilution lines of discharge waste plume, summer months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.4 kt).

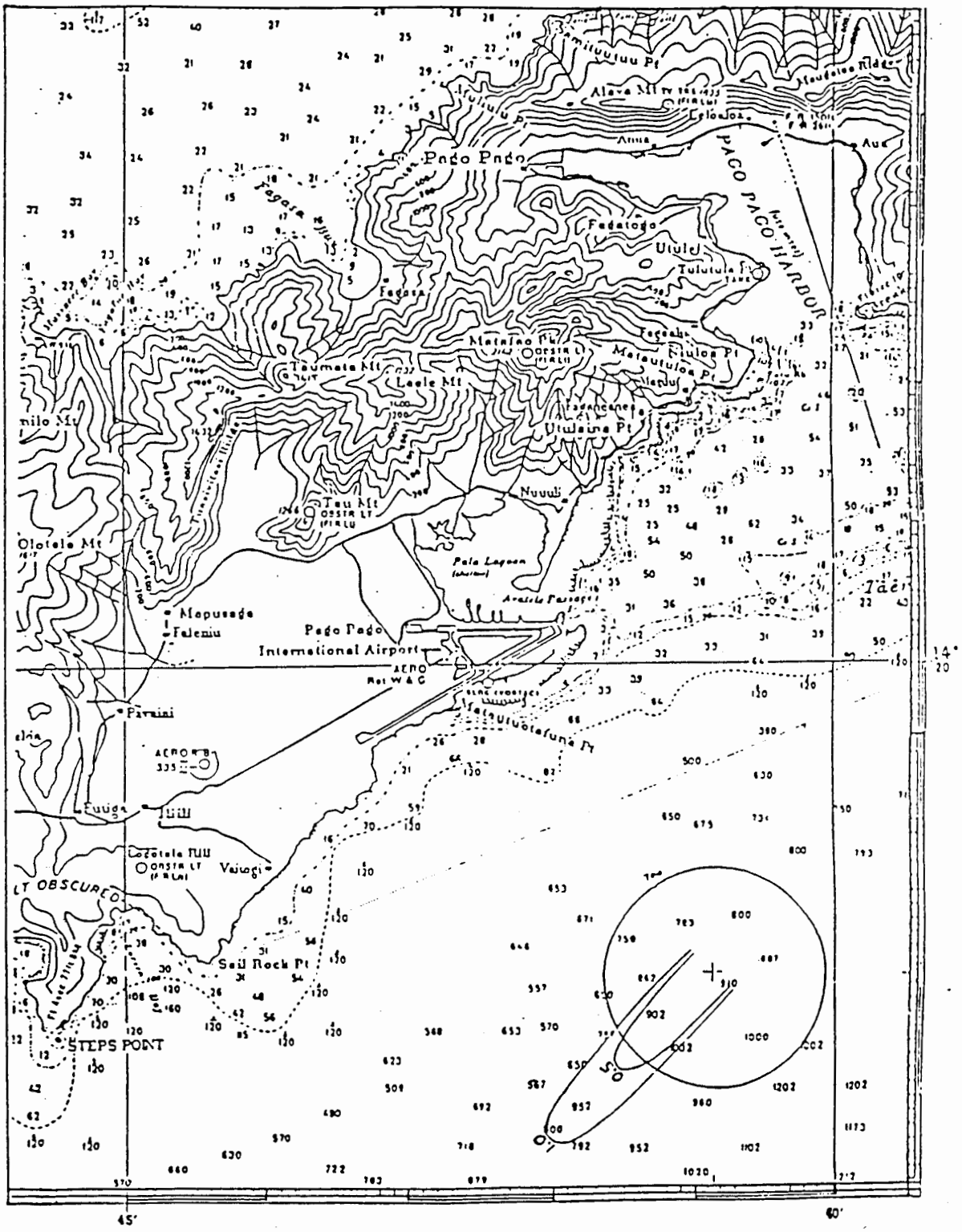


Figure 3-7. Equi-dilution lines of discharge waste plume, winter months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.2 kt).

Figure 3-6 shows the extent of the waste plume with a SW current of 0.4 kt. Comparing the results in Figure 3-6 with those in Figure 3-5, one observes that the effect of a stronger current is to advect the plume swiftly downstream in the current direction. Therefore, the extent of lateral diffusion is much narrower.

Figures 3-7 and 3-8 show the corresponding pictures for the winter months. By comparing these results with those presented in Figures 3-5 and 3-6, one can observe that a greater dilution is achieved in the winter months due to increased vertical diffusion.

The drogue studies conducted by Soule and Oguri (1984) indicate a current toward the southwest (SW) direction and that the data on the surface current presented in Figure III.8 also show predominant southwest surface current. However, some 1987 current meter data detect current in the northwest (NW) direction. Some current data indicated that a current in the southwest direction with a magnitude of 0.25 knots outside of the 120-fathom depth contour (CH2M Hill, 1976). A sketch confirming the direction of drogue movement (along the SW direction) after CH2M Hill is shown in Figure 3-9. Since the coastal current normally follows the depth contour, it is reasonable to expect a worst case illustration having a NW current (0.2 knots) at the dumpsite would at first carry the plume initially in the NW direction; however, as the plume propagates toward the shore the current will gradually bend the plume in a pattern such as shown in Figure 3-10. In fact, the simulated plume trajectory for this worst case scenario is illustrated in Figure 3-11. In Figure 3-11 the equi-dilution lines are drawn for the summer months with a waste discharge of 500 gpm in a current of 0.2 knots toward the NW direction at the dumpsite. It is seen that the dilution ratio of 1.0 (corresponds to 250,000

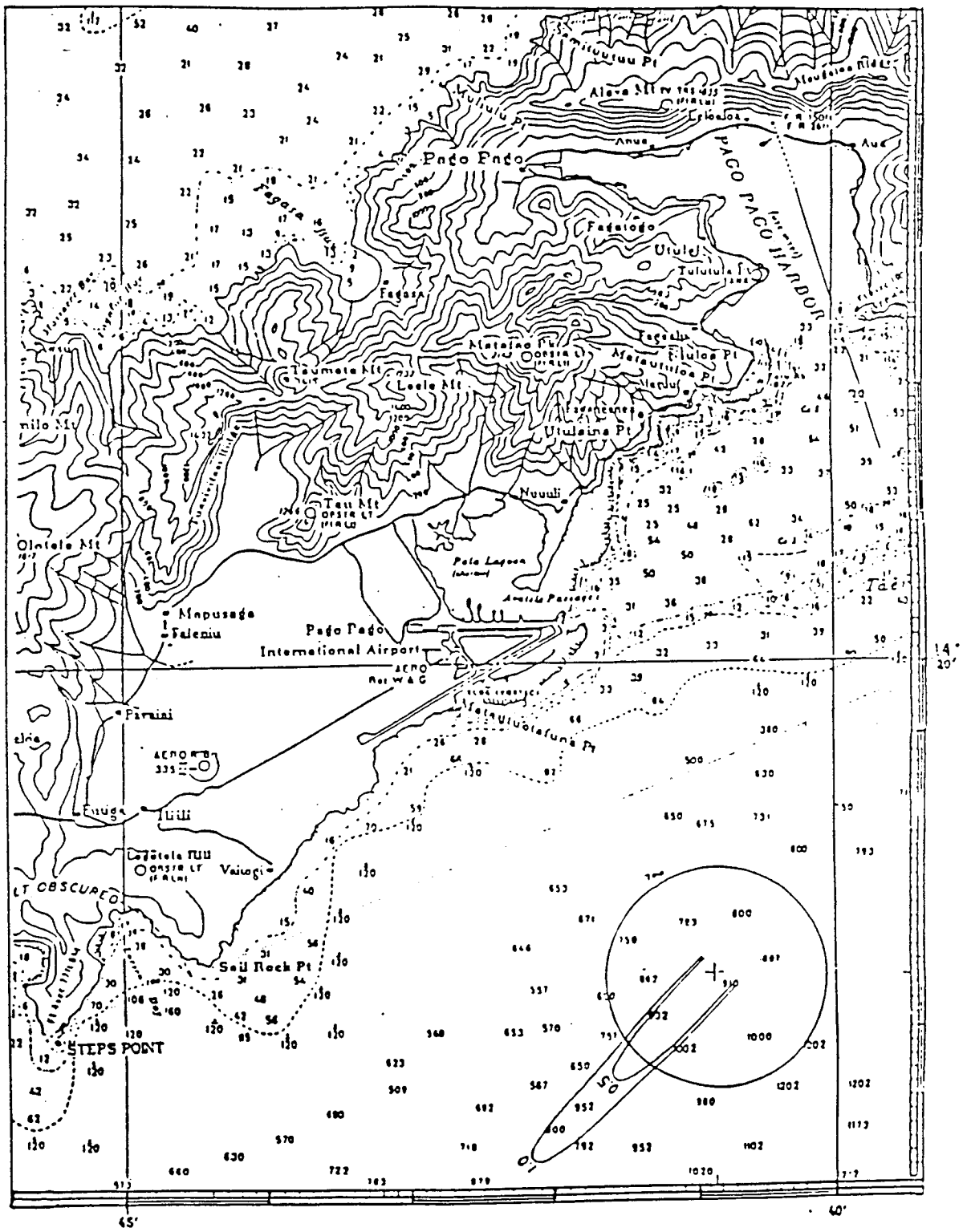


Figure 3-8. Equi-dilution lines of discharge waste plume, winter months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.4 kt).

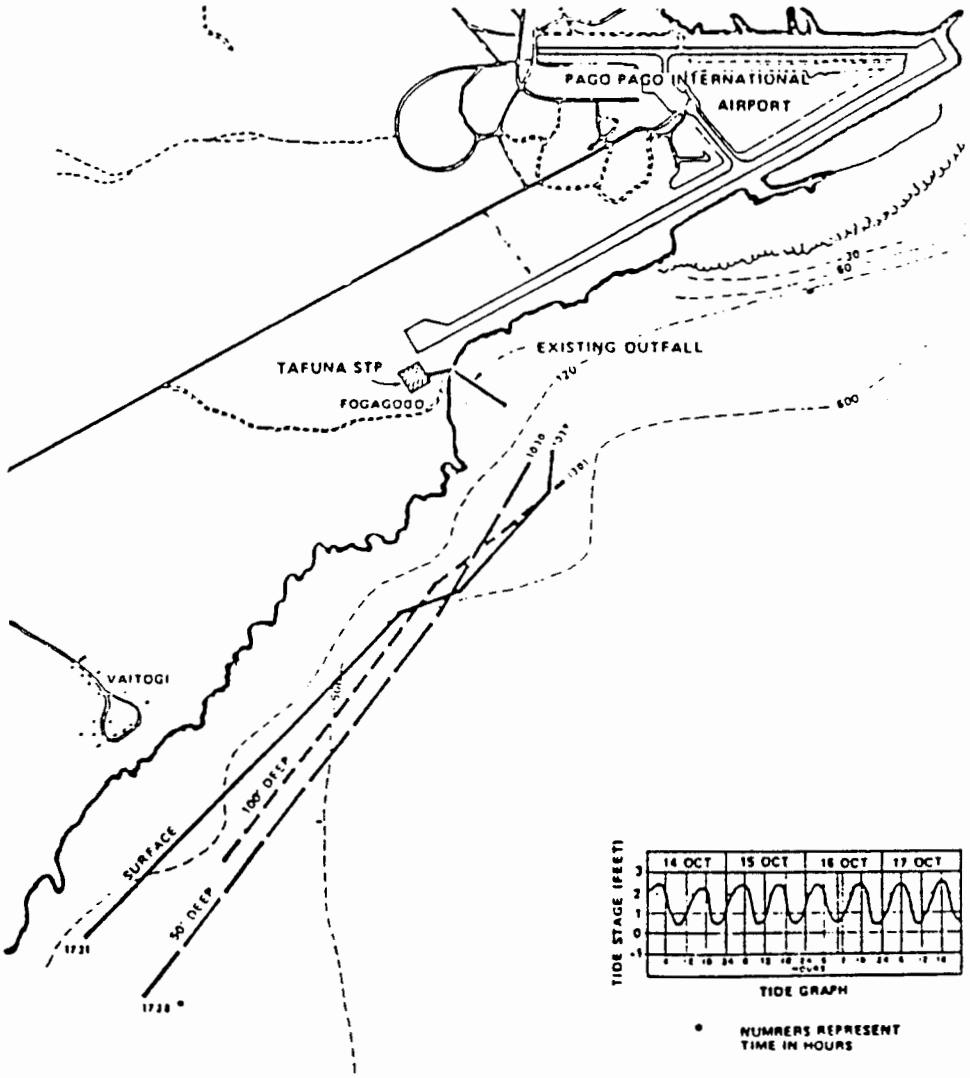


Figure 3-9. Drogue movement along shore (after CH_2M Hill, 1976).

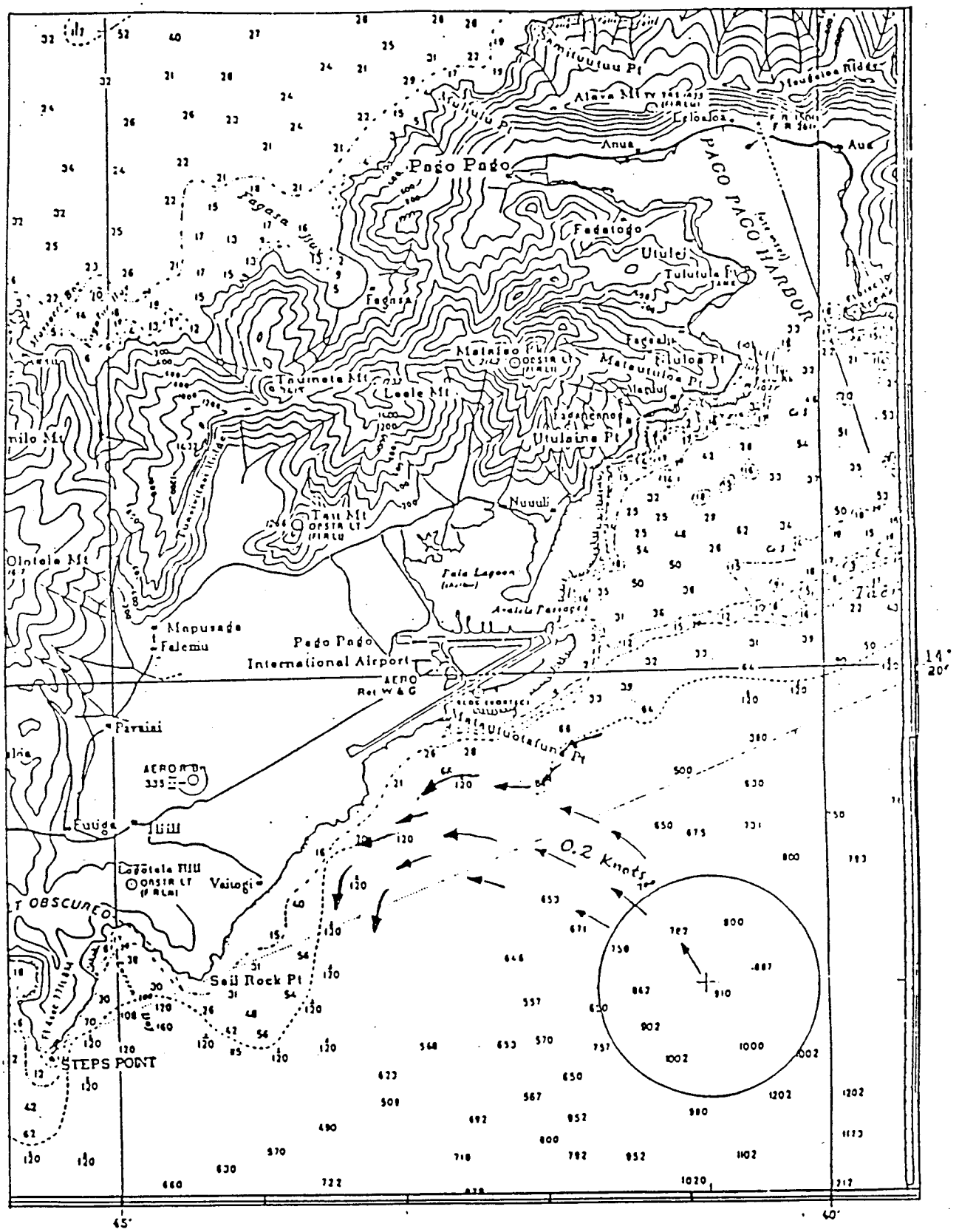


Figure 3.10. The expected near shore current pattern assuming the worst case scenario of NW current at the dumpsite.

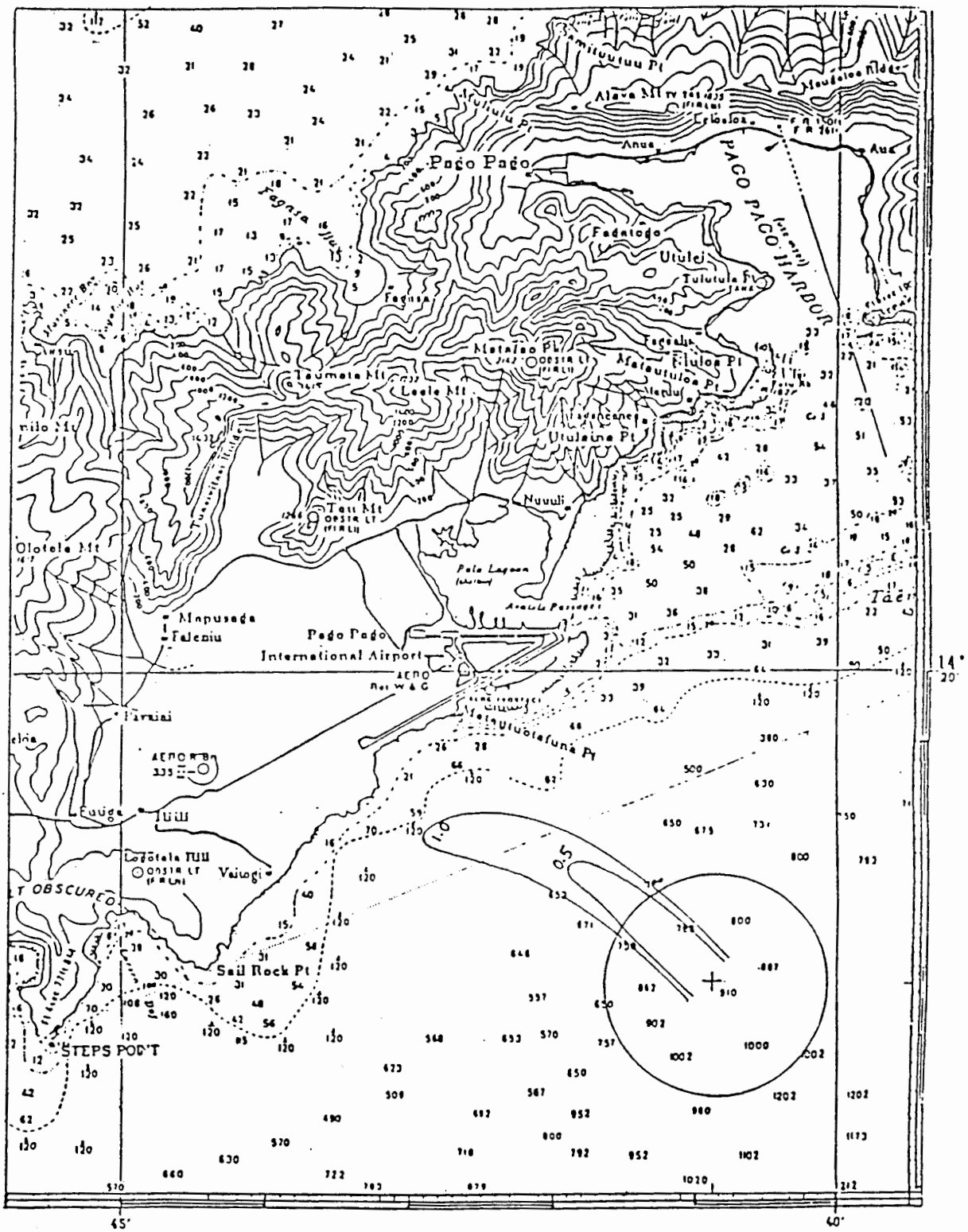


Figure 3-11. The worst-case illustration of the direction of the plume without the SW longshore current. the 250,000 dilution is reached before the plume reaches the 120 fm depth contour. Equi-dilution lones of discharge waste plume, summer months NW current (Q = 500 gpm, Vfall = 0.01 cm/s, Ua = 0.2 kt).

dilution) does not even reach a region at the 120-fathom contour, where significant change in water depth occurs. The longshore current in the SW direction would carry the plume in that direction, preventing the plume from reaching the shore region.

The longshore current to the SW is described in Section III.B.2.b. Therefore, the plume is expected to gradually bend toward the SW direction following the depth contour line (a direction along island shoreline) carrying the plume with it. In order to make a further, detailed prediction of the direction and the extent of the plume in this shallower water region, more definitive information on the seaward extent of the longshore current and its magnitude is needed. It should be emphasized that the results in Figure 3-9 are for the summer months. Results for the winter months would indicate more mixing, therefore greater dilution within the region shown.

3.4 Extent of Plume at Deeper Water Preferred Site.

With the selection of the deeper water site as the preferred site, the curves containing the equi-dilution lines were plotted for the same conditions shown in Figures 3-5 through 3-8 and 3-11 and discussed in Sectin 33. The results are shown in Figures 3-12 through 3-16.

Although the plumes are plotted from the center of the site, it has been recommended to EPA that the dump protocol be changed. The dump vessel would make observations of the surface current direction before dumping begins and dump at the upstream periphery, circling within the dumpsite during discharge. This would result in the plumes being dissipated to the LPC concentration of 1:250,000 within the dumpsite under most conditions.

The plume would not move inshore sufficiently to reach the longshore

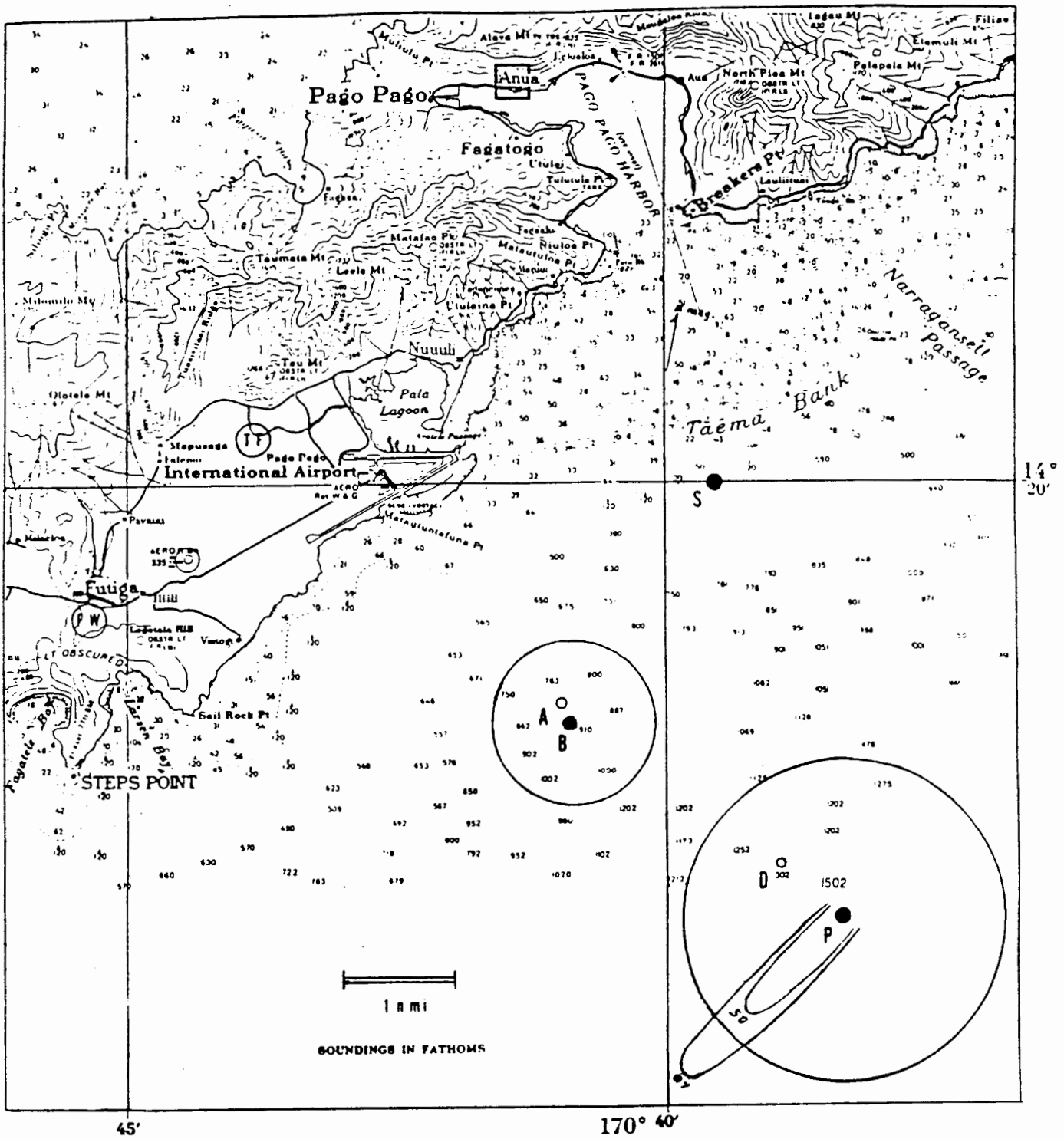


Figure 3-12. Equi-dilution lines of discharge waste plume, summer months SW current (Q= 500 gpm, Vfall = 0.01 cm/s Ua = 0.2 kt). If dumping were to take place at the NE periphery under these conditions, the plume would be fully dissipated, reaching background levels, within the dumpsite circle.

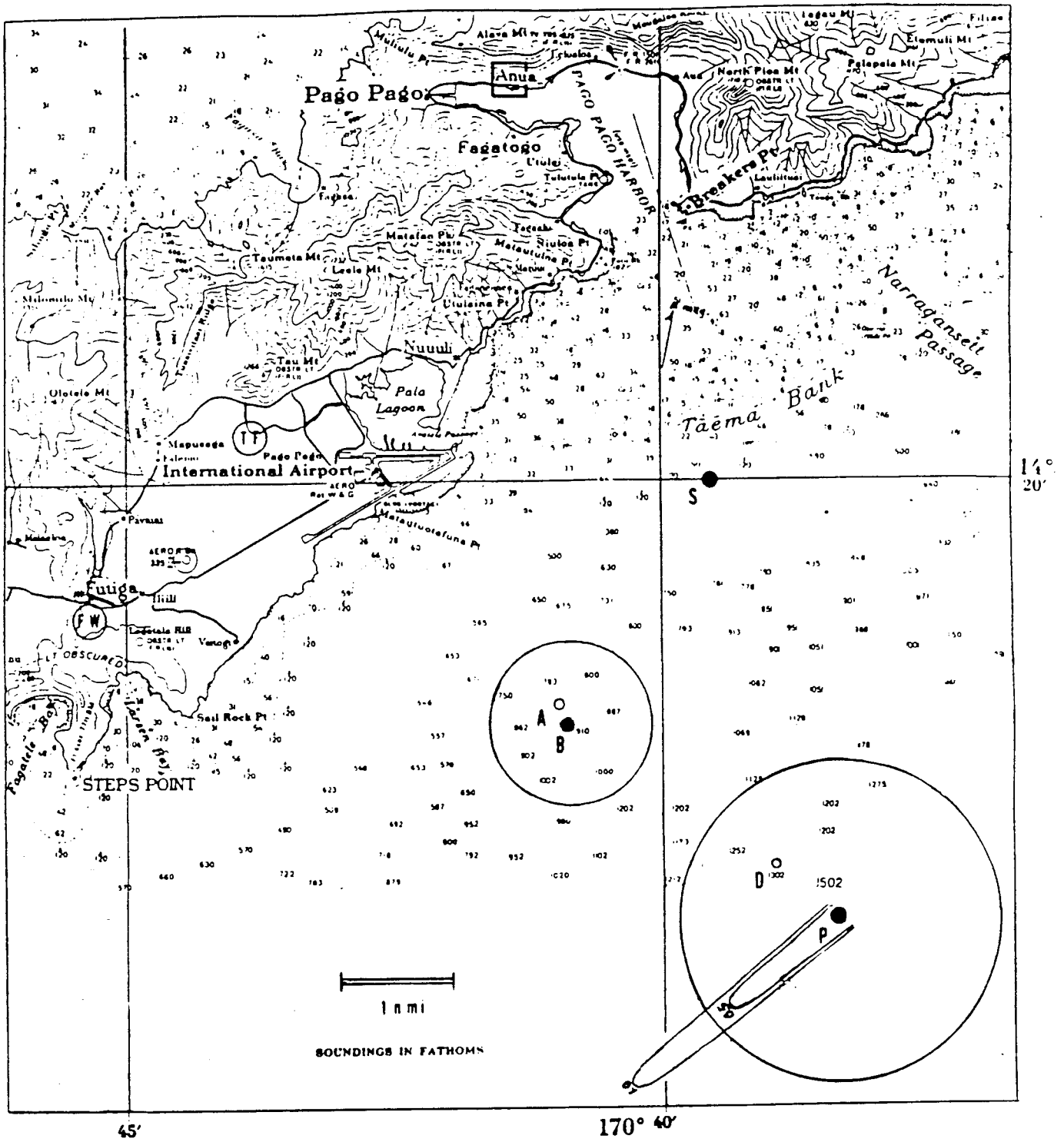


Figure 3-13. Equi-dilution lines of discharge waste plume, summer months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.4 kt). If dumping were to take place at the NE periphery under these conditions, the plume would be mostly dissipated within the dump circle.

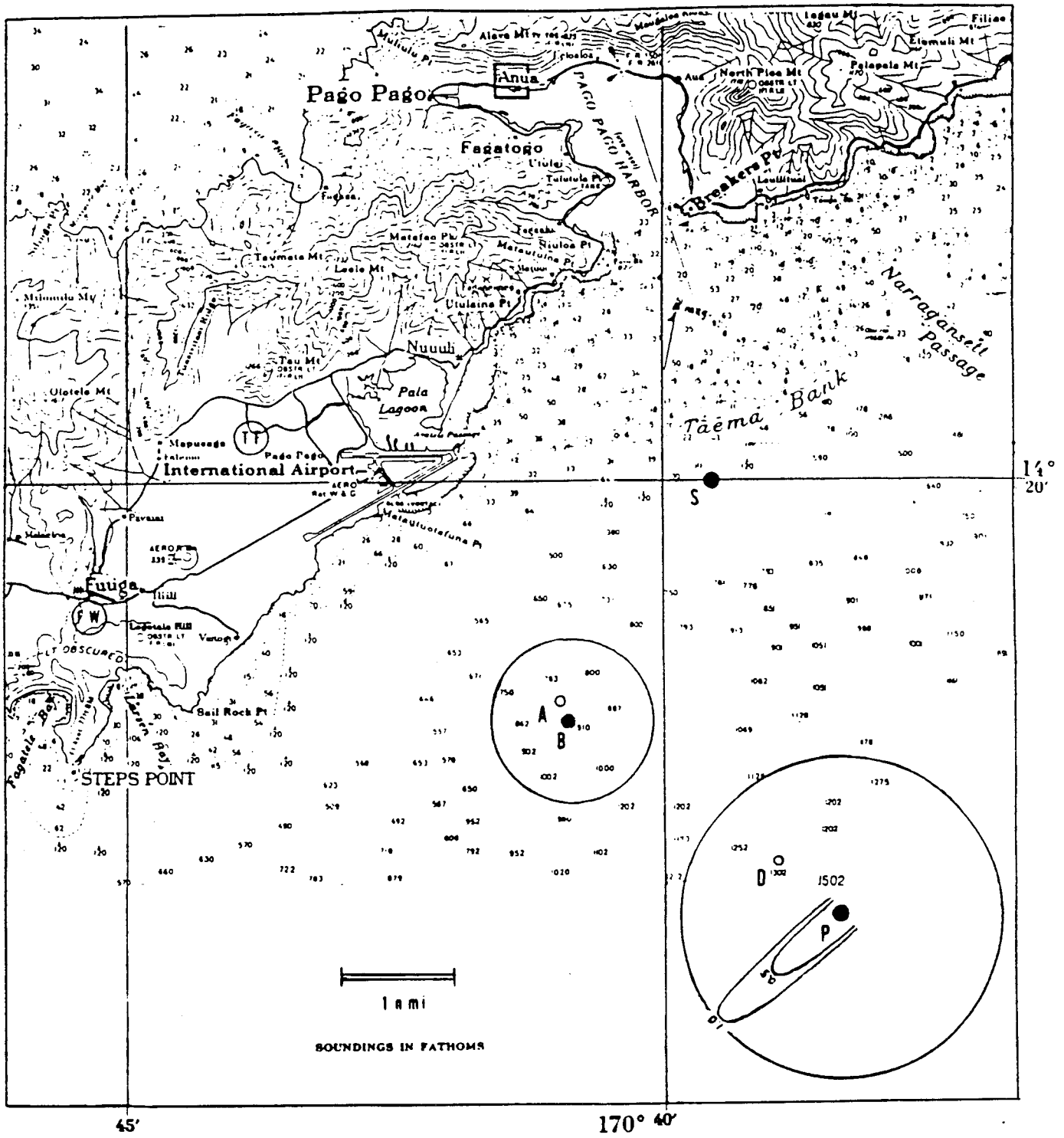


Figure 3-14. Equi-dilution lines of discharge waste plume, winter months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = 0.2 kt). If dumping were to take place at the NE periphery under these conditions, the plume would be dissipated within the dumpsite circle.

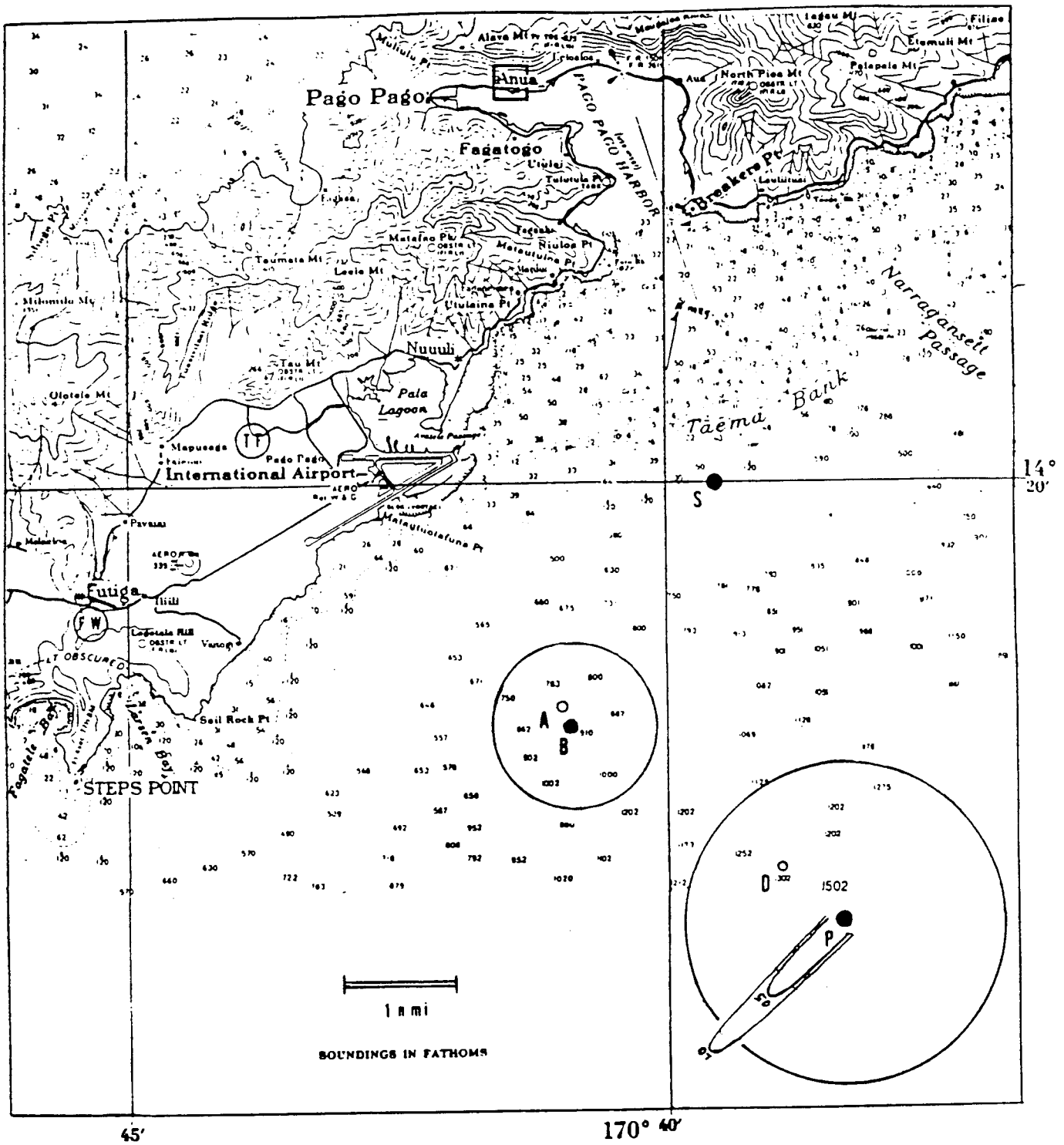


Figure 3-15. Equi-dilution lines of discharge waste plume, winter months SW current (Q = 500 gpm, Vfall = 0.01 cm/s Ua = o.4 kt). If dumping were to take place at the NE periphery under these conditions the plume would be dissipated within the dumpsite circle.

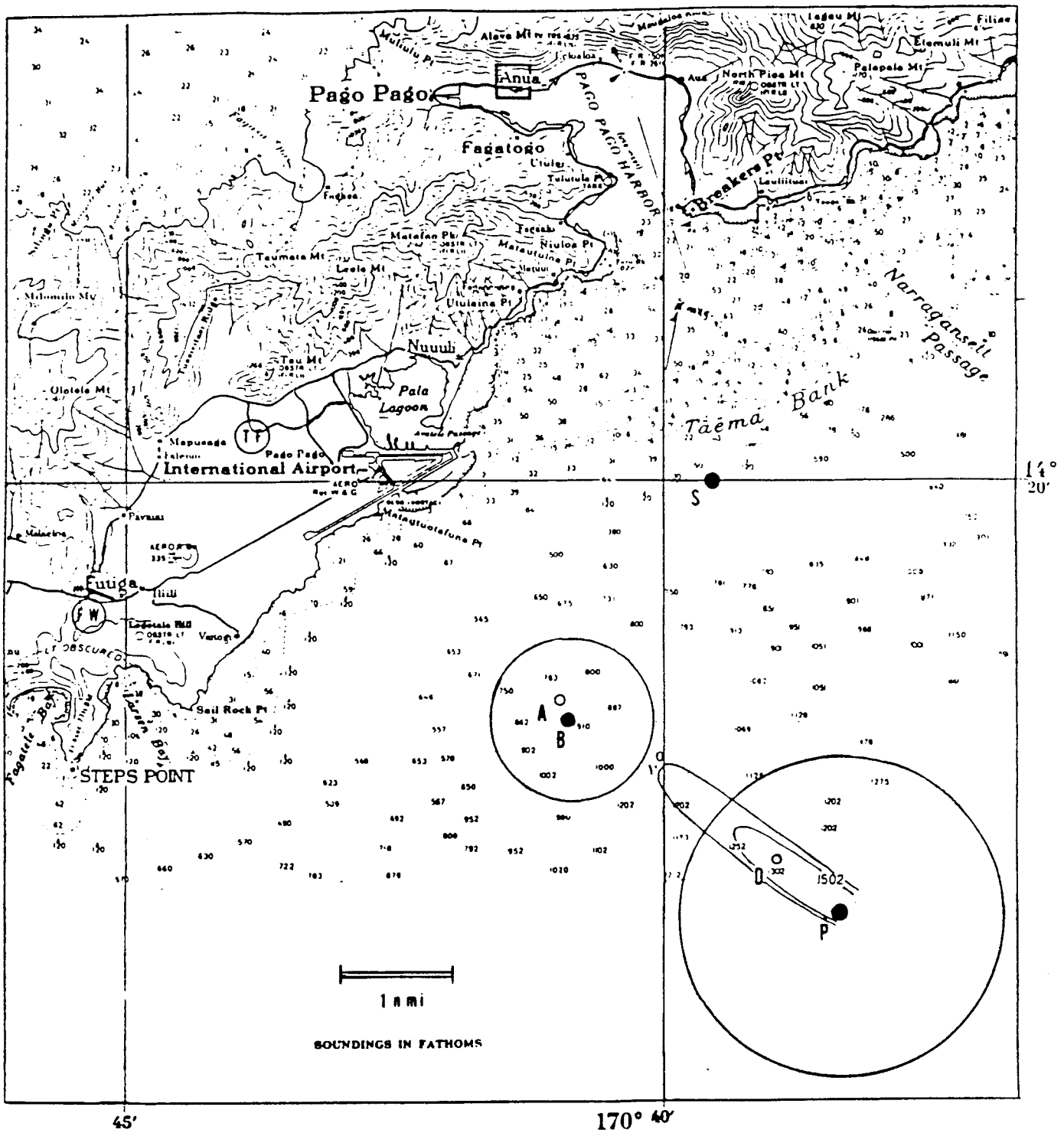


Figure 3-16. The worst-case illustration of the direction of the plume without the SW current. The 250, 000 dilution is reached before the plume reaches territorial waters. Equi-dilution lines of discharge waste plume, summer months NW current (Q = gpm, Vfall = 0.01 cm/s, Ua = 0.2 kt). If dumping were to begin at the SE periphery of the circle, the plume would be dissipated within the dumpsite circle.

current that generally flows southwest between the 120 fm and 600 fm contours. Even if a slick persisted on the surface it would generally be carried farther out to sea to the southwest and could not approach shallow waters.

4. CONCLUSION AND RECOMMENDATION

The results presented in this study are computed by a mathematical model of which the accuracy is dependent on the available data. Whenever the required data are not available, assumptions have been made for the parameters. We have used our best judgment in the estimation of the parameters. We believe that the results obtained by this mathematical model are at least as good as those obtained by any model using the present state of the knowledge.

The present mathematical model predicts the dilution as a function of distance and time from the point of release if the current direction is specified. The extent of the plume has also been shown under various conditions. A key factor in the determination of the plume trajectory is the direction of the ocean current. Field measurements indicate two persistent current directions, SW direction and NW direction. For current going towards the SW direction, it is shown that the plume at the present site will be advected in that direction at a distance at least 2 n mi south of Sail Rock Point. For current in the NW direction, significant dilution has been achieved when the plume reaches the region of shallower depth. Therefore, the longshore current is expected to carry such diluted plume again in SW direction (along the island shoreline direction). More definitive current, information especially on the incidence of reversal of the longshore current in the shallower depth region would be needed in order to predict the extent of the plume in the shallow depth region if

the present site were to continue to be used.

By using the preferred deepwater site, and by dumping upstream of the direction of flow, the plume would be fully dissipated within the dumpsite circle in most cases. The plume would not reach territorial waters, the longshore current, or the reefs.

If there is significant change in vessel size or in quantities dumped, the model should be run again to determine the nature of the plume trajectory and extent. A small change in vessel beam is not considered significant.

REFERENCES

Brooks, N.H. 1960. "Diffusion of Sewage Effluent in an Ocean Current." Proc. Int. Conf. Waste Disposal Mar. Environ., 1st. pp. 246-267. Pergamon, Oxford.

CH2M Hill. 1976. Wastewater Facilities Plan, American Samoa. Vol 2, Appendices. Government of American Samoa.

Fischer, H.B., List, E.J., Koh, R.C.Y., Imberger, J., and Brooks, N.H. 1979. Mixing in Inland and Coastal Waters. Academic Press. 483 pp.

Koh, R.C.Y. and Chang, Y.C. 1973. "Mathematical Model for Barged Ocean Disposal of Wastes." Prepared for Office of Research and Development, U.S. Environmental Protection Agency. EPA-660/2-73-029. 178 pp.

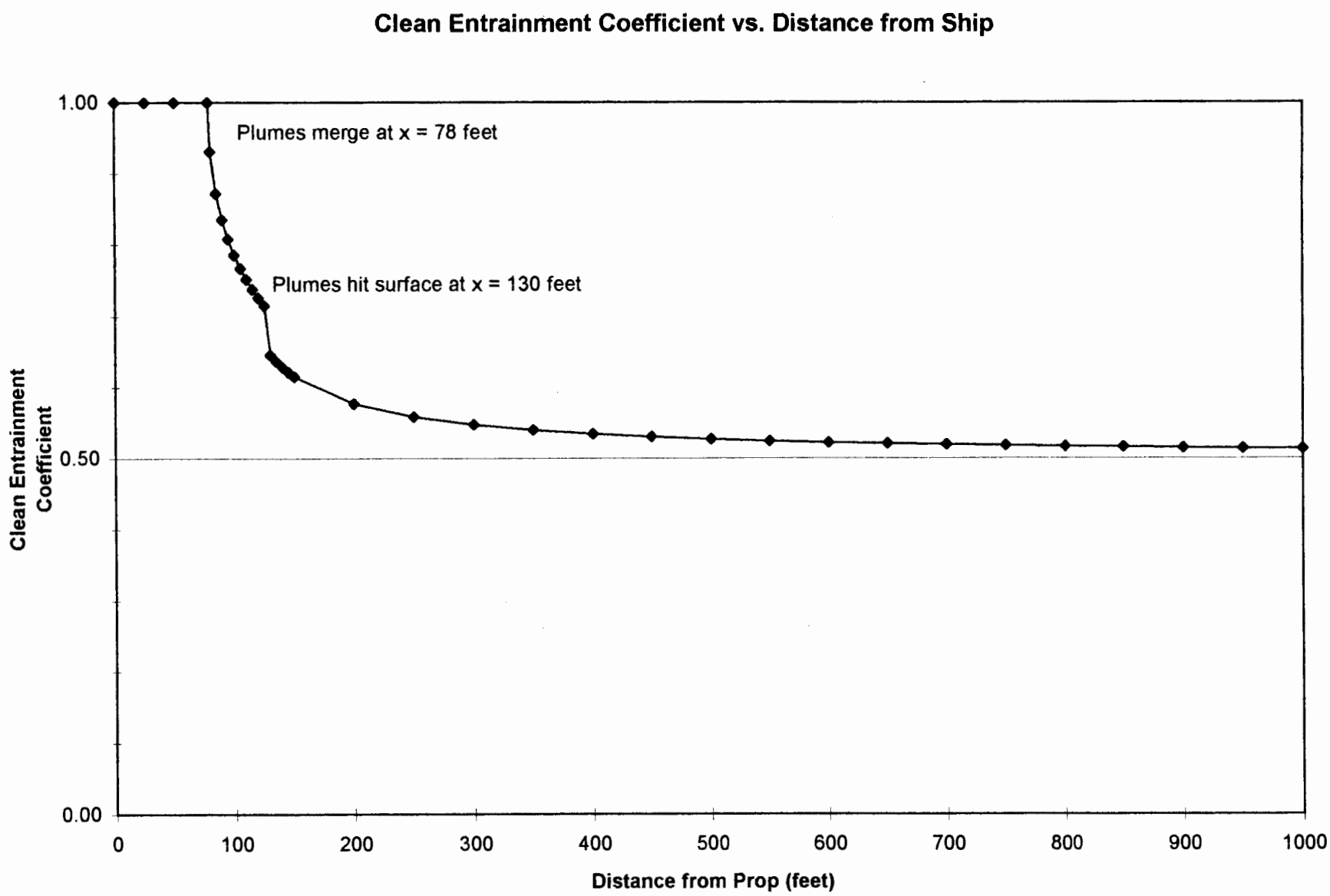
Koh, R.C.Y. and Fan, L.N. 1970. "Mathematical Models for the Prediction of Temperature Distributions Resulting from the Discharge of Heated Water into Large Bodies of Water." Water Quality Office, Environmental Protection Agency. Report Number 16130DWO10/70. Also a Tetra Tech, Inc. Report. 219 pp.

Soule, D.F. and Oguri, M. 1983. "A Report on Ocean Disposal of Fish Processing Wastes off Pago Pago, American Samoa." Prepared for the U.S. Environmental Protection Agency, Region IX, San Francisco, California and NOAA, Department of Commerce on behalf of Star-Kist Foods, Inc., and Van Camp Seafood Division, Ralston Purina Co.

Soule, D.F. and Oguri, M. 1984. "Assessment of the Ocean Disposal Alternative for Management of Fish Processing Wastes." Final Report to NOAA - Grant # NA81RAD00009. Harbors Environmental Projects, Institute for Marine and Coastal Studies, University of Southern California.

U.S. Navy Marine Climatic Atlas of the World 1979. Volume V, South Pacific Ocean. Produced by the Naval Weather Service Detachment, Asheville, N.C. for the Commander, Naval Oceanography Command.

Appendix 9
FEIS Model Description (Appendix B of 1989 FEIS)

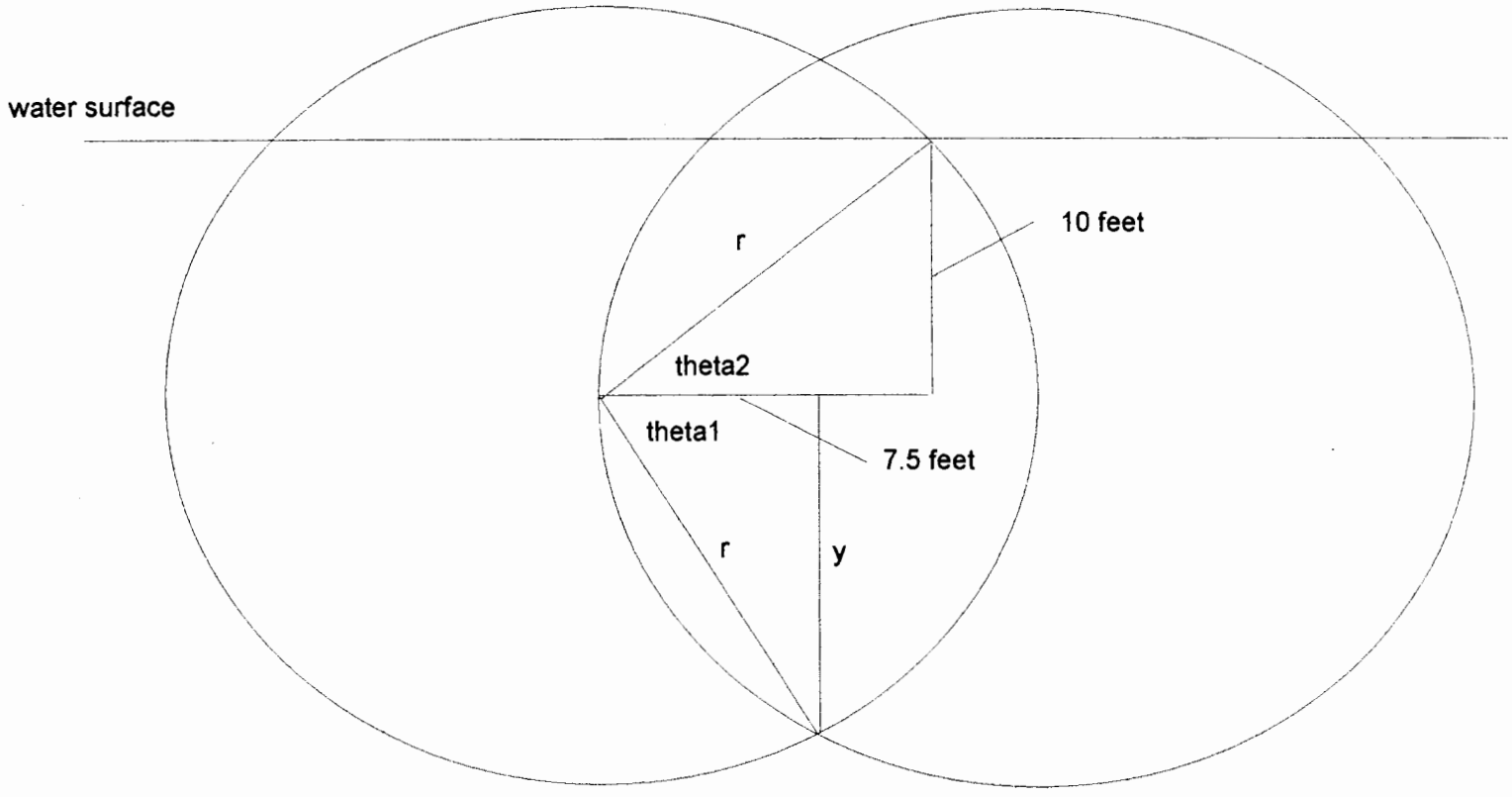

Clean Entrainment Coefficient vs. Distance from Ship
Plumes merge at x = 78 feet
Plumes hit surface at x = 130 feet
Clean Entrainment Coefficient
1.00
0.50
0.00
0
100
200
300
400
500
600
700
800
900
1000
Distance from Prop (feet)

Merging Plumes from Adjacent Propellers - with Surface Boundary

Dilution is a function of the ratio of the perimeter inside and outside the adjacent plume.

Assume entrainment is uniform over the perimeter of the plume.

Propellers located 15 feet apart and 10 feet below water surface.



Calculation scheme for clean entrainment coefficient

Assumptions and Basis for Calculations
plume center horizontal separation = 15 feet
plume width b = 0.096*x
x ranges from 25 to 1000 feet
plumes merge at x = 78.125 feet
at 78.125 feet clean entrainment coefficient = 1.0
plume encounters surface at x = 130 feet

x (feet)	b (feet)	y (feet)	theta1 (rad)	theta2 (rad)	inside perimeter (feet)	clean entrainment coefficient
0	0.0					1.00
25	2.4					1.00
50	4.8					1.00
78.125	7.5	0.0	0.0		0.0	1.00
80	7.7	1.7	0.2		3.3	0.93
85	8.2	3.2	0.4		6.6	0.87
90	8.6	4.3	0.5		9.0	0.83
95	9.1	5.2	0.6		11.0	0.81
100	9.6	6.0	0.7		12.9	0.79
105	10.1	6.7	0.7		14.8	0.77
110	10.6	7.4	0.8		16.5	0.75
115	11.0	8.1	0.8		18.2	0.74
120	11.5	8.7	0.9		19.9	0.73
125	12.0	9.4	0.9		21.5	0.71
130	12.5	10.0	0.9	0.6	19.6	0.65
135	13.0	10.6	1.0	0.7	21.3	0.64
140	13.4	11.2	1.0	0.7	23.0	0.63
145	13.9	11.7	1.0	0.8	24.7	0.62
150	14.4	12.3	1.0	0.8	26.3	0.62
200	19.2	17.7	1.2	1.0	42.1	0.58
250	24.0	22.8	1.3	1.1	57.5	0.56
300	28.8	27.8	1.3	1.2	72.7	0.55
350	33.6	32.8	1.3	1.3	87.8	0.54
400	38.4	37.7	1.4	1.3	103.0	0.53
450	43.2	42.5	1.4	1.3	118.1	0.53
500	48.0	47.4	1.4	1.4	133.2	0.53
550	52.8	52.3	1.4	1.4	148.3	0.52
600	57.6	57.1	1.4	1.4	163.4	0.52
650	62.4	61.9	1.5	1.4	178.5	0.52
700	67.2	66.8	1.5	1.4	193.6	0.52
750	72.0	71.6	1.5	1.4	208.6	0.52
800	76.8	76.4	1.5	1.4	223.7	0.52
850	81.6	81.3	1.5	1.4	238.8	0.52
900	86.4	86.1	1.5	1.5	253.9	0.51
950	91.2	90.9	1.5	1.5	269.0	0.51
1000	96.0	95.7	1.5	1.5	284.1	0.51

Appendix 10
Farfield Model Output

Farfield Dilution Model

Winter Conditions - Ocean Current 0.2 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.2 (knots)

Dissipation Parameter (A)
0.001

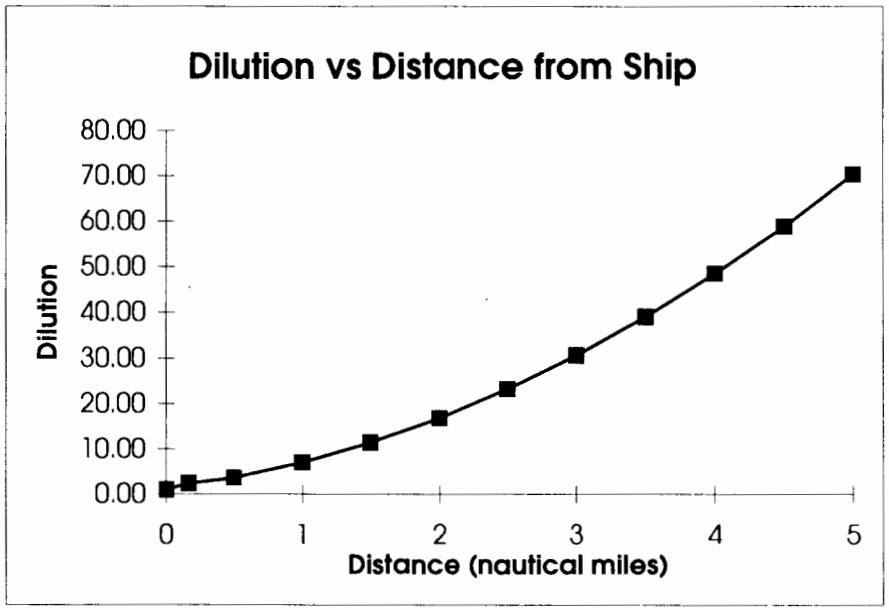
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	1.4	0.42	0.42	2.41
3040	0.5	2.5	0.28	0.28	3.59
6080	1	5.0	0.14	0.14	7.01
9120	1.5	7.5	0.09	0.09	11.43
12160	2	10.0	0.06	0.06	16.85
15200	2.5	12.5	0.04	0.04	23.26
18240	3	15.0	0.03	0.03	30.66
21280	3.5	17.5	0.03	0.03	39.06
24320	4	20.0	0.02	0.02	48.46
27360	4.5	22.5	0.02	0.02	58.86
30400	5	25.0	0.01	0.01	70.25



Farfield Dilution Model

Winter Conditions - Ocean Current 0.4 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.4 (knots)

Dissipation Parameter (A)
0.001

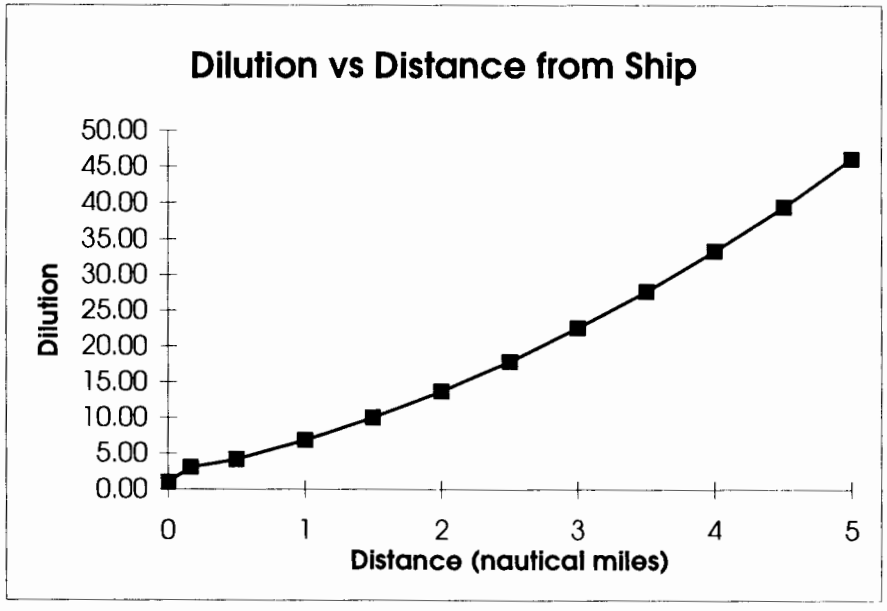
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.7	0.33	0.33	3.07
3040	0.5	1.3	0.24	0.24	4.18
6080	1	2.5	0.15	0.15	6.86
9120	1.5	3.8	0.10	0.10	10.03
12160	2	5.0	0.07	0.07	13.69
15200	2.5	6.3	0.06	0.06	17.85
18240	3	7.5	0.04	0.04	22.50
21280	3.5	8.8	0.04	0.04	27.65
24320	4	10.0	0.03	0.03	33.29
27360	4.5	11.3	0.03	0.03	39.43
30400	5	12.5	0.02	0.02	46.06

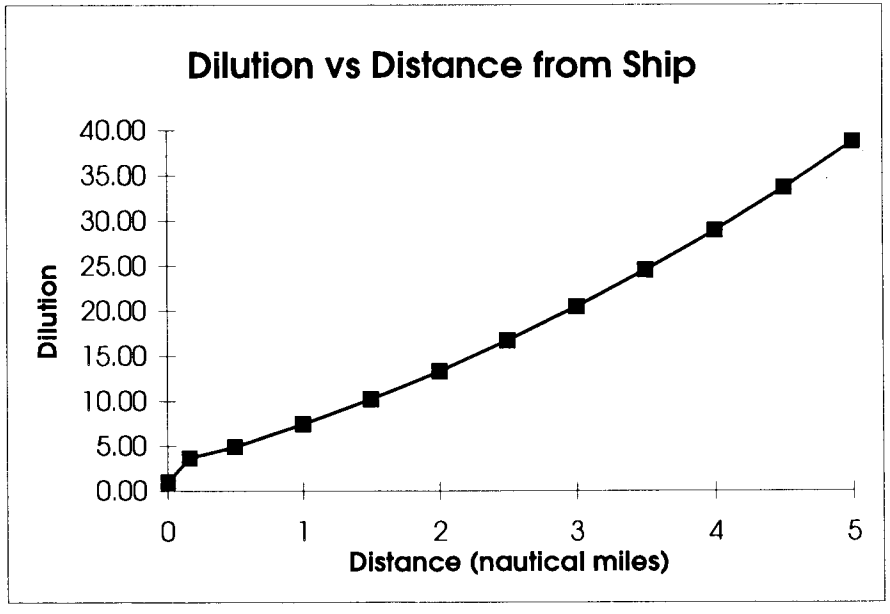


Farfield Dilution Model

Winter Conditions - Ocean Current 0.6 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
1400 (gpm)	17.3 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
0.6 (knots)	0.001	50 (m)	10 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.5	0.27	0.27	3.68
3040	0.5	0.8	0.20	0.20	4.90
6080	1	1.7	0.13	0.13	7.44
9120	1.5	2.5	0.10	0.10	10.20
12160	2	3.3	0.08	0.08	13.29
15200	2.5	4.2	0.06	0.06	16.70
18240	3	5.0	0.05	0.05	20.45
21280	3.5	5.8	0.04	0.04	24.52
24320	4	6.7	0.03	0.03	28.92
27360	4.5	7.5	0.03	0.03	33.65
30400	5	8.3	0.03	0.03	38.71



Farfield Dilution Model

Winter Conditions - Ocean Current 0.8 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.8 (knots)

Dissipation Parameter (A)
0.001

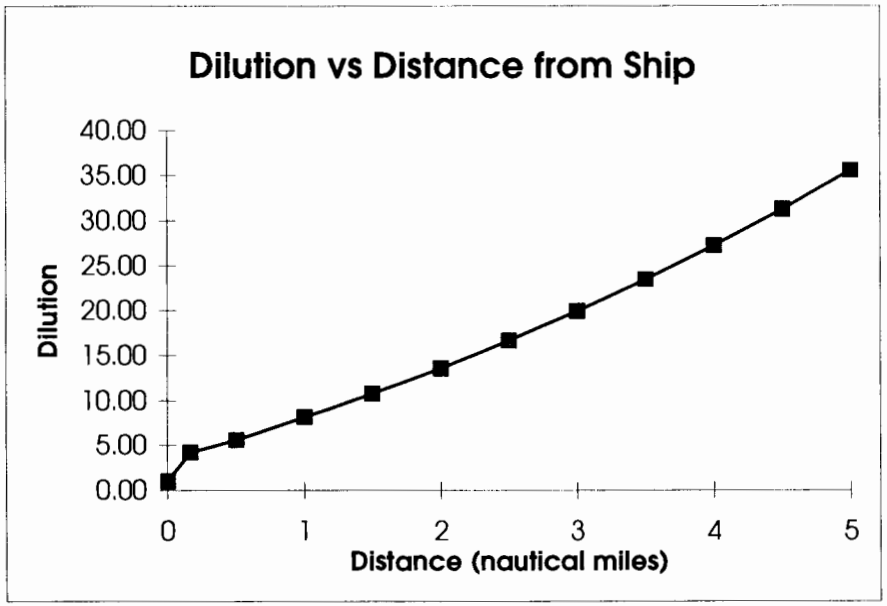
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.24	0.24	4.20
3040	0.5	0.6	0.18	0.18	5.58
6080	1	1.3	0.12	0.12	8.16
9120	1.5	1.9	0.09	0.09	10.75
12160	2	2.5	0.07	0.07	13.56
15200	2.5	3.1	0.06	0.06	16.61
18240	3	3.8	0.05	0.05	19.90
21280	3.5	4.4	0.04	0.04	23.44
24320	4	5.0	0.04	0.04	27.22
27360	4.5	5.6	0.03	0.03	31.25
30400	5	6.3	0.03	0.03	35.52



Farfield Dilution Model

Winter Conditions - Ocean Current 1.0 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
1 (knots)

Dissipation Parameter (A)
0.001

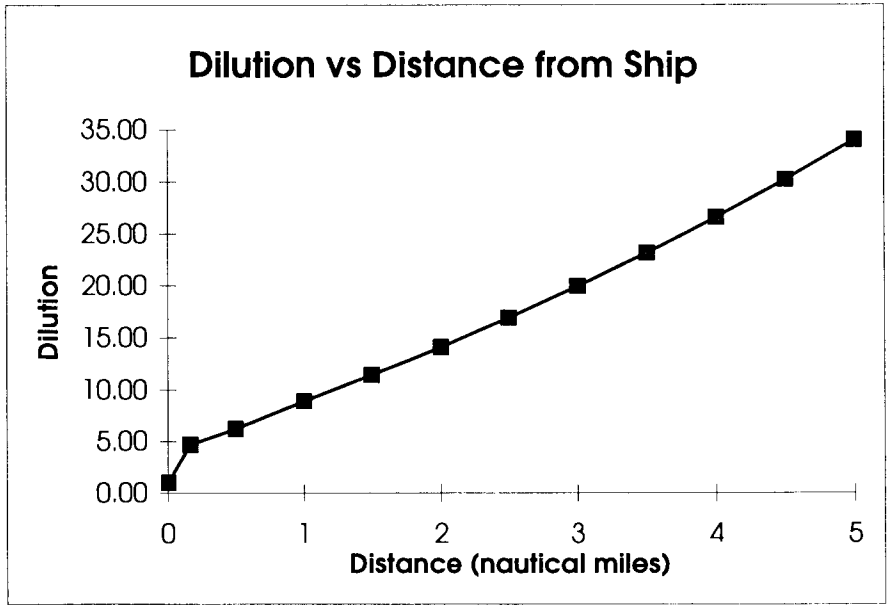
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.21	0.21	4.67
3040	0.5	0.5	0.16	0.16	6.21
6080	1	1.0	0.11	0.11	8.90
9120	1.5	1.5	0.09	0.09	11.44
12160	2	2.0	0.07	0.07	14.10
15200	2.5	2.5	0.06	0.06	16.93
18240	3	3.0	0.05	0.05	19.95
21280	3.5	3.5	0.04	0.04	23.17
24320	4	4.0	0.04	0.04	26.58
27360	4.5	4.5	0.03	0.03	30.19
30400	5	5.0	0.03	0.03	34.00



Farfield Dilution Model

Winter Conditions - Ocean Current 0.2 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.2 (knots)

Dissipation Parameter (A)
0.001

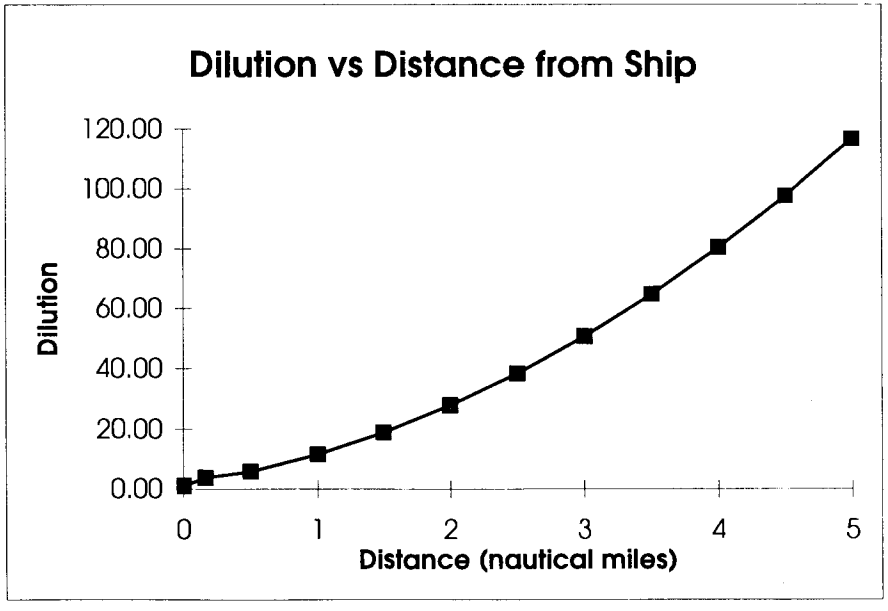
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	1.4	0.27	0.27	3.76
3040	0.5	2.5	0.17	0.17	5.76
6080	1	5.0	0.09	0.09	11.45
9120	1.5	7.5	0.05	0.05	18.80
12160	2	10.0	0.04	0.04	27.79
15200	2.5	12.5	0.03	0.03	38.44
18240	3	15.0	0.02	0.02	50.75
21280	3.5	17.5	0.02	0.02	64.72
24320	4	20.0	0.01	0.01	80.35
27360	4.5	22.5	0.01	0.01	97.63
30400	5	25.0	0.01	0.01	116.58



Farfield Dilution Model

Winter Conditions - Ocean Current 0.4 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.4 (knots)

Dissipation Parameter (A)
0.001

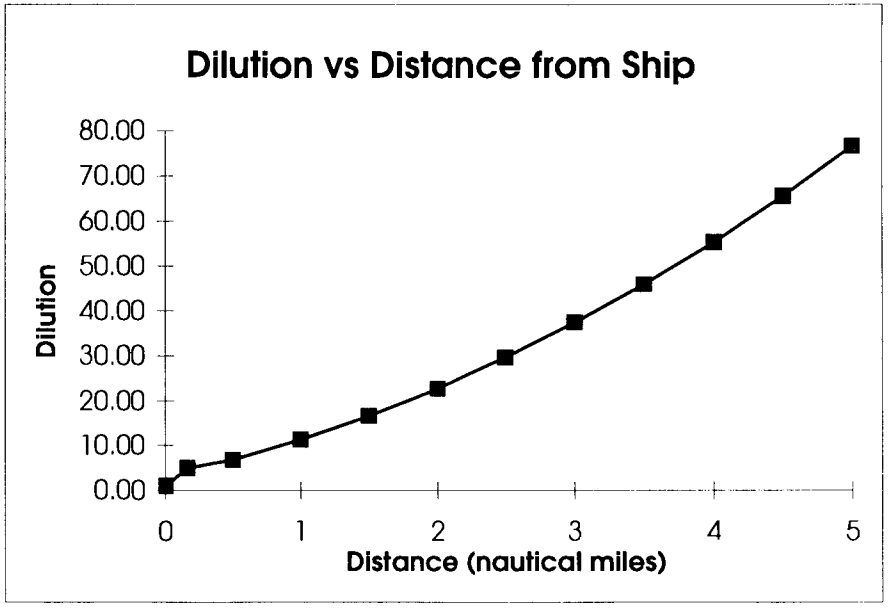
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.7	0.20	0.20	4.94
3040	0.5	1.3	0.15	0.15	6.82
6080	1	2.5	0.09	0.09	11.32
9120	1.5	3.8	0.06	0.06	16.60
12160	2	5.0	0.04	0.04	22.70
15200	2.5	6.3	0.03	0.03	29.62
18240	3	7.5	0.03	0.03	37.37
21280	3.5	8.8	0.02	0.02	45.94
24320	4	10.0	0.02	0.02	55.33
27360	4.5	11.3	0.02	0.02	65.56
30400	5	12.5	0.01	0.01	76.61



Farfield Dilution Model

Winter Conditions - Ocean Current 0.6 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
1400 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.6 (knots)

Dissipation Parameter (A)
0.001

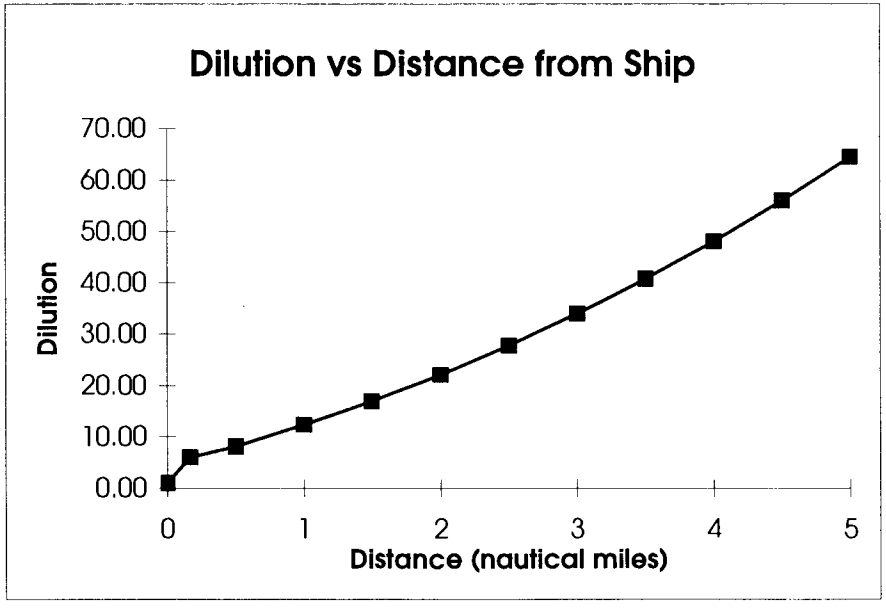
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.5	0.17	0.17	5.98
3040	0.5	0.8	0.12	0.12	8.05
6080	1	1.7	0.08	0.08	12.31
9120	1.5	2.5	0.06	0.06	16.93
12160	2	3.3	0.05	0.05	22.07
15200	2.5	4.2	0.04	0.04	27.76
18240	3	5.0	0.03	0.03	34.00
21280	3.5	5.8	0.02	0.02	40.78
24320	4	6.7	0.02	0.02	48.11
27360	4.5	7.5	0.02	0.02	55.99
30400	5	8.3	0.02	0.02	64.42



Farfield Dilution Model

Winter Conditions - Ocean Current 0.8 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
840 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.8 (knots)

Dissipation Parameter (A)
0.001

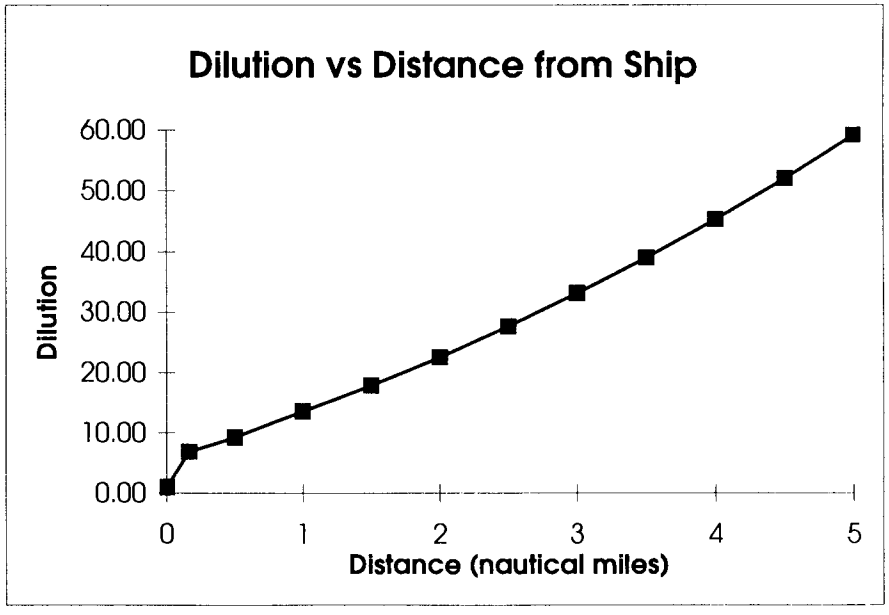
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.15	0.15	6.88
3040	0.5	0.6	0.11	0.11	9.21
6080	1	1.3	0.07	0.07	13.52
9120	1.5	1.9	0.06	0.06	17.86
12160	2	2.5	0.04	0.04	22.55
15200	2.5	3.1	0.04	0.04	27.62
18240	3	3.8	0.03	0.03	33.11
21280	3.5	4.4	0.03	0.03	39.00
24320	4	5.0	0.02	0.02	45.30
27360	4.5	5.6	0.02	0.02	52.02
30400	5	6.3	0.02	0.02	59.14



Farfield Dilution Model

Winter Conditions - Ocean Current 1.0 knots - Vessel Speed 6knots

Discharge Rate of Waste , in gpm (Q)
840 (gpm)

Diffusion Coefficient (Kv)
17.3 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
1 (knots)

Dissipation Parameter (A)
0.001

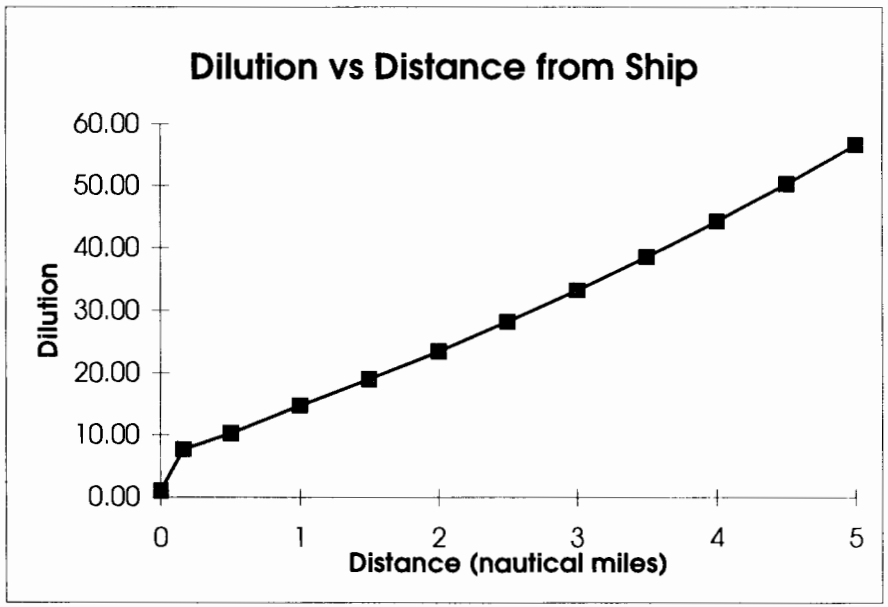
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.13	0.13	7.67
3040	0.5	0.5	0.10	0.10	10.27
6080	1	1.0	0.07	0.07	14.78
9120	1.5	1.5	0.05	0.05	19.01
12160	2	2.0	0.04	0.04	23.44
15200	2.5	2.5	0.04	0.04	28.17
18240	3	3.0	0.03	0.03	33.20
21280	3.5	3.5	0.03	0.03	38.57
24320	4	4.0	0.02	0.02	44.25
27360	4.5	4.5	0.02	0.02	50.27
30400	5	5.0	0.02	0.02	56.61



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.2 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1200 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.2 (knots)

Dissipation Parameter (A)
0.001

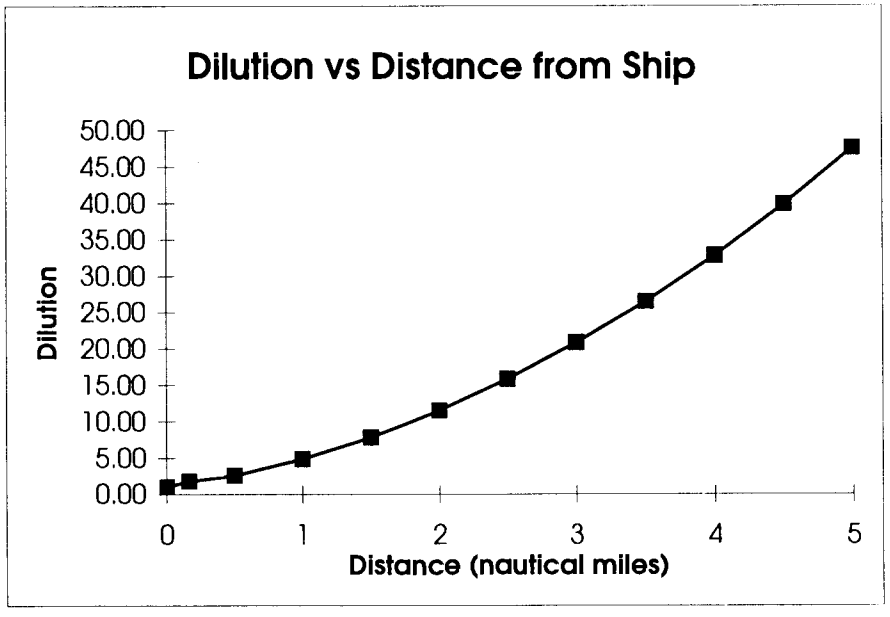
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	1.4	0.56	0.56	1.80
3040	0.5	2.5	0.39	0.39	2.58
6080	1	5.0	0.20	0.20	4.88
9120	1.5	7.5	0.13	0.13	7.87
12160	2	10.0	0.09	0.09	11.53
15200	2.5	12.5	0.06	0.06	15.86
18240	3	15.0	0.05	0.05	20.86
21280	3.5	17.5	0.04	0.04	26.53
24320	4	20.0	0.03	0.03	32.86
27360	4.5	22.5	0.03	0.03	39.87
30400	5	25.0	0.02	0.02	47.54

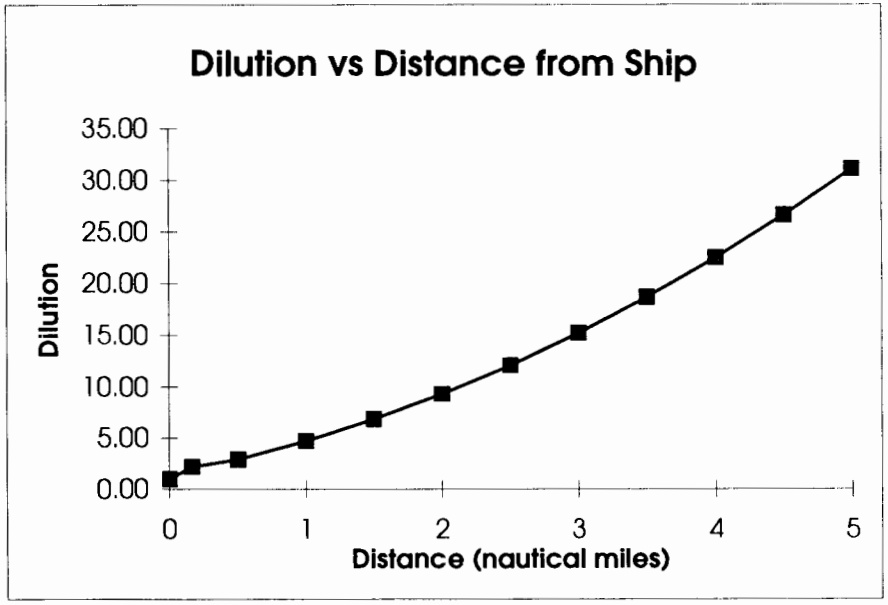


Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.4 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
1200 (gpm)	7.8 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
0.4 (knots)	0.001	50 (m)	10 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	(Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.7	0.46	0.46	2.19
3040	0.5	1.3	0.34	0.34	2.91
6080	1	2.5	0.21	0.21	4.70
9120	1.5	3.8	0.15	0.15	6.82
12160	2	5.0	0.11	0.11	9.29
15200	2.5	6.3	0.08	0.08	12.08
18240	3	7.5	0.07	0.07	15.21
21280	3.5	8.8	0.05	0.05	18.67
24320	4	10.0	0.04	0.04	22.46
27360	4.5	11.3	0.04	0.04	26.59
30400	5	12.5	0.03	0.03	31.05



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.6 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1200 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.6 (knots)

Dissipation Parameter (A)
0.001

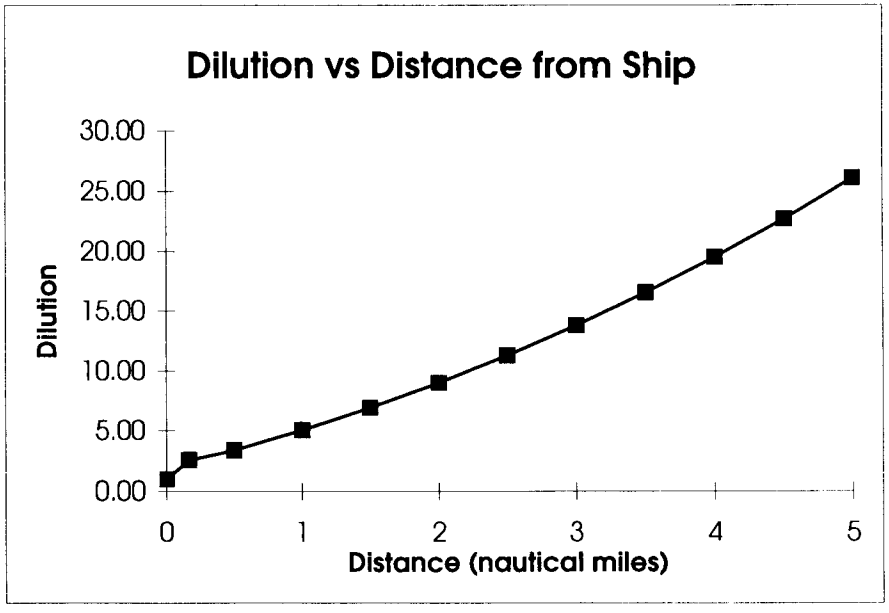
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.5	0.39	0.39	2.58
3040	0.5	0.8	0.30	0.30	3.37
6080	1	1.7	0.20	0.20	5.06
9120	1.5	2.5	0.14	0.14	6.91
12160	2	3.3	0.11	0.11	8.98
15200	2.5	4.2	0.09	0.09	11.28
18240	3	5.0	0.07	0.07	13.79
21280	3.5	5.8	0.06	0.06	16.53
24320	4	6.7	0.05	0.05	19.48
27360	4.5	7.5	0.04	0.04	22.66
30400	5	8.3	0.04	0.04	26.06



Farfield Dilution Model

Summer Surface - Ocean Current 0.8 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1200 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.8 (knots)

Dissipation Parameter (A)
0.001

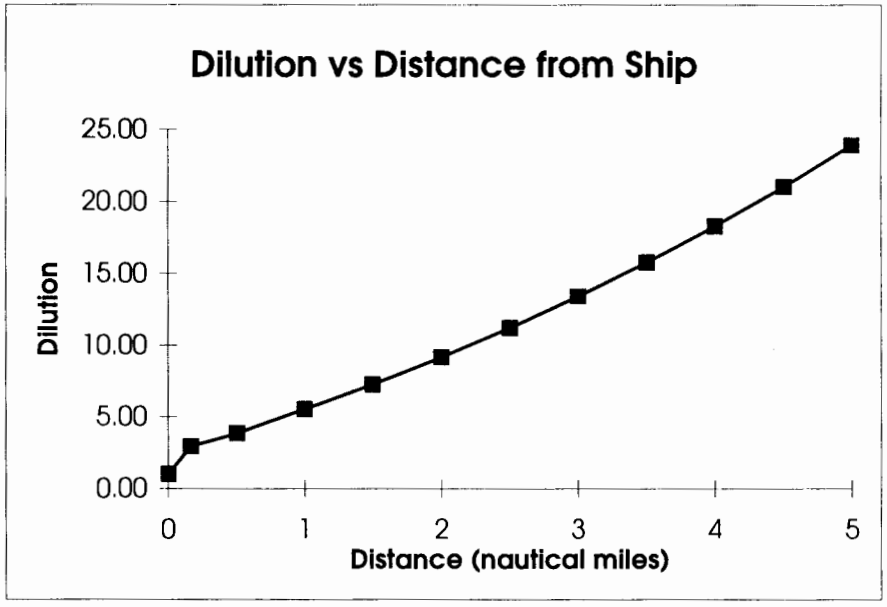
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.34	0.34	2.92
3040	0.5	0.6	0.26	0.26	3.82
6080	1	1.3	0.18	0.18	5.53
9120	1.5	1.9	0.14	0.14	7.27
12160	2	2.5	0.11	0.11	9.15
15200	2.5	3.1	0.09	0.09	11.20
18240	3	3.8	0.07	0.07	13.41
21280	3.5	4.4	0.06	0.06	15.78
24320	4	5.0	0.05	0.05	18.32
27360	4.5	5.6	0.05	0.05	21.03
30400	5	6.3	0.04	0.04	23.90



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 1.0 knots - Vessel Speed 10 knots

Discharge Rate of Waste , in gpm (Q)
1200 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
1 (knots)

Dissipation Parameter (A)
0.001

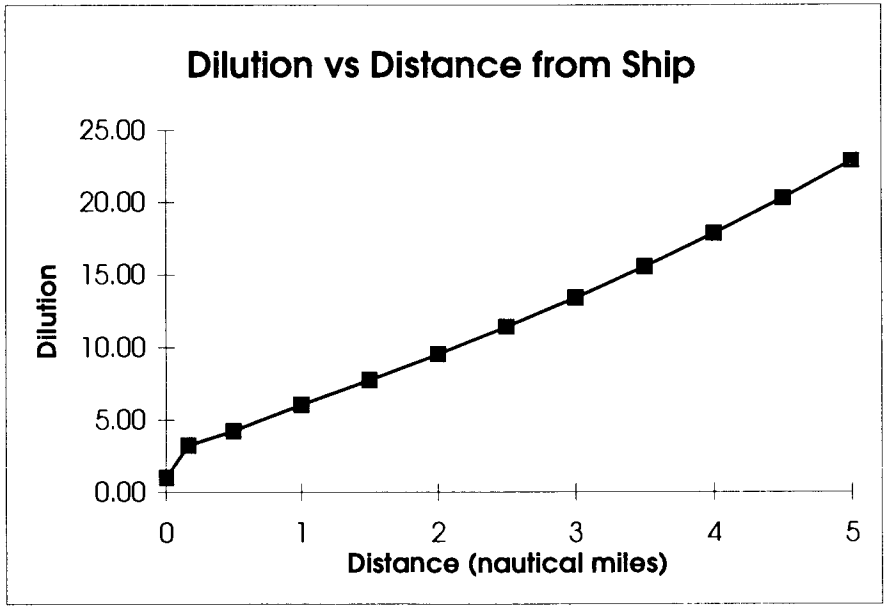
Ship's Length
50 (m)

Ship's Speed, in knots
10 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.31	0.31	3.22
3040	0.5	0.5	0.24	0.24	4.24
6080	1	1.0	0.17	0.17	6.03
9120	1.5	1.5	0.13	0.13	7.72
12160	2	2.0	0.11	0.11	9.50
15200	2.5	2.5	0.09	0.09	11.40
18240	3	3.0	0.07	0.07	13.43
21280	3.5	3.5	0.06	0.06	15.59
24320	4	4.0	0.06	0.06	17.88
27360	4.5	4.5	0.05	0.05	20.31
30400	5	5.0	0.04	0.04	22.86



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.2 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
720 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.2 (knots)

Dissipation Parameter (A)
0.001

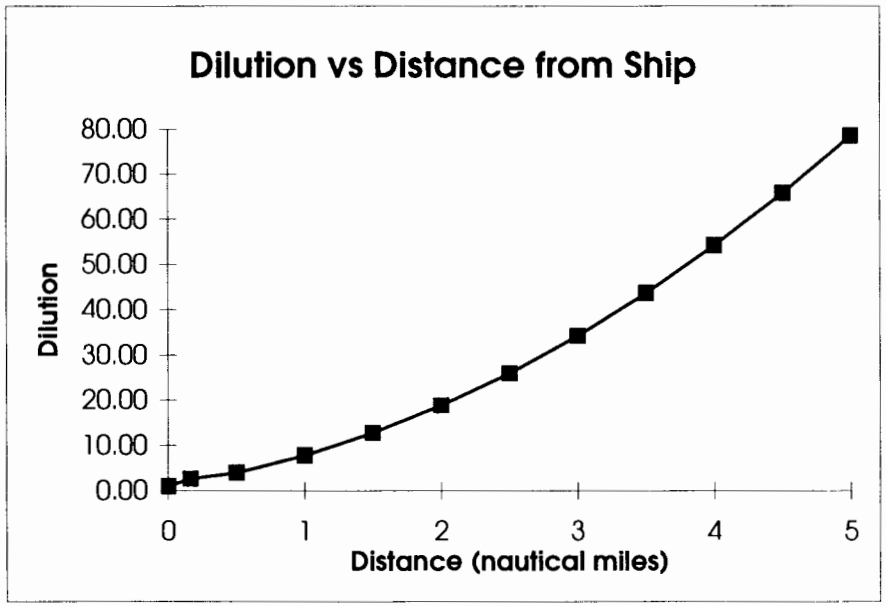
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	1.4	0.38	0.38	2.64
3040	0.5	2.5	0.25	0.25	3.97
6080	1	5.0	0.13	0.13	7.80
9120	1.5	7.5	0.08	0.08	12.74
12160	2	10.0	0.05	0.05	18.79
15200	2.5	12.5	0.04	0.04	25.96
18240	3	15.0	0.03	0.03	34.24
21280	3.5	17.5	0.02	0.02	43.64
24320	4	20.0	0.02	0.02	54.14
27360	4.5	22.5	0.02	0.02	65.77
30400	5	25.0	0.01	0.01	78.51



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.4 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
720 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.4 (knots)

Dissipation Parameter (A)
0.001

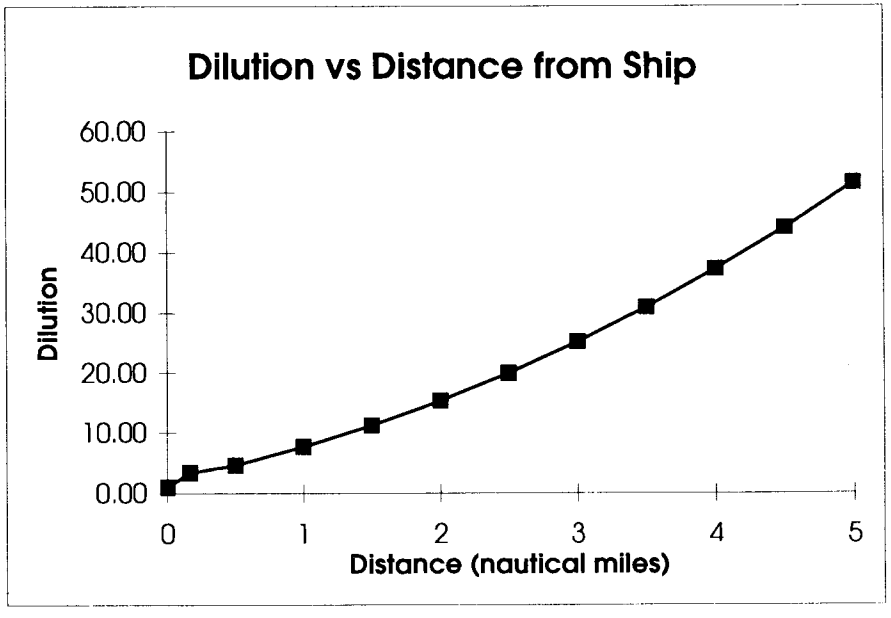
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.7	0.29	0.29	3.40
3040	0.5	1.3	0.22	0.22	4.65
6080	1	2.5	0.13	0.13	7.66
9120	1.5	3.8	0.09	0.09	11.20
12160	2	5.0	0.07	0.07	15.30
15200	2.5	6.3	0.05	0.05	19.95
18240	3	7.5	0.04	0.04	25.15
21280	3.5	8.8	0.03	0.03	30.91
24320	4	10.0	0.03	0.03	37.22
27360	4.5	11.3	0.02	0.02	44.09
30400	5	12.5	0.02	0.02	51.52



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.6 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
720 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
0.6 (knots)

Dissipation Parameter (A)
0.001

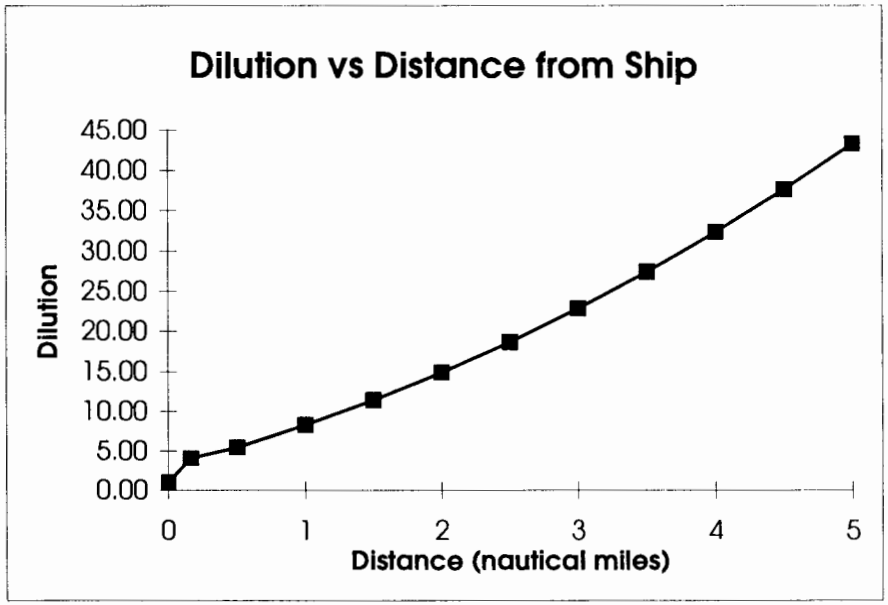
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.5	0.24	0.24	4.08
3040	0.5	0.8	0.18	0.18	5.46
6080	1	1.7	0.12	0.12	8.30
9120	1.5	2.5	0.09	0.09	11.40
12160	2	3.3	0.07	0.07	14.86
15200	2.5	4.2	0.05	0.05	18.68
18240	3	5.0	0.04	0.04	22.86
21280	3.5	5.8	0.04	0.04	27.42
24320	4	6.7	0.03	0.03	32.34
27360	4.5	7.5	0.03	0.03	37.64
30400	5	8.3	0.02	0.02	43.30

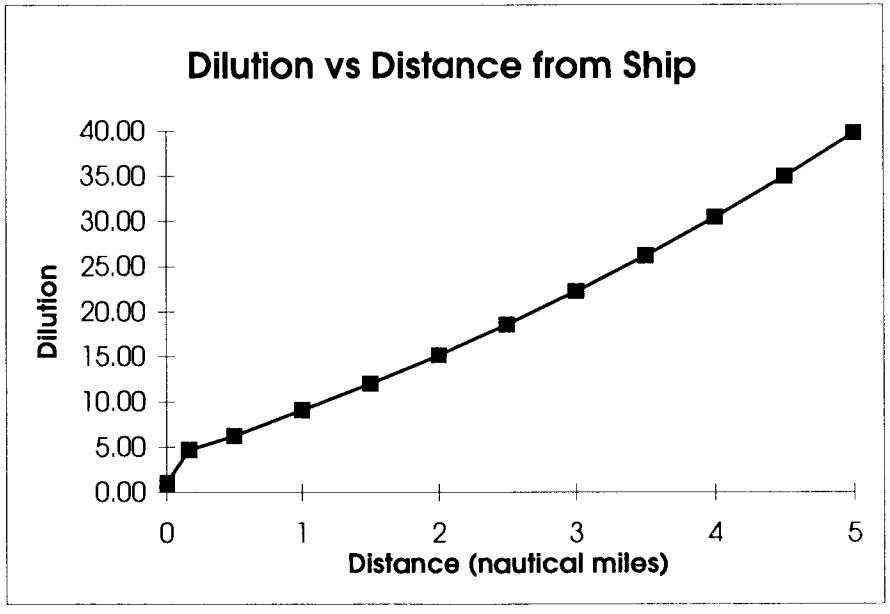


Farfield Dilution Model

Summer Surface Conditions - Ocean Current 0.8 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)	Diffusion Coefficient (Kv)	Ship's Beam	Ship's Draft
720 (gpm)	7.8 (cm^2/sec)	11.58 (m)	3.66 (m)
Ambient Ocean Current, in knots (U)	Dissipation Parameter (A)	Ship's Length	Ship's Speed, in knots
0.8 (knots)	0.001	50 (m)	6 (knots)
Length Parameter, in meters (L)	Initial Concentration		
741 (m)	1		

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.21	0.21	4.68
3040	0.5	0.6	0.16	0.16	6.23
6080	1	1.3	0.11	0.11	9.11
9120	1.5	1.9	0.08	0.08	12.02
12160	2	2.5	0.07	0.07	15.17
15200	2.5	3.1	0.05	0.05	18.58
18240	3	3.8	0.04	0.04	22.26
21280	3.5	4.4	0.04	0.04	26.21
24320	4	5.0	0.03	0.03	30.45
27360	4.5	5.6	0.03	0.03	34.95
30400	5	6.3	0.03	0.03	39.74



Farfield Dilution Model

Summer Surface Conditions - Ocean Current 1.0 knots - Vessel Speed 6 knots

Discharge Rate of Waste , in gpm (Q)
720 (gpm)

Diffusion Coefficient (Kv)
7.8 (cm^2/sec)

Ship's Beam
11.58 (m)

Ship's Draft
3.66 (m)

Ambient Ocean Current, in knots (U)
1 (knots)

Dissipation Parameter (A)
0.001

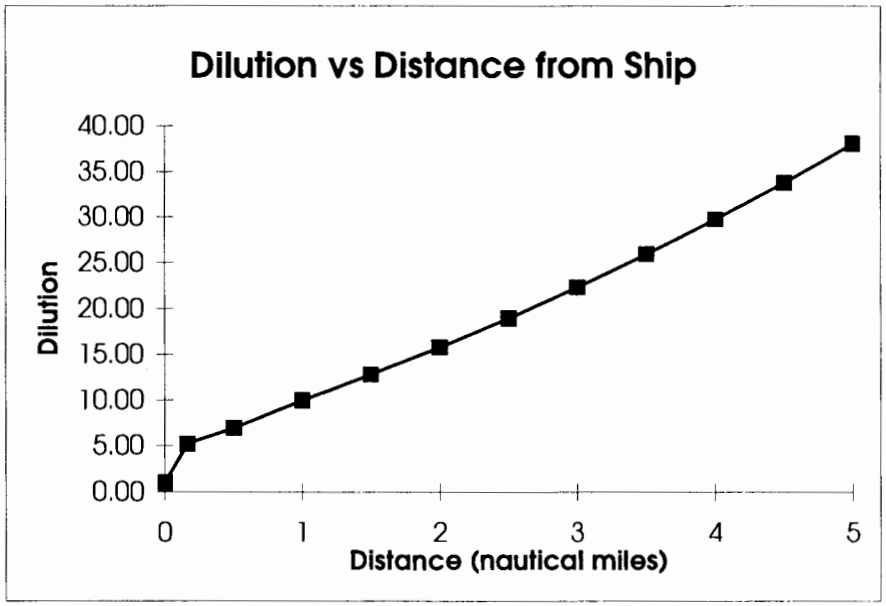
Ship's Length
50 (m)

Ship's Speed, in knots
6 (knots)

Length Parameter, in meters (L)
741 (m)

Initial Concentration
1

Distance from Ship (Feet)	Distance from Ship (Nautical Miles)	Time (hours)	Cmax/Co	Cmax	Dilution
0	0	0.0	1.00	1.00	1.00
1000	0.16	0.3	0.19	0.19	5.21
3040	0.5	0.5	0.14	0.14	6.93
6080	1	1.0	0.10	0.10	9.95
9120	1.5	1.5	0.08	0.08	12.79
12160	2	2.0	0.06	0.06	15.76
15200	2.5	2.5	0.05	0.05	18.93
18240	3	3.0	0.04	0.04	22.32
21280	3.5	3.5	0.04	0.04	25.92
24320	4	4.0	0.03	0.03	29.74
27360	4.5	4.5	0.03	0.03	33.78
30400	5	5.0	0.03	0.03	38.04



EVALUATION OF OCEAN DISPOSAL OF CANNERY SLUDGE IN AMERICAN SAMOA

Prepared for:

Starkist Foods, Inc.

and

Ralston Purina Co.

Prepared by:

M&E Pacific, Inc.
Environmental Engineers
190 South King Street
Honolulu, Hawaii 96813

September 1979

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CHAPTER I

INTRODUCTION

Two tuna canneries, Starkist and Van Camp, are located adjacent to each other at the shoreline of Pago Pago Harbor in American Samoa (see Figure I-1). The Starkist cannery, owned by Starkist Foods, Inc., and the Van Camp cannery, a division of Ralston Purina Company, together constitute the largest source of employment in American Samoa, except for the government.

In common with other food processing operations, there are no significant toxic substances involved in the cannery operations and the wastewater contains primarily those materials that could not reasonably be recovered from the fish processing operations and used for one of the variety of products produced by the canneries. The installation at both canneries of wastewater treatment plants involving alum addition and dissolved air flotation sludge separation has greatly improved the conditions in Pago Pago Harbor by significantly reducing the amounts of suspended solids, biological oxygen demand (BOD), and grease being discharged.

The present practice of land disposal of the sludge resulting from the dissolved air flotation (DAF) treatment of the wastewaters is being restricted by the Government of American Samoa. A primary alternative for disposal of this sludge is the ocean. Before governmental approval of ocean disposal can be obtained, the Environmental Protection Agency (EPA) has to complete an environmental impact assessment or statement concerning the possible effects at the proposed disposal site. The principal purpose of this study is to provide the information necessary for the EPA to prepare that environmental impact document. This study is jointly funded by Starkist and Van Camp since the ocean disposal alternative would involve a system that would combine both sludges.

Most of the data required for this study were gathered during the last half of July 1979 during a field investigation involving sludge sampling and analysis and alternative disposal area evaluation. Some of the data used in this report are from a separate study in the same area conducted by M&E Pacific, Inc. for the U.S. Army Corps of Engineers.

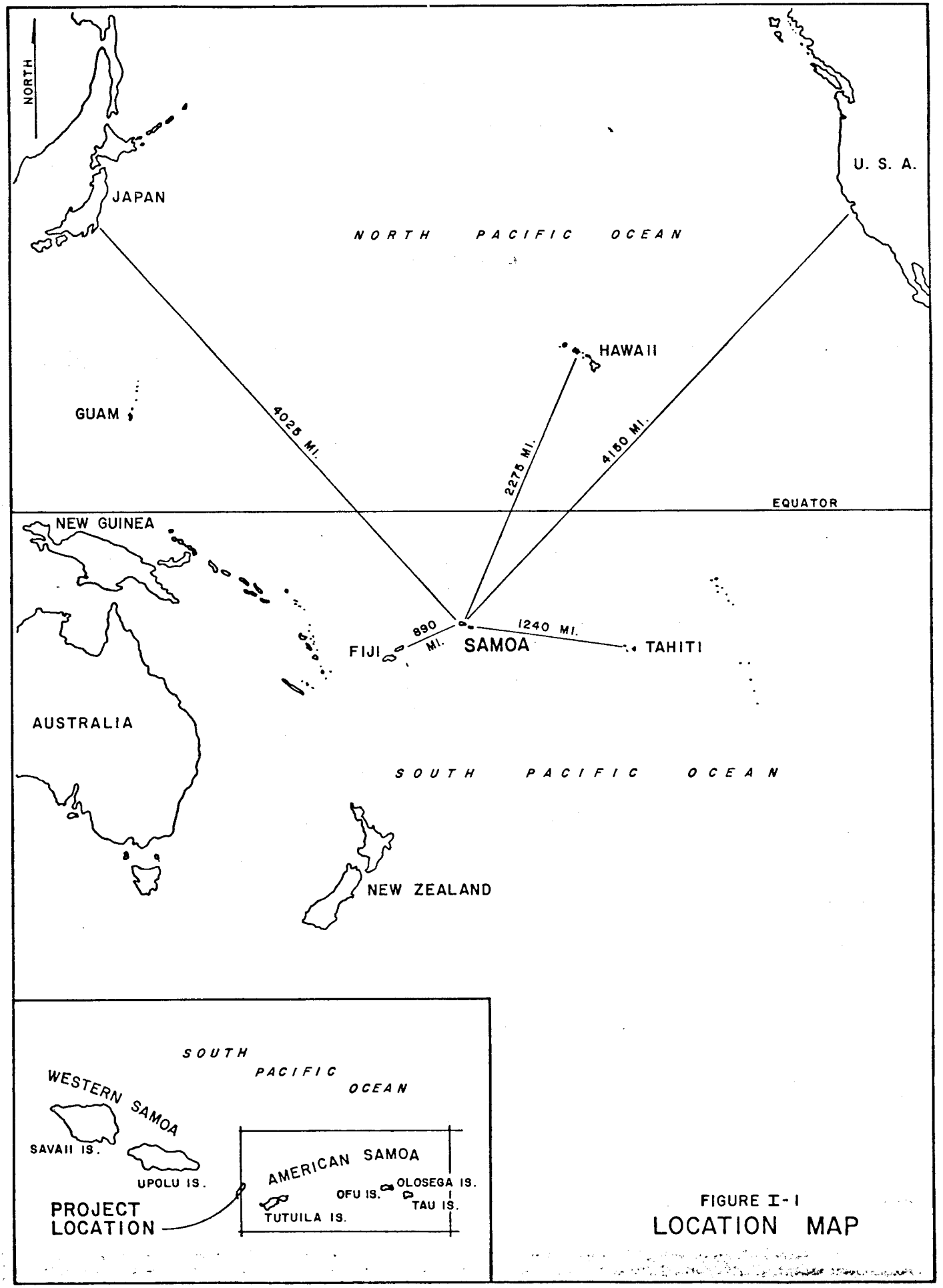


FIGURE I-1
LOCATION MAP

Permission to use these data was obtained from the Corps of Engineers with the understanding that its source is a draft report and therefore subject to final revision. Some data and projections were also provided by Starkist and Van Camp.

This study basically involves the following three steps:

1. The description of the quality and quantity characteristics of the sludges that will be disposed

2. The description of the transport and water quality characteristics of the alternative open ocean and nearshore disposal areas being considered

3. The projection of the probable impacts of sludge disposal at the two alternative sites and the recommendation of which site to use and what disposal practices would minimize impacts.

It is anticipated that the EPA will find the information in this report adequate for its environmental evaluation and will concur with the recommended alternative. If ocean disposal of the canneries' sludge is adopted, a monitoring program would serve to identify any unforeseen detrimental effects.

We wish to acknowledge the cooperation and assistance of several people who were instrumental in the conduct of this study. Mr. Dave Ballands of Starkist Foods, Inc. made the basic arrangements for the study. Mr. Bob Buehs of Van Camp and Mr. John Broughton of Starkist provided assistance in obtaining data as well as sludge samples for analysis and for a test open ocean discharge. Mr. Andy Nesheim, skipper of the Tasi II, assisted in the ocean portion of the study.

CHAPTER II

SUMMARY AND CONCLUSIONS

The measurements of the quality parameters of the sludges from the Starkist and Van Camp operations in American Samoa showed that the predominent characteristic with respect to environmental effects is the high organic content and the accompanying oxygen demand and slick forming materials. The present wastewater treatment scheme using alum and dissolved air flotation is very effective in removing suspended material, grease and oil, as well as phosphate from the waste stream. The grease and phosphate tend to be bound up by the alum and do not readily separate to form slicks or contribute to the nutrient loading. The concentrations of potentially toxic compounds such as MBAS, mercury, cadmium, DDT or DDE in the sludges are relatively low. The vigorous biological degradation and high rate of gas production in the sludge is evidence of the low concentration of toxicants.

The present average combined production rate of sludge from the two canneries is about 400,000 gallons per month. This rate may increase by up to 100% over the next five years.

The water quality and transport conditions at the offshore alternative discharge area, Dump Site No. 1, can be characterized as open ocean. The depth is more than 4,000 feet and the current structure is a combination of a wind influenced surface drift over a prevailing subsurface current toward the east. A minimum in the current speed occurs at around 20 to 30 feet where the two current regimes interfere. The water quality shows no evidence of stratification to at least 100 feet and probably to 300 feet. The photic zone is down to about 170 feet and the water is low in turbidity, nutrients and chlorophyll-a. Fish population densities are correspondingly sparce. Water quality parameters can be described by log-normal distributions.

The water quality characteristics at the nearshore alternative discharge area by the present Tafuna outfall are similar to those of the

open ocean except for a slight decrease in the photic zone depth and slight increases in turbidity, nutrients and chlorophyll-a. The current structure is a combination of reversing tide related longshore current with surface layer wind related transport and a nearshore breaking wave, rip current recirculation system. The wind direction is frequently onshore. The net transport in the subsurface layer is parallel to shore toward the southwest. The benthic biological community in the area is coral based but has recently suffered extensive predation by crown of thorns starfish.

Test discharges of sludges from Starkist and Van Camp at the surface at Dump Site No. 1 showed that the large majority of the material mixes readily with sea water and tends to disperse and sink. A very small amount of scum separates from the rest of the material and a slick tends to form. No measurable dissolved oxygen depletion was noted within the sludge dilution zone.

Bioassays using the changes in dissolved oxygen in outer Pago Pago Harbor surface waters showed that the two sludges responded similarly but with somewhat greater oxygen demand exhibited by the Van Camp sludge. The short term photosynthesis rate was not measurably affected by the addition of small quantities of sludge, and accompanying nutrients. Measurements of the respiration rate showed that the sludge had both an immediate oxygen demand and a slower rate oxygen demand related to the biological degradation of the organic material. The oxygen demand of the sludge decreased significantly with storage. Using the results of these respiration bioassays minimum dilution requirements were estimated.

The potential detrimental effects of discharging the sludge at Dump Site No. 1 can be alleviated by providing adequate initial dilution and discharging below the surface.

At the Tafuna outfall, it is not reasonably possible to provide sufficient initial dilution to comply with dissolved oxygen reduction limits in the water column. Also, it is likely that detrimental sludge accumulation would occur in the transport area parallel to the shoreline as well as floatable accumulation at the shoreline.

The recommendations resulting from this study include the designation of Dump Site No. 1 as the ocean disposal area and the use of controlled subsurface discharge of the sludge from a moving vessel. A monitoring program should identify any problem areas which can then be alleviated.

CHAPTER III

METHODOLOGY

The field and laboratory measurements used in this study have generally been developed and used over a period of several years for similar studies at several locations in the Pacific.

Where applicable, Standard Methods (14th Edition) methods or EPA specified methods were employed to measure sludge and receiving water characteristics. For some cases, however, the methods reported by Strickland and Parsons (1968) were used since neither the EPA nor the Standard Methods methods were designed for sea water analyses.

The receiving water data were statistically analyzed and found to be adequately described by log-normal distributions. Data from the Corps of Engineers' study were included in the statistical analysis so as to form a broader data base covering spatial and temporal variations.

Some observations and tests were adapted to the purposes of this study, including the test release of sludge in the open ocean and the bioassay using the response of the local plankton population.

Descriptions of the specific methods used for the field and laboratory portions of this study are given in the remainder of this chapter.

CURRENT MEASUREMENTS

Currents were measured by the use of a current meter and drogues.

Current Meter

An Endeco Type 105 current meter was installed at the Tafuna study area to give a temporal description of the nearshore currents. The meter depth at this location was 30 feet. A typical installation configuration for this type of meter is shown on Figure III-1. The anchor for the mooring line was placed by divers at a depth of 65 feet. This meter is an axial flow, ducted impeller recording meter designed for continental shelf and estuarine environmental monitoring. It was specifically selected because it is capable of measuring very low current velocities. The meter

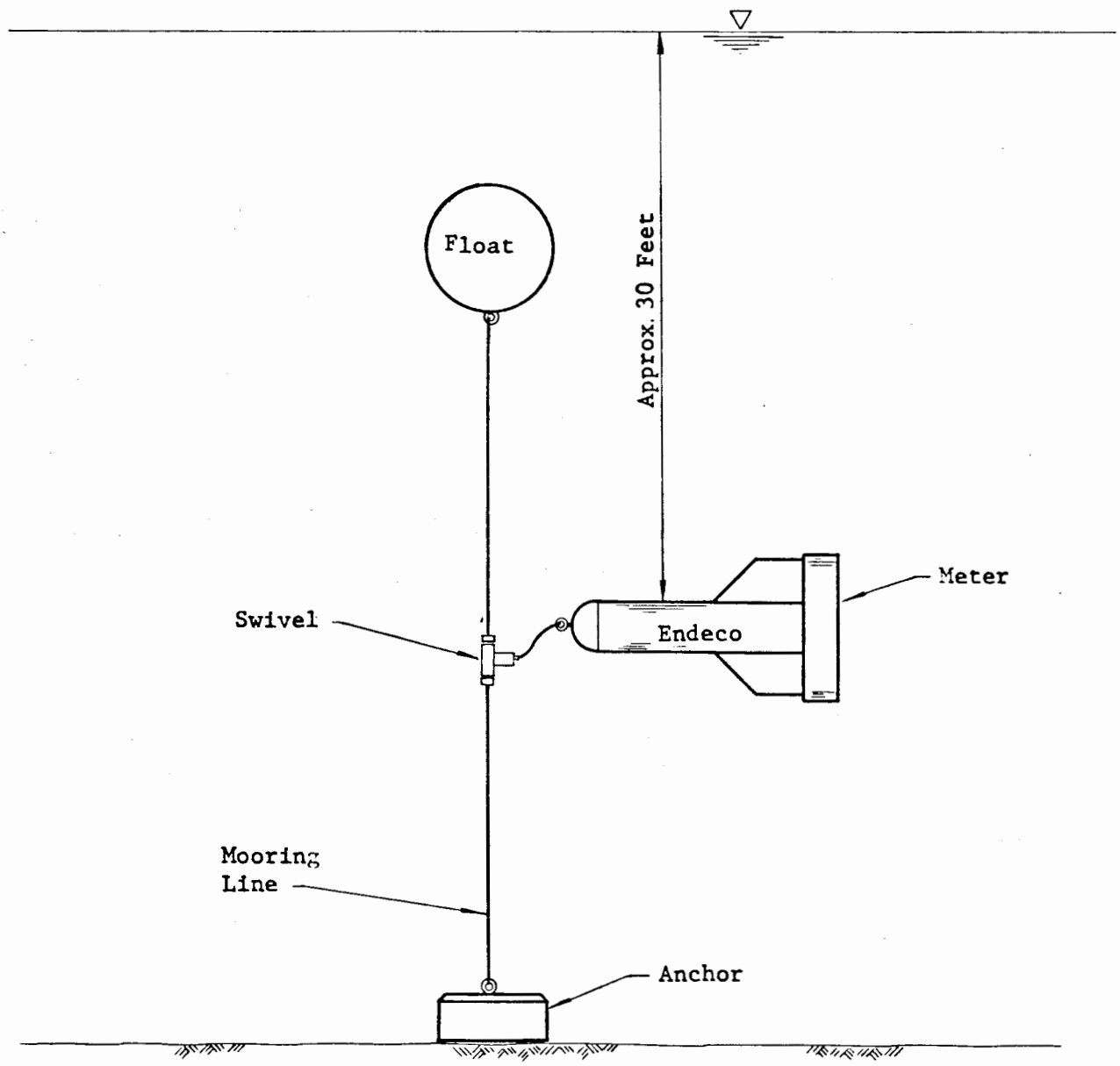


FIGURE III-1

TYPICAL CURRENT METER INSTALLATION

was set to record the current speed and direction at 30-minute intervals and was in place for 20 days. The speed and direction data were recorded on 16 mm film for subsequent data retrieval. Possible interference with the sensitive rotor by the growth of attached marine organisms was effectively eliminated by antifouling paint.

Drogues

The type of drogues used to give a spatial description of the currents in both the open ocean and the Tafuna outfall area is shown on Figure III-2. The general procedure was to release drogues at three depths. Tracking was accomplished using a boat and a sextant and measuring two angles among three landmarks. These data would then be used to plot drogue vectors. A wind correction factor was applied for all subsurface drogues.

MIXING MEASUREMENTS

A dye study was conducted to determine the dispersion and mixing characteristics of the open coastal area at Tafuna.

The general procedure involves the release of two pounds of Rhodamine-B dye from a boat. Vertical aerial photographs (slides) are then taken of the expanding dye patch with the time after dye release noted and the scale given by the dimensions of the boat.

The resulting slides are then projected on a sheet of paper and the outline of the dye patch traced. The area of the patch for each timed photograph is then determined by using a planimeter.

The horizontal dispersion coefficient is then calculated using the definition developed by Brooks (1960) based on Fick's First Law:

$$k = 1/2 \frac{d\sigma^2}{dt}$$

Where k = dispersion coefficient

t = time

σ = standard deviation of the tracer concentration distribution

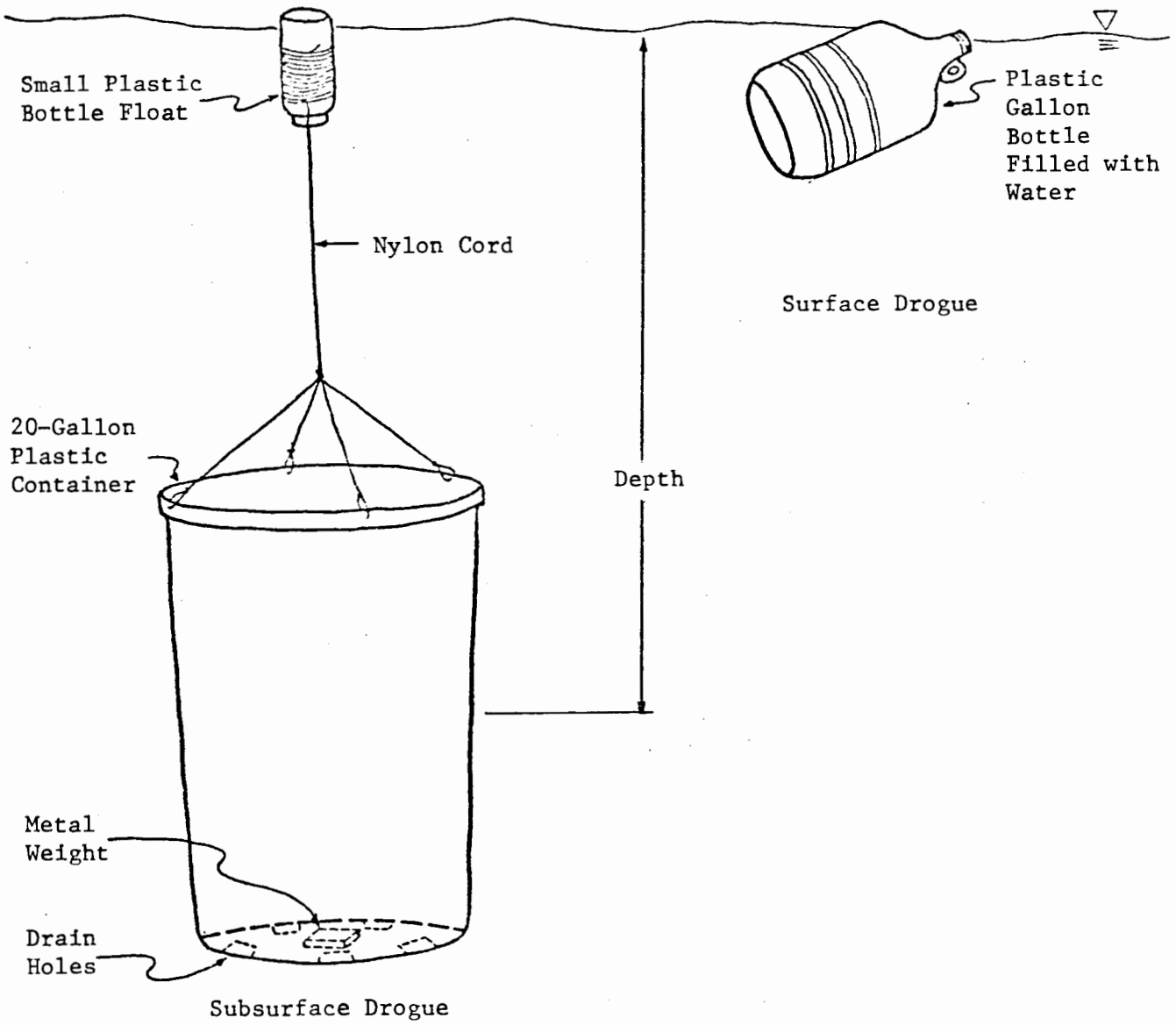


FIGURE III-2

SURFACE AND SUBSURFACE DROGUES

Using the assumption that 4σ is approximately equal to the average horizontal dimension of the patch and using the Brooks (1960) definition of scale, $L = 2\sqrt{3}\,\sigma$, Fick's First Law can be integrated to give a working definition of the dispersion coefficient.

$$k = \frac{0.04(A_2 - A_1)}{T_1 - T_2}$$

where k = dispersion coefficient (ft^2/sec)

A_2 = area of dye patch at time = T_2

A_1 = area of dye patch at time = T_1

The corresponding scale is given by L, which is approximated by the square root of the dye patch area for the period in question; i.e.:

$$L = \sqrt{\frac{A_2 + A_1}{2}}$$

The resulting relationship between the scale and dispersion coefficient can then be plotted on log-log paper and compared to Richardson's law for an infinite ocean; i.e.:

$$k = a\,L^{4/3}$$

It should be noted that the use of aerial photographs for this determination is only valid for 30 to 35 minutes after the dye is released; after that time the edges of the dye patch become too indefinite to be readily identifiable.

WATER QUALITY MEASUREMENTS

Measurements of various water quality parameters at each station were generally made twice during each of the February and July field trips. Some parameters were measured directly in the field, others were measured

on water samples brought from the field to the public health water laboratory in the LBJ medical center, and some were measured on preserved samples in Honolulu.

Sampling Procedures

Sampling of ocean and nearshore stations was accomplished using a Van Dorn sampler. One gallon samples were taken at depths of 3 and 60 feet. In addition, two samples were taken at 300 feet at Station "Dump Site No. 1."

Sludge samples were taken on three occasions at both the Starkist and Van Camp treatment plants.

Field Measurements

Salinity was measured using a Kahlsico Salinometer with a 100-foot probe. In order to detect any stratification, measurements were taken at the surface, 5 feet, 10 feet, then at every 10-foot interval to a depth of 100 feet.

Temperature readings were taken simultaneously with salinity measurements using the same instrument.

Dissolved oxygen concentrations were measured using a Yellow Springs Instruments Co., Inc. (YSI) Model 57 oxygen meter calibrated with oxygen saturated fresh water. Measurements were made at depths of 3 feet and 50 feet in ocean stations.

Irradiance measurements were made using a Hydro Products Model 620 A irradiance meter. The percentage of incident light at various depths was determined by comparison of the readings of a surface and a subsurface photometer. Measurements were made at regular intervals (usually at every 10 feet) until the one percent incident light level was reached. This level is usually considered as the depth of the compensation level below which no significant photosynthetic activity occurs.

Fecal coliform counts were obtained using Millipore filter field kits and a Millipore portable water bath incubator. Cultures were inoculated in the field, with subsequent incubation in the laboratory. The "Membrane

Filter Method" as described in Standard Methods (14th edition) was used. Sea water samples were diluted with sterilized tap water to minimize any excess salt effects.

Laboratory Measurements Conducted in American Samoa

pH was measured at the American Samoa Water Quality Laboratory using an Orion Research Ionalyzer Model 407A specific ion meter calibrated with appropriate pH buffer solutions.

Turbidity was measured using a Hach Chemical Co. Model 2100 A Turbidimeter with turbidity standards relative to the Formazin Turbidity Unit.

Suspended solids test was conducted according to Standard Methods, 14th edition. In addition, the filters were thoroughly rinsed with distilled water to remove any residual salt after the salt water sample was filtered.

Chlorophyll-a was determined according to the method described by Strickland and Parsons in A Practical Handbook of Seawater Analysis (1968). 2,000-ml portions of sample were filtered through GF/C glass fiber filters and the filters placed in 100-ml nalgene bottles containing 50 ml of 90 percent acetone. The nalgene bottles were packed in ice and air freighted to Honolulu in styrofoam containers where they were analyzed using a centrifuge and spectrophometer. The chlorophyll-a content was calculated according to the Strickland and Parsons formula.

Bioassays to determine the possible effects of the discharge of sludge on the biota at the recommended disposal site were conducted using the short-term response of the plankton community. This approach was chosen because, with an open ocean discharge, any exposure period would be short term and the predominant organisms in the area are plankton. The fish population density in the desert-like conditions of nutrient-poor, deep tropical waters is extremely sparse and would not serve as good bioassay subjects because no base line tests are available and the fish are very difficult to obtain in consistent sizes and adequate numbers. In any case, it is highly unlikely that the sludge has any significant direct toxic effect on fish that would be measurable in an acute bioassay test. The major effect is one of DO demand, which is best measured directly.

The bioassay procedure utilizing plankton involved the measurement of photosynthesis and respiration rate changes with exposure times up to three hours with various dilutions of sludge with sea water. The background test water selected was outer Pago Pago Harbor surface water because it contained a more significant plankton concentration than the open ocean water. Bottles (500 ml size) filled with test water with 0.5, 0.2, 0.1, 0.01, and 0.005 percent sludge additions were incubated for three hours under light and dark conditions in outer Pago Pago Harbor. The initial and final dissolved oxygen concentrations were measured using a DO meter as previously described. An initial test of this procedure using three replicates shows excellent reproducibility, within 0.1 mg/l DO.

The incubation temperature was the ambient water temperature in the upper layer of outer Pago Pago Harbor, which varied between 28.0 and 28.8°C.

A time sequence test was also conducted to observe the rate of change of DO with a constant sludge addition of 0.2 percent. This test showed how much of the DO demand is immediate (i.e., generally chemical) and how much is due to biological action.

Test sludge releases were conducted with both Starkist and Van Camp sludges at Dump Site No. 1 using 30 gallons for each release. To simulate the worst case condition as well as to allow ready observation, the 30 gallons were released all at once at the surface. Observations were made of the approximate rate of dispersion and rate of sinking by means of photographs and diver observations. The amounts of floatable and slick forming materials were also noted.

LABORATORY MEASUREMENTS CONDUCTED IN HONOLULU

With the exception of the analyses for chlorophyll-a, all analyses were conducted in duplicate. Demineralized tap water was used for all distilled water needs.

The samples for the analyses of TKN, NO_2+NO_3, and TP were preserved with sulfuric acid to a pH under two in 500 ml nalgene wide-mouth bottles. Heavy metals analyses were performed on sludge samples preserved with nitric acid. These sample bottles were packed with ice in styrofoam ice

coolers then shipped to the laboratory in Honolulu via air freight. Chlorophyll-a acetone extraction samples were also packed in these styrofoam coolers. Sludge samples for DDT and DDE and other analyses were shipped in glass bottles. Once transported to the laboratory, samples were immediately stored in a refrigerator maintained at a temperature of 4°C.

Total Kjeldahl Nitrogen

The method described by Strickland and Parsons in A Practical Handbook of Seawater Analysis was followed with the following modifications. Digestion of samples was complete after all "smoke" cleared in the 125 ml erlenmeyer flasks. The addition of 11 ml of the developing solution for seawater samples consisted of this ratio: 100 ml NaOH (330 g/2,000 ml), 10 ml KBr (1.5 g/250 ml), and 0.75 ml Chlorox. The developing period was 3.5 hours. For the fresh water samples, the developing solution consisted of this ratio: 100 ml NaOH, 10 ml KBr, and 1.5 ml Chlorox and the developing period was 1.5 hours.

Nitrate Plus Nitrite Nitrogen

The cadmium reduction column method of Strickland and Parsons was used. To maximize the reducing power of cadmium, samples were filtered through GF/C glass fiber filter papers, which retain particles in the semi-colloidal range, before passage through the reduction columns. Duplicate blanks and triplicate standards were passed through each of the two columns used for each day on which the columns were used.

Total Phosphorus

The "Single Reagent Method" described in the Manual of Methods for Chemical Analysis of Water and Wastes, Environmental Protection Agency, 1974, was used for seawater and estuarine waters. Boiling glass beads where used to prevent bumping and make evaporation of samples smoother.

Oil and Grease

The "Separatory Funnel Extraction Method" described in the Manual of Methods for Chemical Analysis of Water and Wastes was used.

Chlorophyll-a

The pigments were allowed to extract at 4°C in a refrigerator for at least two days instead of about 20 hours as described by Strickland and Parsons. The longer extraction period was designed to compensate for the fact that filters were not ground up for more efficient extraction. Magnesium carbonate was not added for long-term preservation because work on samples was started at the earliest possible time. Instead of using 10 ml extract, 50 ml was used because of the use of 10 cm cells, which hold about 25 ml of sample. To correct for evaporation during extraction, the volume of the extract was measured just prior to the 10 minute centrifugation and measurement on the spectrophotometer.

Protein

As per the Association of Official Analytical Chemist Methods, fertilizer section, 11th edition, 1970.

Fats

As per Standard Methods for the Examination of Water and Wastewater, "Soxhlet Extraction Method," 14th edition, APHA, AWWA, WPCF, 1975.

Aluminum and Cadmium

As per Analytical Methods for Metal and Pesticide Analysis, Ho Lee Young, Ph.D., Chief, Chemistry Section, Laboratory Support Branch, EPA Region 9.

Mercury

As per Manual of Methods for Chemical Analysis of Water and Wastes, "Manual Cold Vapor Technique (Sediment)," U.S. Environmental Protection Agency Technology Transfer, 1974.

DDT and DDE

As per Manual of Analytical Methods for the Analysis of Pesticide Residues in Human and Environmental Samples, Section 11,B, "Sample Preparation and Analysis of Bottom Sediments," EPA, February 1978.

CHAPTER IV

SLUDGE CHARACTERISTICS

Prior to the present alum addition with dissolved air flotation treatment, the wastewaters from the canneries were discharged directly into inner Pago Pago Harbor. The major difficulties with this practice were the accumulation of floatables (primarily grease) along the downwind shoreline, significant odor problems, low dissolved oxygen concentrations, and generally aesthetically unpleasant water conditions. As a result of the installation of the treatment plants, the problems in Pago Pago Harbor associated with grease, BOD, and direct discharge of suspended solids from the canneries have been greatly alleviated.

The addition of alum, along with some use of polyelectrolytes as well as NaOH for pH adjustment, and the bubble-induced separation serve to partly emulsify and generally remove the grease as well as particulate BOD and suspended solids. The treatment is very effective, with the resulting float containing the alum sludge, which has tied up most of the grease and phosphate, as well as other particulate material all in a bubble matrix. This material is skimmed off the separation tank and stored in an aerated holding tank. Odor-reducing chemicals are added and the sludge is presently transported by tank truck to land disposal sites in the Tafuna area. Because of severe limitations in the availability of suitable land disposal areas for this sludge, other disposal or use possibilities are being explored.

SLUDGE CHARACTERISTICS

Table IV-1 gives the medians and ranges of values for a number of parameters measured during this study on both the Starkist and Van Camp sludges. In general the two sludges are similar, except that the higher alum dosage by Van Camp is clearly evident in the higher aluminum content of the Van Camp sludge. The Van Camp sludge also appears to be somewhat higher in solids concentration and BOD_5.

Of special note is that the potentially toxic substances, methylene blue active substances (MBAS), cadmium (Cd), and mercury (Hg) are all low.

TABLE IV-1

AMERICAN SAMOA CANNERY SLUDGE CHARACTERISTICS**

Parameter	Units	Starkist	Van Camp	Overall Range
pH	Units	5.9	6.1	5.8 to 6.2
Bulk Density	grams/ml	0.958	0.893	0.773 to 1.017
Suspended Solids	w/w %	14.1	18.5	9.6 to 21.4
Volatile Solids	% of SS	86.5	95.4	79.4 to 96.5
Total Organic Carbon	grams/kg dry weight	567	625	456 to 799
Total Phosphorus	mg/kg	793	804	739 to 1,031
Total Kjeldahl Nitrogen	mg/kg	621	678	587 to 769
NO_3+NO_2 Nitrogen	mg/kg	0.89	1.00	0.77 to 1.24
BOD_5	mg/l	142,000	225,000	105,000 to 258,000
Protein	w/w %	4.28	2.54	1.48 to 4.72
Fat	w/w %	6.32	6.16	5.80 to 6.50
MBAS	mg/l	12.0	2.8	0.5 to 13.4
Aluminum	mg/kg dry weight	1,260	5,770	711 to 10,400
Cadmium	mg/kg dry weight	3.3	3.5	1.3 to 6.4
Mercury	mg/kg dry weight	0.015	0.030	0.011 to 0.050
DDT	mg/kg	ND*	ND	-
DDE	mg/kg	ND*	ND	-

* ND = none detected, detection limits are 0.01 mg/kg.

** Median values of three sets of samples

The predominant characteristic of these sludges is the significant concentrations of total organic carbon (TOC) and BOD_5. These sludges are very biologically active and exhibit no signs of inhibiting toxic responses. Gas production is vigorous if these sludges are held without pH adjustment or other biologically inhibiting preservation technique.

Additionally, it should be noted that these sludges contain significant concentrations of total kjeldahl nitrogen (TKN) and especially total phosphorus (TP). The TP content can be largely attributed to the use of alum in the treatment process. If ocean disposal of this sludge is generally to areas below the photic zone, then there should be little effect from these nutrient additions, especially since the material sinks and the phosphorus is tied up with the aluminum.

The most likely effect that this sludge would have on an open ocean disposal area is possible oxygen stress related to BOD and TOC. This problem can best be dealt with by providing adequate dilution and transport and avoiding possible collecting areas for floatables or settleables.

Sludge Quantities

According to information provided by the two companies, the present averages of sludge productions are as shown in Table IV-2.

TABLE IV-2

PRESENT CANNERY SLUDGE QUANTITIES IN AMERICAN SAMOA

Parameter	Units	Starkist	Van Camp	Total
Minimum	US gallons/month	100,000	210,000	310,000
Average	US gallons/month	200,000	325,000	525,000
Maximum	US gallons/month	300,000	420,000	720,000

The values in Table IV-2 indicate that, on a volume basis, Starkist would account for 38 percent and Van Camp 62 percent of the total amount of sludge to be disposed. Van Camp has projected that it expects a doubling of its sludge production over the next five-year period. Although no

The predominant characteristic of these sludges is the significant concentrations of total organic carbon (TOC) and BOD_5. These sludges are very biologically active and exhibit no signs of inhibiting toxic responses. Gas production is vigorous if these sludges are held without pH adjustment or other biologically inhibiting preservation technique.

Additionally, it should be noted that these sludges contain significant concentrations of total kjeldahl nitrogen (TKN) and especially total phosphorus (TP). The TP content can be largely attributed to the use of alum in the treatment process. If ocean disposal of this sludge is generally to areas below the photic zone, then there should be little effect from these nutrient additions, especially since the material sinks and the phosphorus is tied up with the aluminum.

The most likely effect that this sludge would have on an open ocean disposal area is possible oxygen stress related to BOD and TOC. This problem can best be dealt with by providing adequate dilution and transport and avoiding possible collecting areas for floatables or settleables.

Sludge Quantities

According to information provided by the two companies, the present averages of sludge productions are as shown in Table IV-2.

TABLE IV-2

PRESENT CANNERY SLUDGE QUANTITIES IN AMERICAN SAMOA

Parameter	Units	Starkist	Van Camp	Total
Minimum	US gallons/month	100,000	100,000	200,000
Average	US gallons/month	200,000	200,000	400,000
Maximum	US gallons/month	300,000	300,000	600,000

The values in Table IV-2 indicate that, on a volume basis, Starkist and Van Camp would each account for 50% of the total amount of sludge to be disposed. Van Camp has projected that it expects a doubling of its sludge production over the next five-year period. Although no

projections are available from Starkist, it is reasonable to expect that it will have a similar rate of increase. Consequently, for planning and permit purposes, the average sludge production is expected to increase from the present 400,000 gallons per month to 800,000 gallons per month in five years.

The operation schedule for both canneries varies from three to six days per week, with an average of five days per week. The schedules for the two plants do not necessarily coincide. This variation in operation schedule as well as the vagaries of the weather means that some storage facilities may be necessary if open ocean sludge disposal is adopted. It is expected that a workable ocean disposal system would also include the capability of land disposal for emergency conditions when the storage capacity is exceeded and lengthy adverse weather periods or boat breakdowns occur.

CHAPTER V

RECEIVING WATER CHARACTERISTICS

Two areas were investigated for the possibility of ocean disposal of the sludge from the canneries. These areas, shown on Figure V-1, are the Tafuna outfall area near the west end of the runway and an offshore area outside of the general shipping lanes into and out of Pago Pago Harbor. This offshore area has a water depth of 700 to 800 fathoms and can be considered as open ocean.

TAFUNA OUTFALL AREA

The transport, mixing, and water quality characteristics at the Tafuna outfall area were measured during February and July 1979 as part of the baseline water quality study for American Samoa under the auspices of the U.S. Army Engineer Division. The data presented herein are used with their permission.

The current structure in the nearshore area in the vicinity of the present and proposed municipal wastewater outfalls is a result of tidal, wind, and wave forces. The surface layer generally responds directly to the wind, while the overall water column is mostly influenced by the tide-related longshore current. The area shoreward of the breaker zone is dominated by onshore breaking wave transport and the recirculating rip current pattern.

The results of the drogue measurements at Tafuna are given on Figures V-2 through V-5. An overall summary of the July 1979 current meter data at Tafuna is given on Figure V-6, with the flood tide distribution shown on Figure V-7 and the ebb on Figure V-8.

These data show that in February (and also October according to a report by CH_2M Hill) the tide-related longshore current is northeasterly during ebb and southwesterly during flood. The July data show a reversal in this pattern, with the ebb-related current moving toward the southwest and the flood toward the northeast. The net transport at a depth of 30 feet during July is toward the southwest at 5.5 cm/sec (0.1 knots).

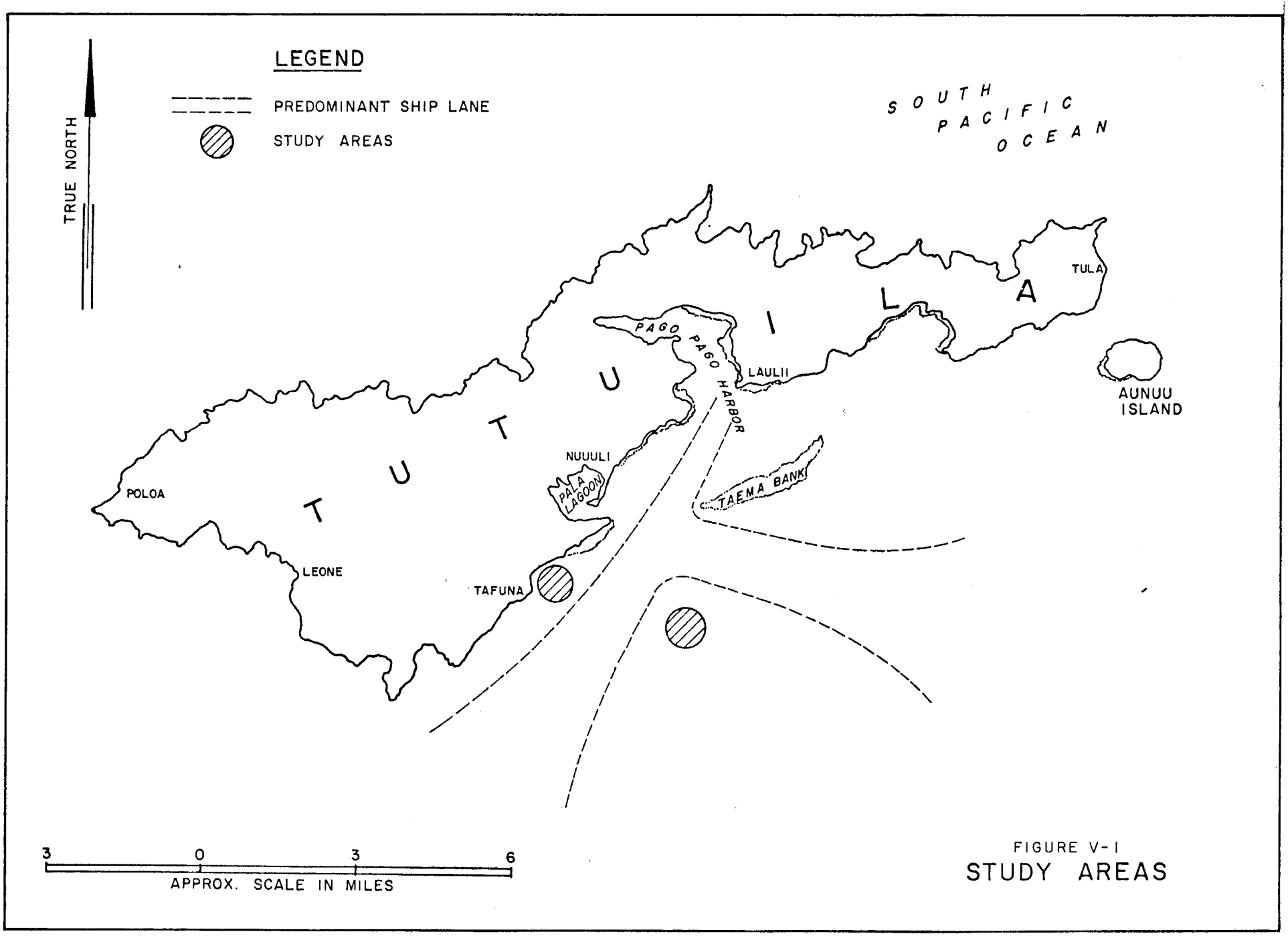
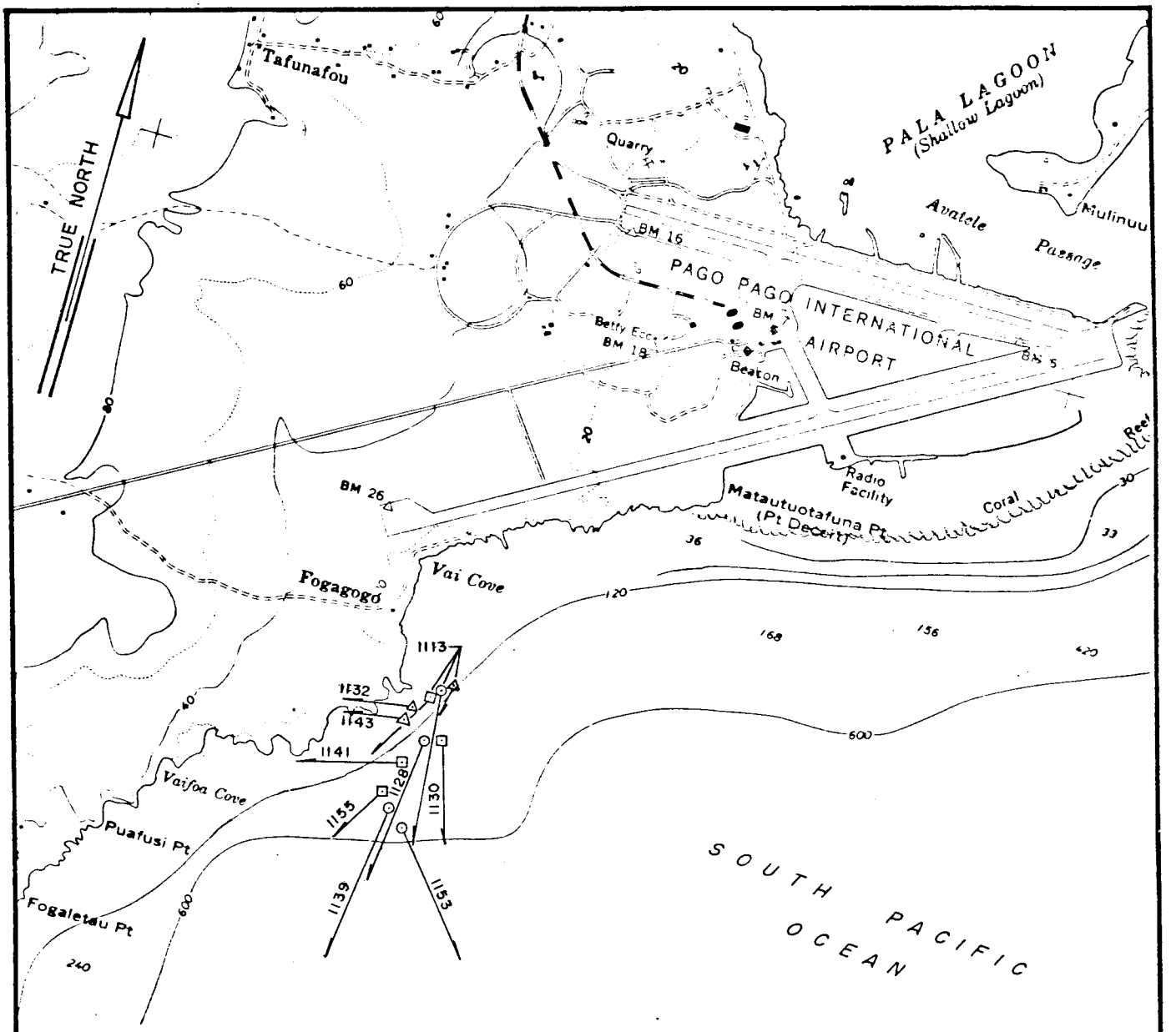
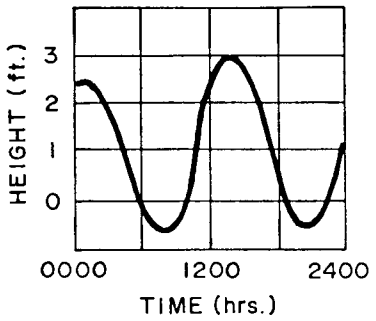


FIGURE V-1
STUDY AREAS



OBSERVED TIDE



WIND: 15 kts. from 330°

DEPTH OF DROGUE

- SURFACE
- 15 FEET
- 30 FEET

SPEED SCALE

CM / SEC

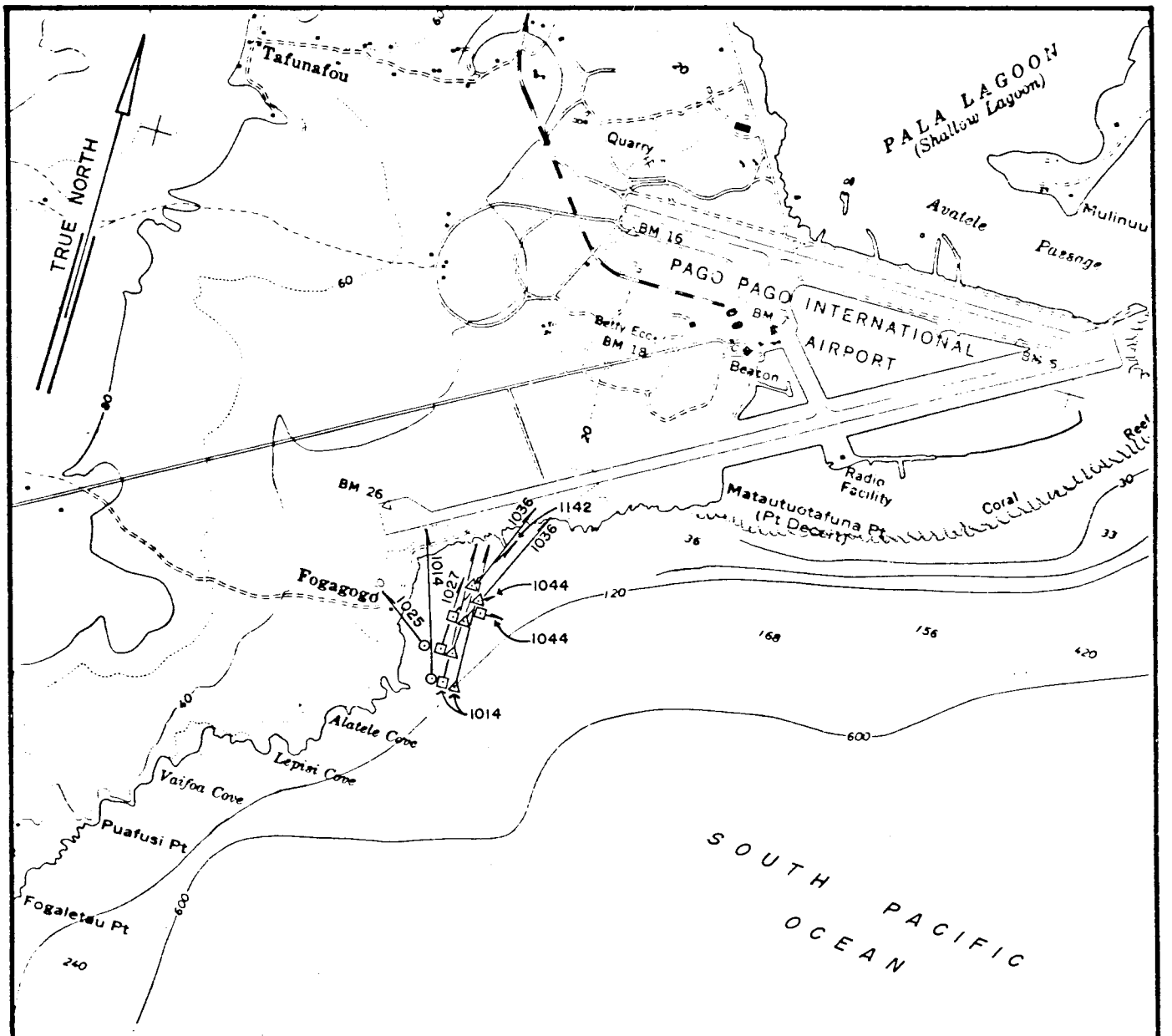
0 5 10 15 20

2000 0 2000

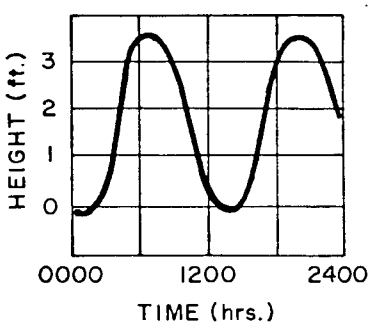
SCALE IN FEET

FIGURE V-2

DROGUE VECTORS
2-20-79



OBSERVED TIDE



WIND: 2-5 kts. from SE

DEPTH OF DROGUE

- ⊙ SURFACE
- ⊡ 15 FEET
- △ 30 FEET

SPEED SCALE

CM / SEC

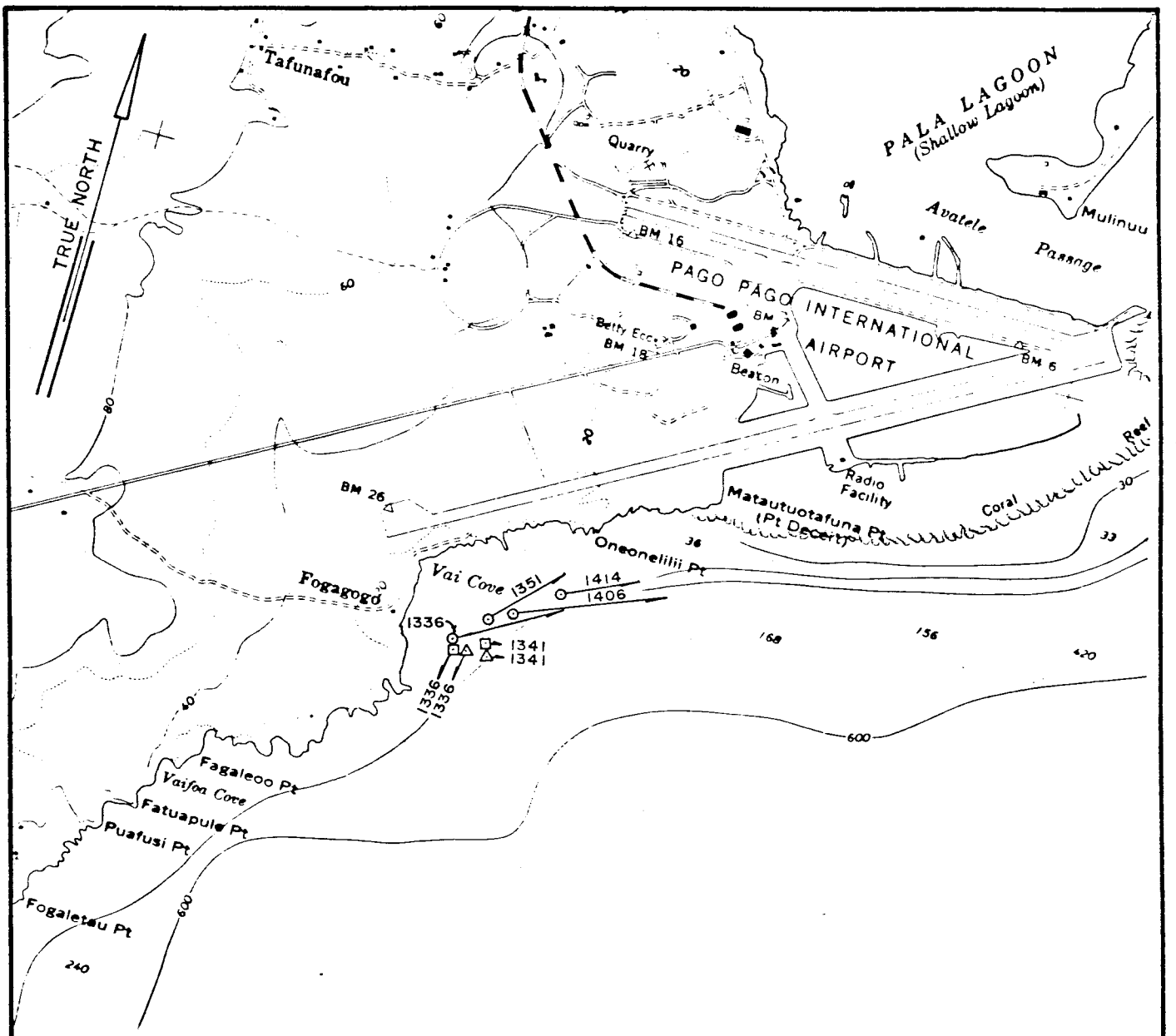
0 5 10 15 20

2000 0 2000

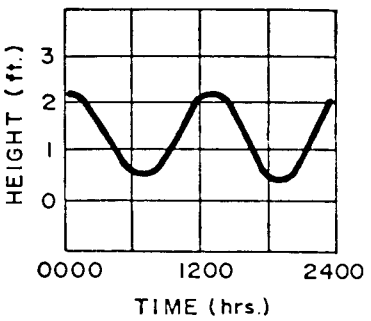
SCALE IN FEET

FIGURE V-3

DROGUE VECTORS
2-27-79



OBSERVED TIDE



WIND: 13 kts. from 245°

DEPTH OF DROGUE

- ⊙ SURFACE
- ⊡ 10 FEET
- △ 30 FEET

SPEED SCALE

CM / SEC

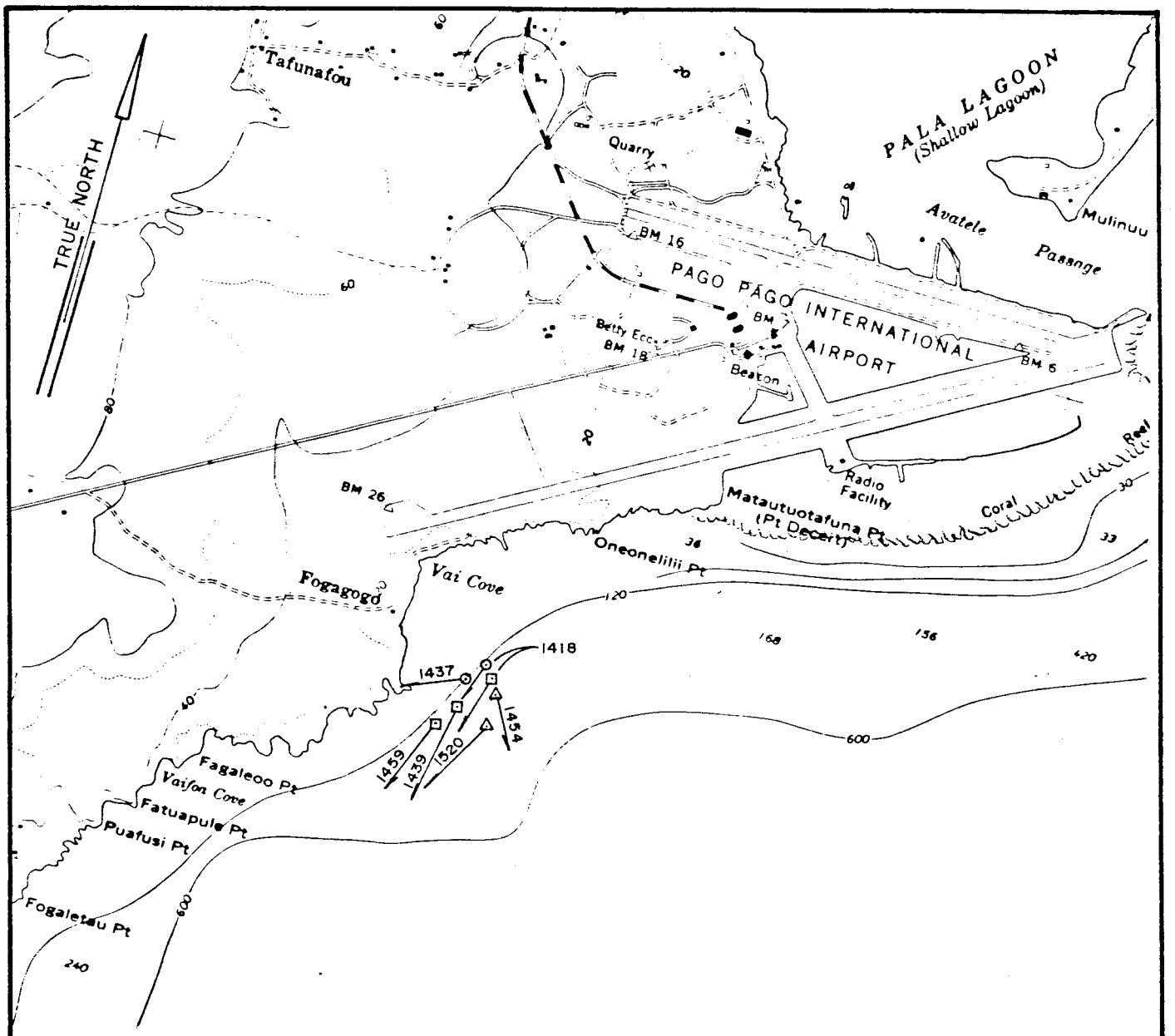
0 5 10 15 20

2000 0 2000

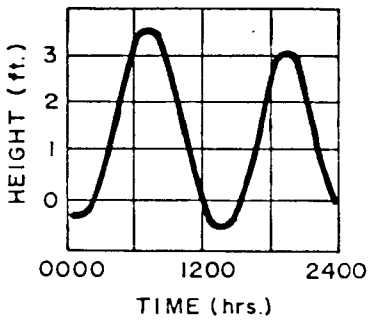
SCALE IN FEET

FIGURE V - 4

DROGUE VECTORS
7- 2 - 79



OBSERVED TIDE



WIND: 3-5 kts. from 110°

DEPTH OF DROGUE

- ○ SURFACE
- □ 10 FEET
- △ 30 FEET

SPEED SCALE

CM / SEC

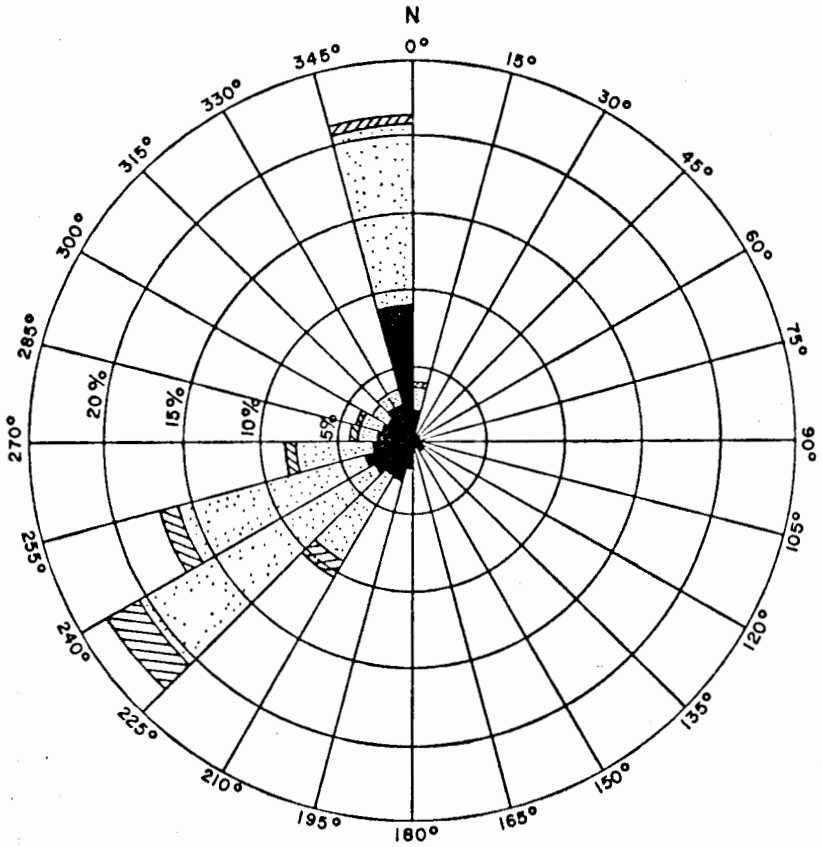
0 5 10 15 20

2000 0 2000

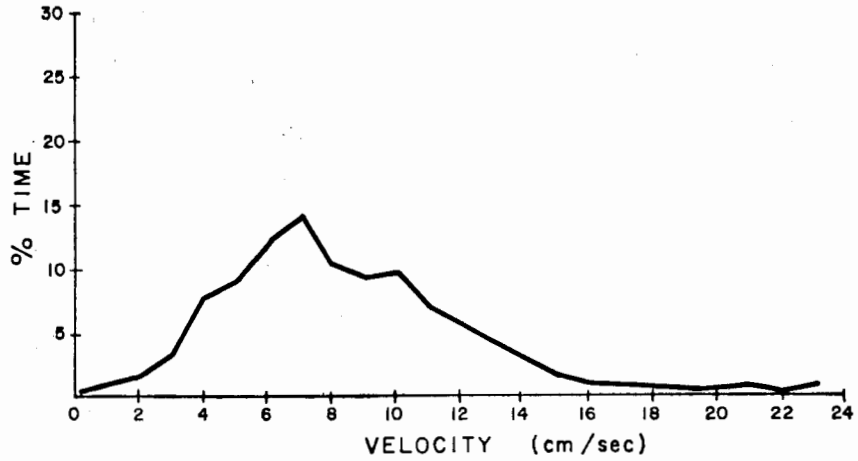
SCALE IN FEET

FIGURE V-5

DROGUE VECTORS
7-10-79



OVERALL TIDE CURRENT ROSE



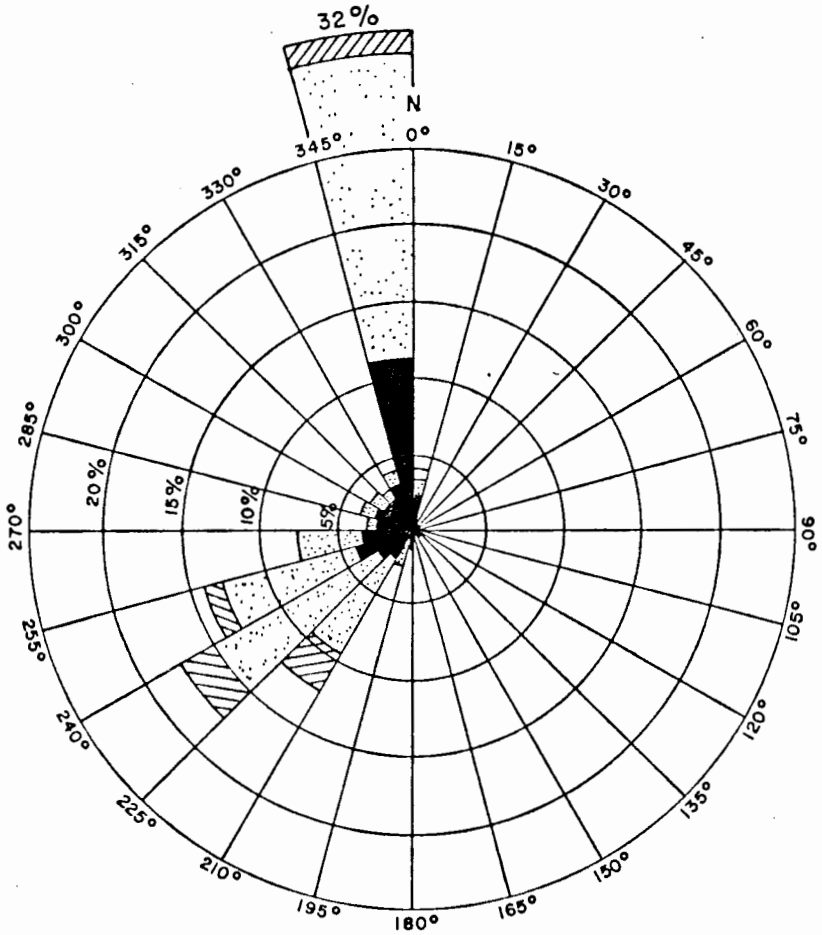
VELOCITY PROFILE

Velocity Symbols

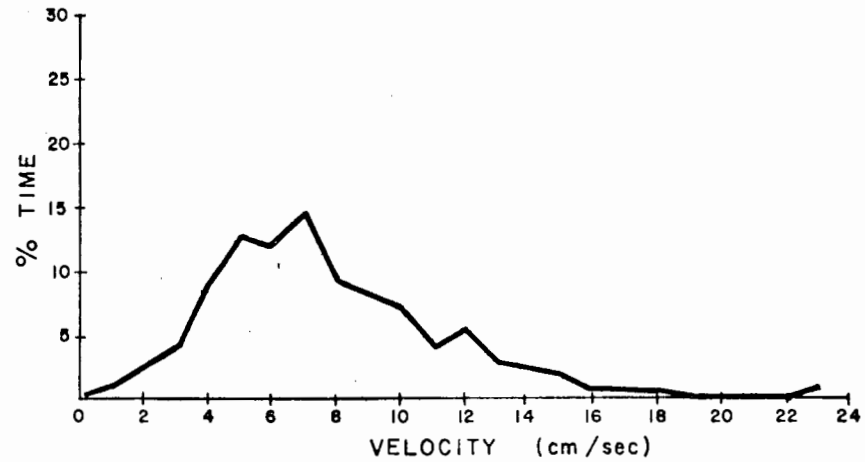
- 0 - 5 cm/sec
- 6 - 13 cm/sec
- 14 - 23 cm/sec

FIGURE V-6

CURRENT ROSE AND VELOCITY PROFILES
TAFUNA 7-3-79 / 7-23-79



FLOOD TIDE CURRENT ROSE



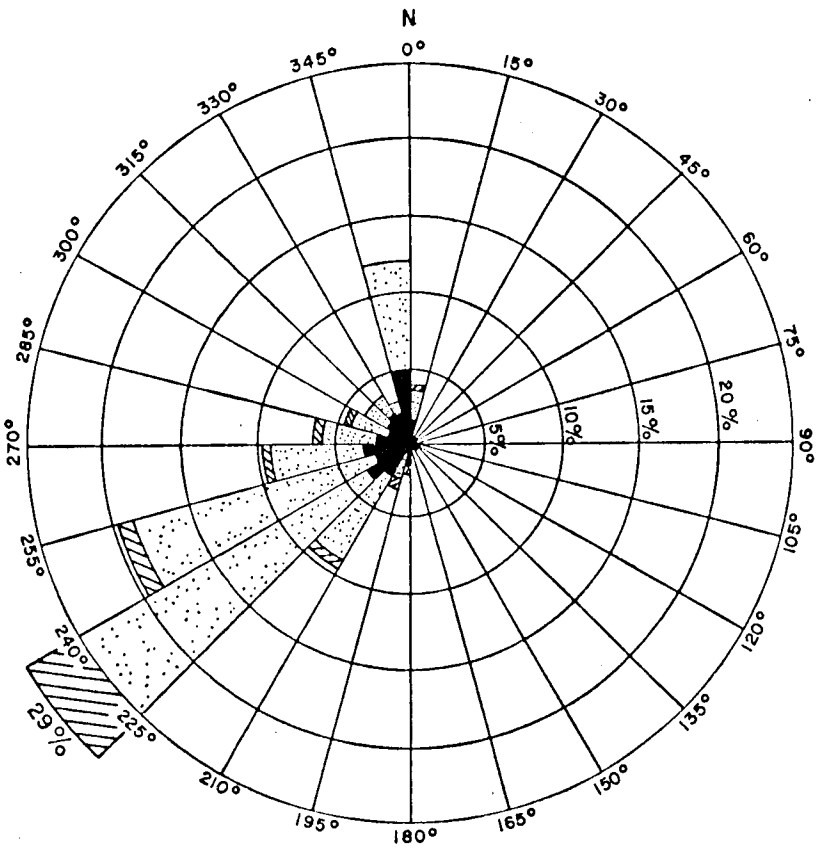
VELOCITY PROFILE

Velocity Symbols

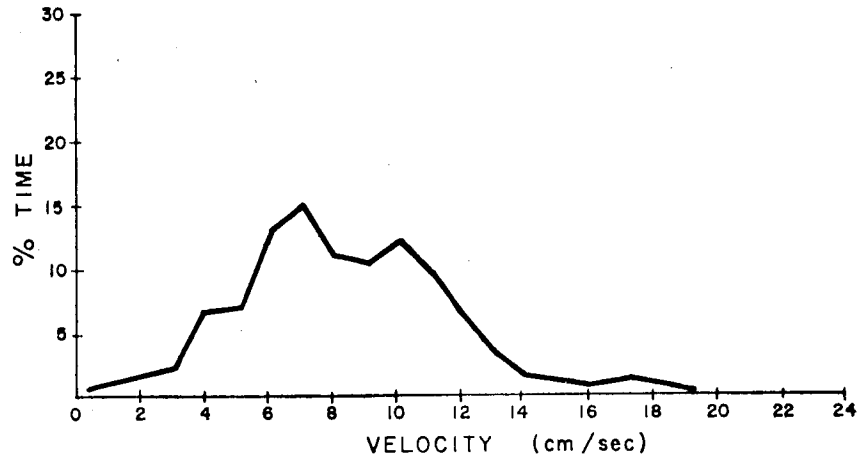
- 0 - 5 cm/sec
- 6 - 13 cm/sec
- 14 - 23 cm/sec

FIGURE V-7

CURRENT ROSE AND VELOCITY PROFILES
TAFUNA 7-3-79 / 7-23-79



EBB TIDE CURRENT ROSE



VELOCITY PROFILE

Velocity Symbols

- 0 - 5 cm/sec
- 6 - 13 cm/sec
- 14 - 23 cm/sec

FIGURE V-8

CURRENT ROSE AND VELOCITY PROFILES
TAFUNA 7-3-79 / 7-23-79

The wind effect is evident in the drogue data, which show that the surface drogue paths are a combination of direct wind influence and underlying tide-related longshore current transport. Some of the subsurface drogues show transport counter to the wind direction.

The breaking wave onshore transport and rip current recirculation were observed during the latter part of the dye mixing study (discussed later).

Since the prevailing wind direction in American Samoa is from the east or southeast, it is evident that the surface layer (and floatable) transport in the Tafuna area is generally shoreward. When this layer reaches the breaking wave zone, it becomes, for a time, part of the breaking wave-rip current system, and any floating materials would tend to accumulate along the shoreline and influence the shallow reef areas. Settleable materials discharged from an outfall would move with the reversing longshore current and settle out and accumulate in the deeper nearshore reef areas. Only the materials that move with the water and neither settle nor float would be transported away from the area to be dispersed in the open ocean.

Mixing measurements were conducted in the vicinity of the Tafuna outfall by using timed vertical photographs of a spreading dye patch. The results of these observations were calculated according to the technique described in the methodology chapter. The results are shown on Figure V-9. These data indicate that there is good mixing in the nearshore area at Tafuna but that the dispersion coefficient does not increase with scale quite as fast as theoretically predicted for an open ocean with no restriction on eddy size. For such a condition, the dispersion coefficient would increase proportionally to the scale to the 4/3 power.

Water quality measurements were made in the Tafuna nearshore area on four occasions, at three stations (Figure V-10), and generally at two depths. All of the results are included in the appendix, while a statistical summary is given in Table V-1. These data show clean water conditions that do not markedly differ from open ocean water quality (discussed later in this chapter). It might be noted that there may be some question about the validity of the NO_3 plus NO_2 nitrogen levels, which exhibited

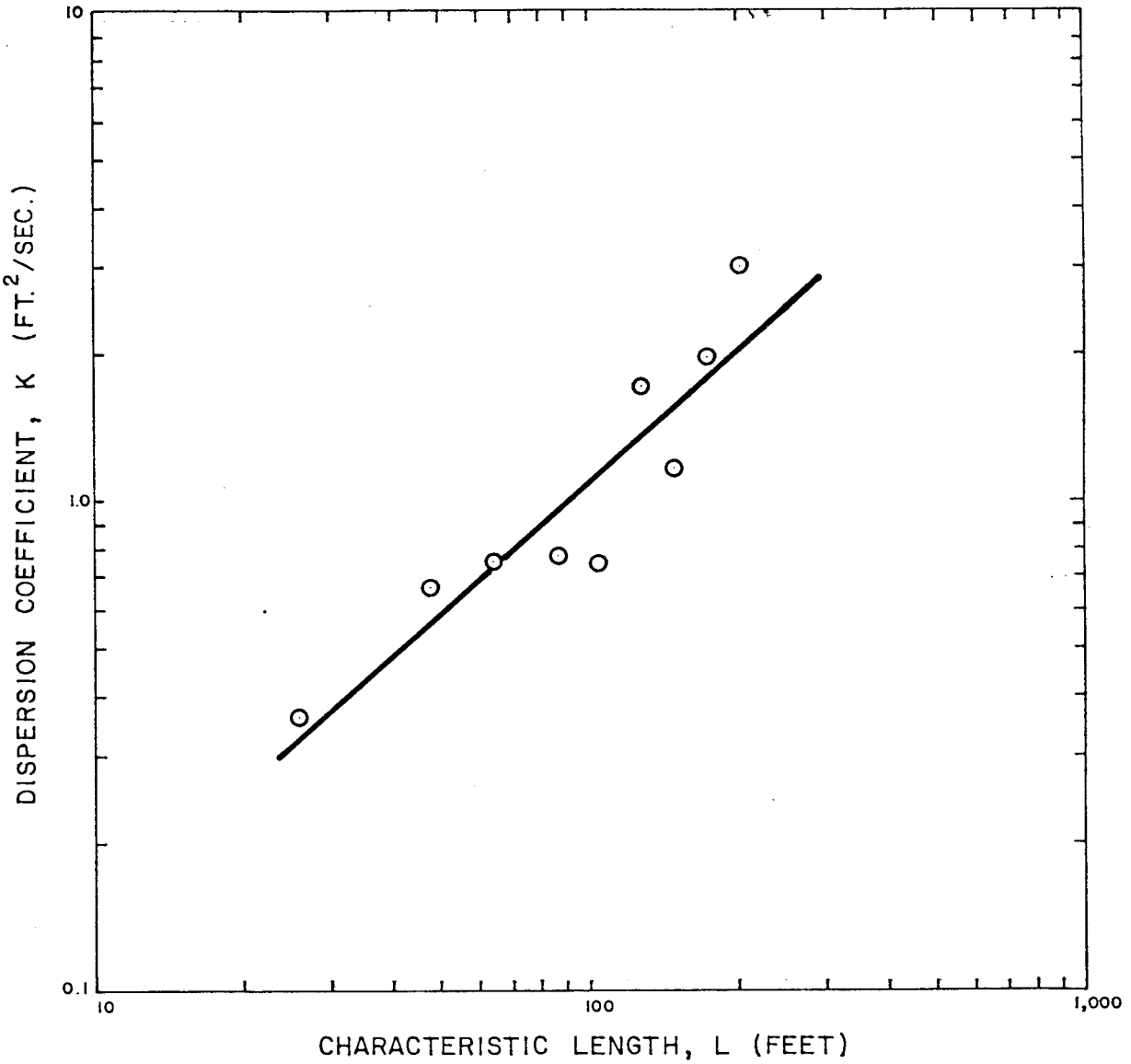
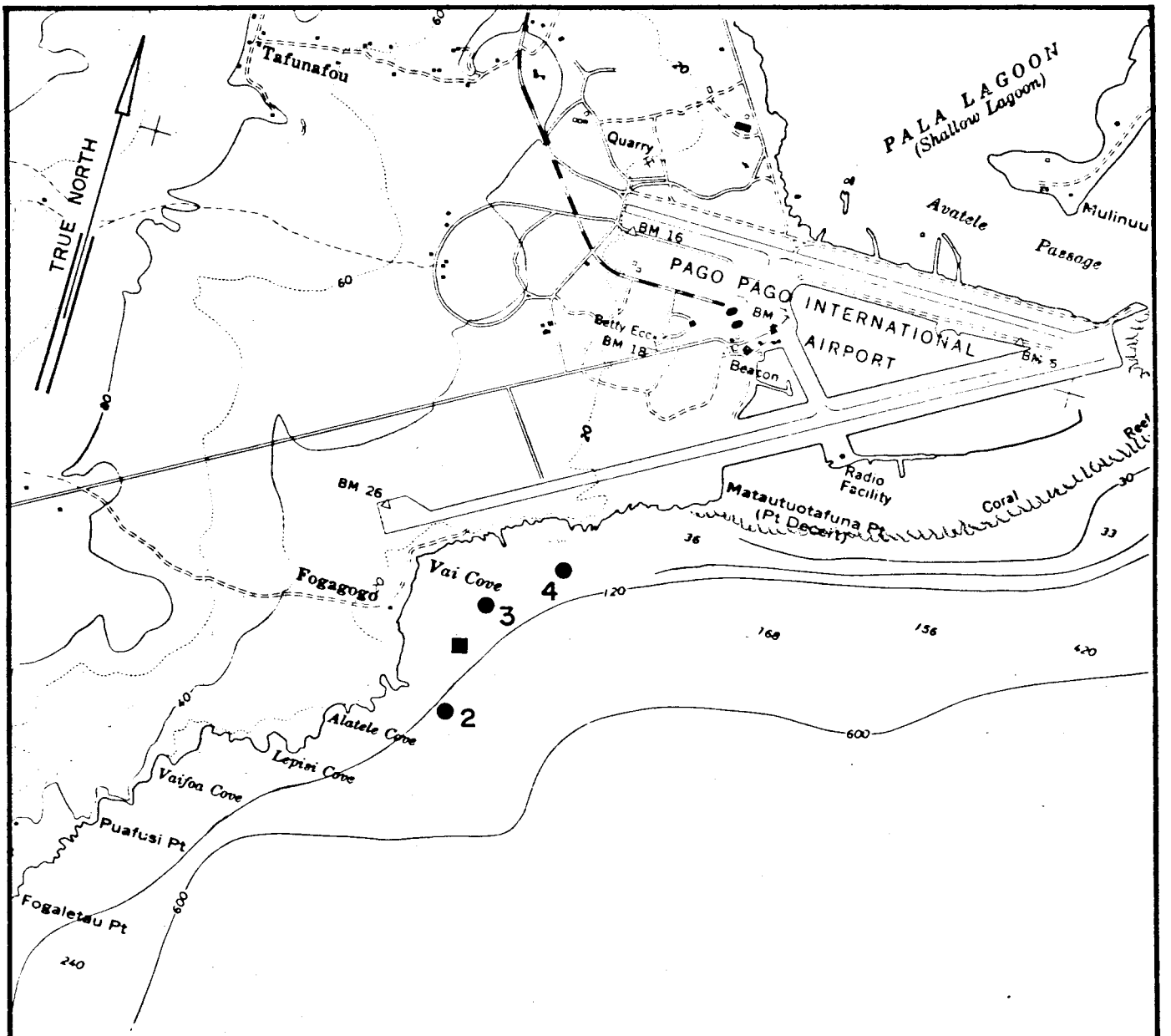


FIGURE V-9

DISPERSION COEFFICIENT VS. CHARACTERISTIC LENGTH FOR THE TAFUNA OUTFALL AREA



LEGEND

● WATER SAMPLING STATION

■ CURRENT METER STATION

1000 0 1000

SCALE IN FEET

FIGURE V-10

TAFUNA WATER SAMPLING AND CURRENT METER STATION LOCATIONS

TABLE V-1

STATISTICAL SUMMARY OF OPEN COASTAL NEARSHORE STATIONS

Parameter (Units)	Depth (feet)	Number of Points	Mean	Standard Deviation	Median	Geometric Mean	Geometric Standard Deviation
Fecal Coliform (#/100 ml)	3	9	<1	0.2	<1	<1	1.36
pH	3	12	8.27	0.056	8.27	8.27	1.01
	60	12	8.27	0.058	8.28	8.27	1.01
Dissolved Oxygen (mg/l)	3	12	6.22	0.154	6.25	6.21	1.31
	50	12	5.99	0.146	5.95	5.99	1.28
Turbidity (NTU)	3	12	0.2	0.058	0.18	0.193	1.31
	60	12	0.179	0.046	0.175	0.174	1.28
Suspended Solids (mg/l)	3	9	1.64	0.905	2	1.28	2.42
	60	9	1.86	1.26	2.1	1.48	2.15
Irradiance (ft)	-	4	153	19	145	152	1.13
Total Kjeldahl Nitrogen (ug/l-N)	3	9	101	21.0	107	99.4	1.23
	60	9	95	30.5	100	87.9	1.62
Nitrate + Nitrite (ug/l-N)	3	12	46.9	33.1	39.2	36.3	2.24
	60	12	35.7	32.9	26.5	24.0	2.74
Total Phosphorus (ug/l-P)	3	12	11.5	8.47	7.45	8.67	2.37
	60	12	6.54	3.26	5.8	5.57	1.96
Chlorophyll-a (ug/l)	3	12	0.277	0.225	0.215	0.185	2.94
	60	12	0.233	0.153	0.177	0.190	1.98

significantly higher levels in July than in February. Perhaps some unknown error in sample preservation occurred for the July samples.

The nearshore waters at Tafuna show no evidence of any significant or consistent stratification down to at least 100 feet. The waters are nutrient poor and, consequently, low in chlorophyll-a. The photic zone and accompanying expected coral depth are down to around 150 feet. At the time of this study, however, diver observations showed that the coral community along this shoreline had been recently severely damaged by crown-of-thorns starfish predation. If experience elsewhere is a valid guide, it will be a few years before the coral community will recover, provided no significant additional stress occurs.

DUMP SITE NO. 1

Partly as a result of a field trip in February 1979 by representatives of the Environmental Quality Commission, Starkist Foods, Marine Resources, Public Works Department, EPA, and M&E Pacific, Dump Site No. 1 was selected as a primary altenative site to be evaluated if ocean disposal of cannery sludge is considered. The factors that were taken into account in making this selection included:

1. The location of the predominant shipping lanes
2. The distance from shallow benthic communities such as Taema Bank and the Tutuila nearshore area
3. The good open ocean mixing and transport conditions and great depth
4. The relatively short distance from the canneries

A second possible open ocean site outside the shipping lanes, Dump Site No. 2, was considered but was rejected because it was closer to Taema Bank and did not offer any advantages over Dump Site No. 1.

The transport characteristics at Dump Site No. 1 were measured on two separate days during flood and ebb tide by the use of drogues. No in situ current meter installation was made because of the great depth. The drogue vectors are given on Figures V-11 and V-12 along with the predicted

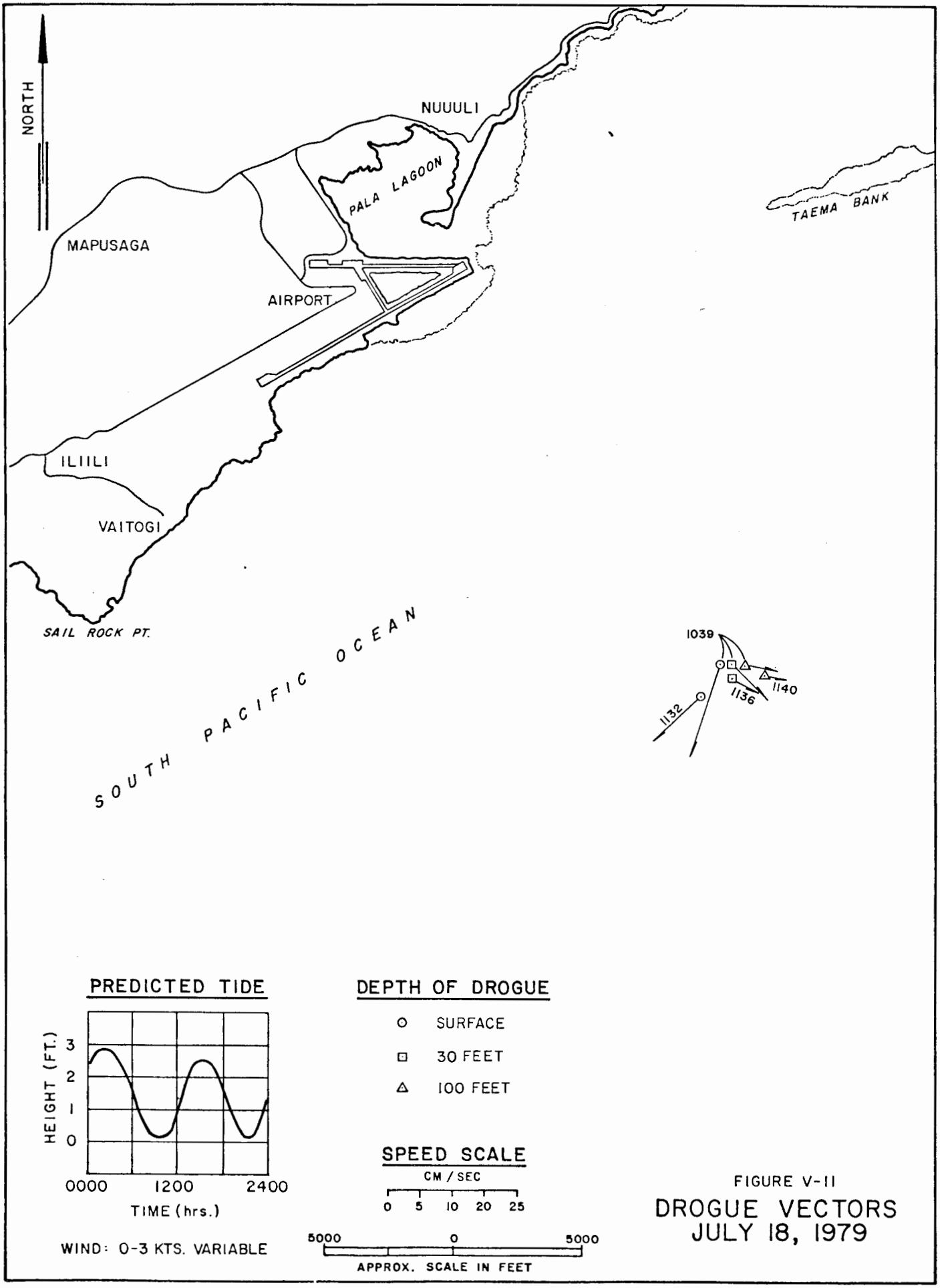


FIGURE V-11

DROGUE VECTORS
JULY 18, 1979

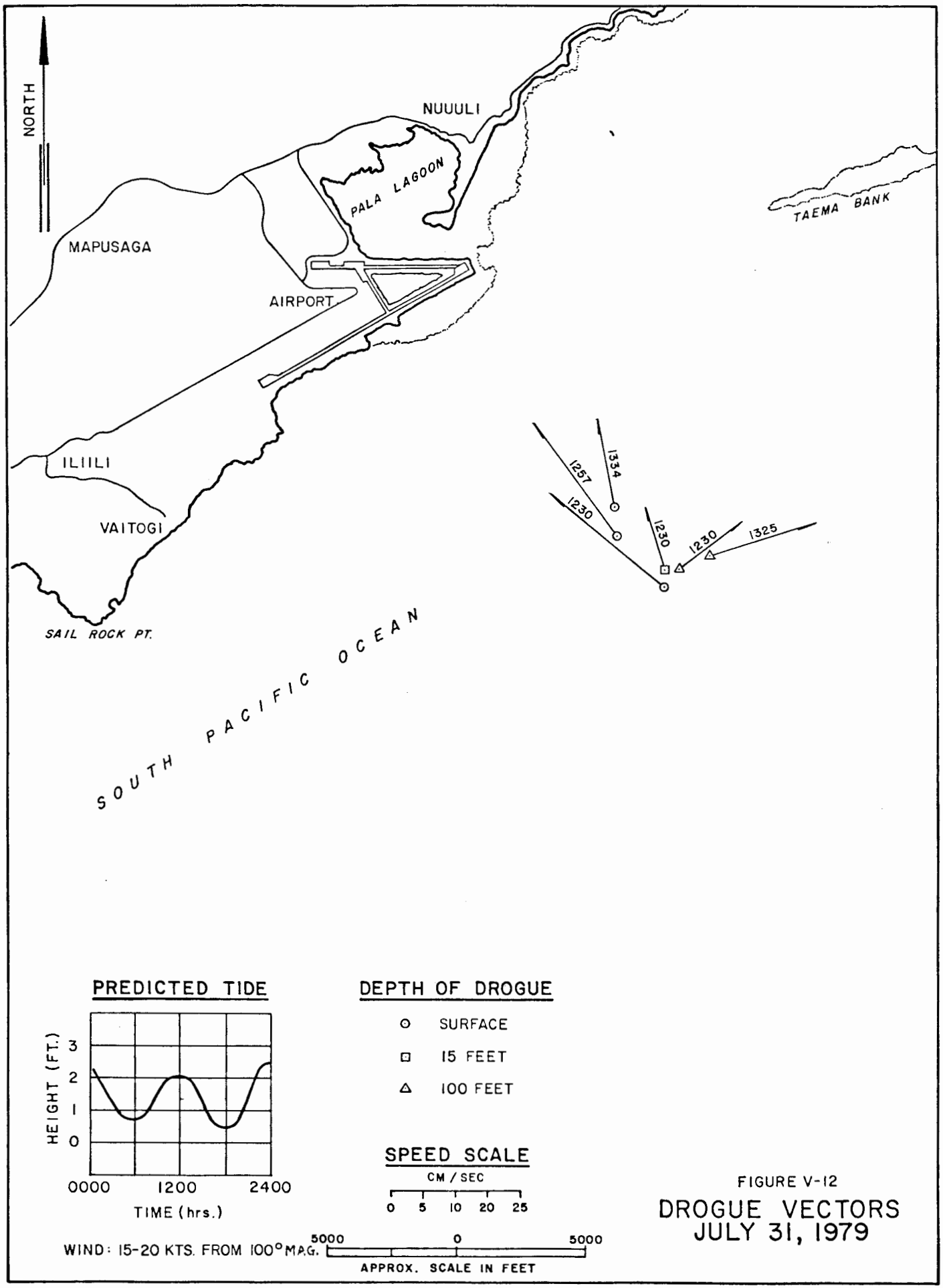


FIGURE V-12

DROGUE VECTORS
JULY 31, 1979

tidal pattern and measured wind conditions. For both days, seas were 10-foot swells from east by southeast, an average condition for this area.

As expected, this area is too far ofshore and too deep to show any observable influence by the tide on the current pattern. The subsurface flow as measured by the 100-foot drogue was consistently toward the east. The surface flow exhibited significant wind influence. Under light and variable wind, the surface flow was toward the south by southwest, while during moderate tradewind conditions the surface flow tended to rotate clockwise toward north by northwest and decrease somewhat in speed in the directon of the shoreline. The intermediate depth drogues at 15 feet and 30 feet had directions intermediate between the surface and 100-foot drogues but with speeds slower than either. Evidently, the 15 to 30-foot depth represents the area of interference between the wind-driven surface layer and the predominant open ocean currents. The interference effect between subsurface and surface flow as well as the restrictive effect of the shoreline and especially an embayment on the current speed are illustrated on Figure V-13.

It might be noted that the easterly setting of the subsurface current in the Dump Site No. 1 area was not as had been predicted on the basis of overall South Pacific circulation. The results of direct measurements, however, have to take precedence over predictions without measurements.

It is possible that there is a very large eddy south of Tutuila of the same type that has been verified at numerous locations in the North Atlantic by intensive investigation (Hartline, 1979). For the purposes of this study, it is sufficient to note that the subsurface current at the depth that might impinge on the coral community of Taema Bank or nearshore Tutuila has a direction that is offshore toward yet deeper waters.

The current structure of deeper areas is unknown but has little direct relevance since there are no areas of upwelling from these depths around Tutuila. Consequently, it can be concluded that there is evidence that the discharge at Dump Site No. 1 of material that sinks would be a disposal method that would not impinge on the coral community or the photic zone.

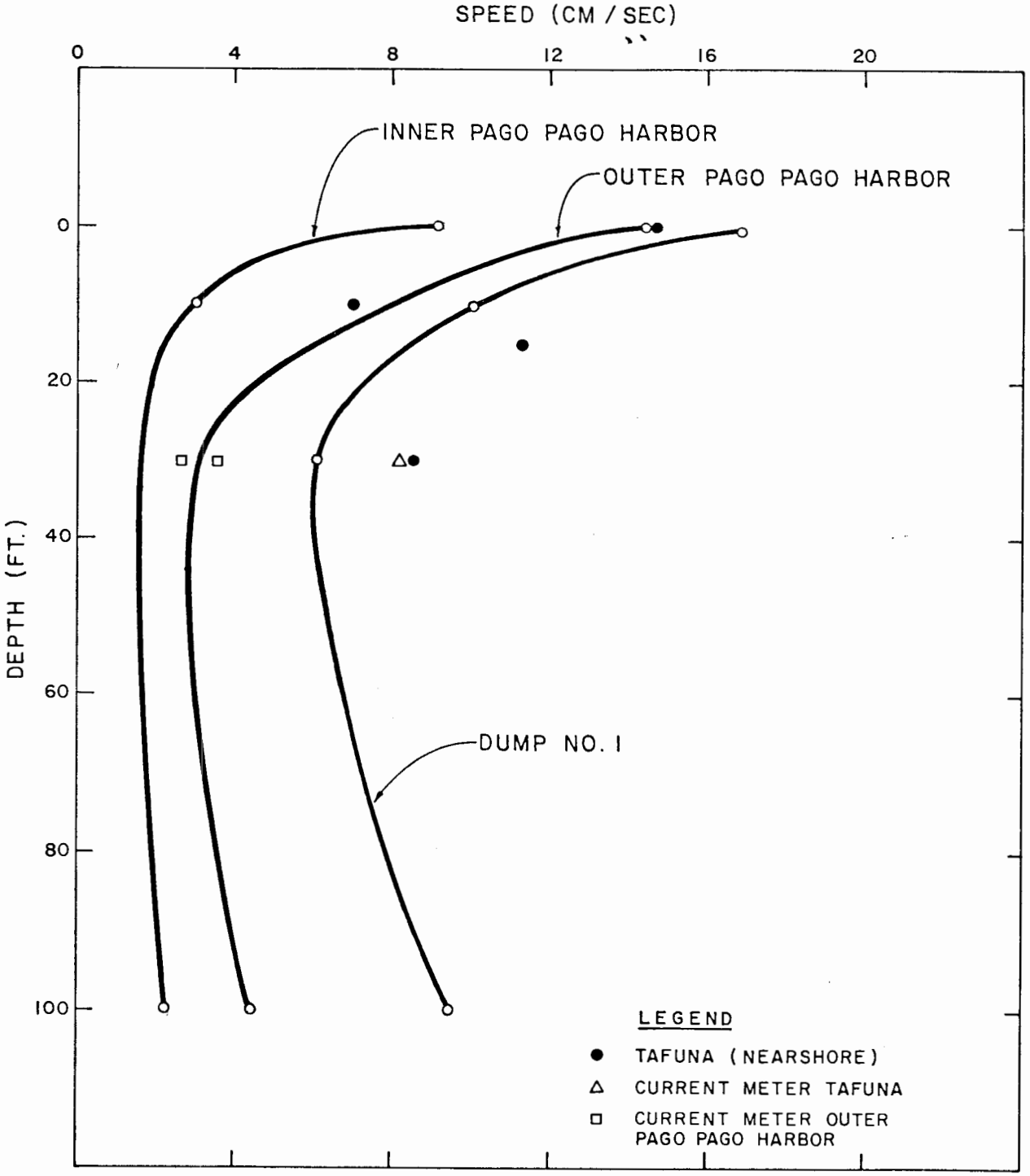


FIGURE V-13

AVERAGE CURRENT SPEED VARIATION WITH DEPTH AND LOCATION

The possible effects of a discharge at Dump Site No. 1 would be from floatable material and from the oxygen demand of the sinking materials. As discussed later, these potential difficulties can be resolved by minimizing floatables by chemically tying up the grease with alum and discharging some distance below the surface and by minimizing the effect of the oxygen demand by good dilution.

Water quality measurements at Dump Site No. 1 showed no significant or persistent evidence of stratification to at least 100 feet and probably to 300 feet. The water quality characteristics did not differ discernibly from the other ocean stations as measured during February and July during the study for the Corps of Engineers. Consequently, all of the ocean water quality data were grouped and statistically analyzed to give a time and space averaged description of ocean water around American Samoa. In addition to the ocean stations shown on Figure V-14, one station off Tau and another off Ofu were included in the data base.

The statistical summary of the ocean water quality data is given in Table V-2. These data indicate a nutrient poor, clear water, low in chlorophyll-a, with a photic zone down to about 170 feet. The variability of the parameters is given by the geometric standard deviation and is illustrated for turbidity, suspended solids, TKN, TP, and chlorophyll-a on Figures V-15 through V-19 respectively. These cumulative distributions show that the variations of these parameters can be confidently described by log-normal statistics. Again, it should be mentioned that there is some question regarding the nitrate plus nitrite data because of the large difference between the February and July results.

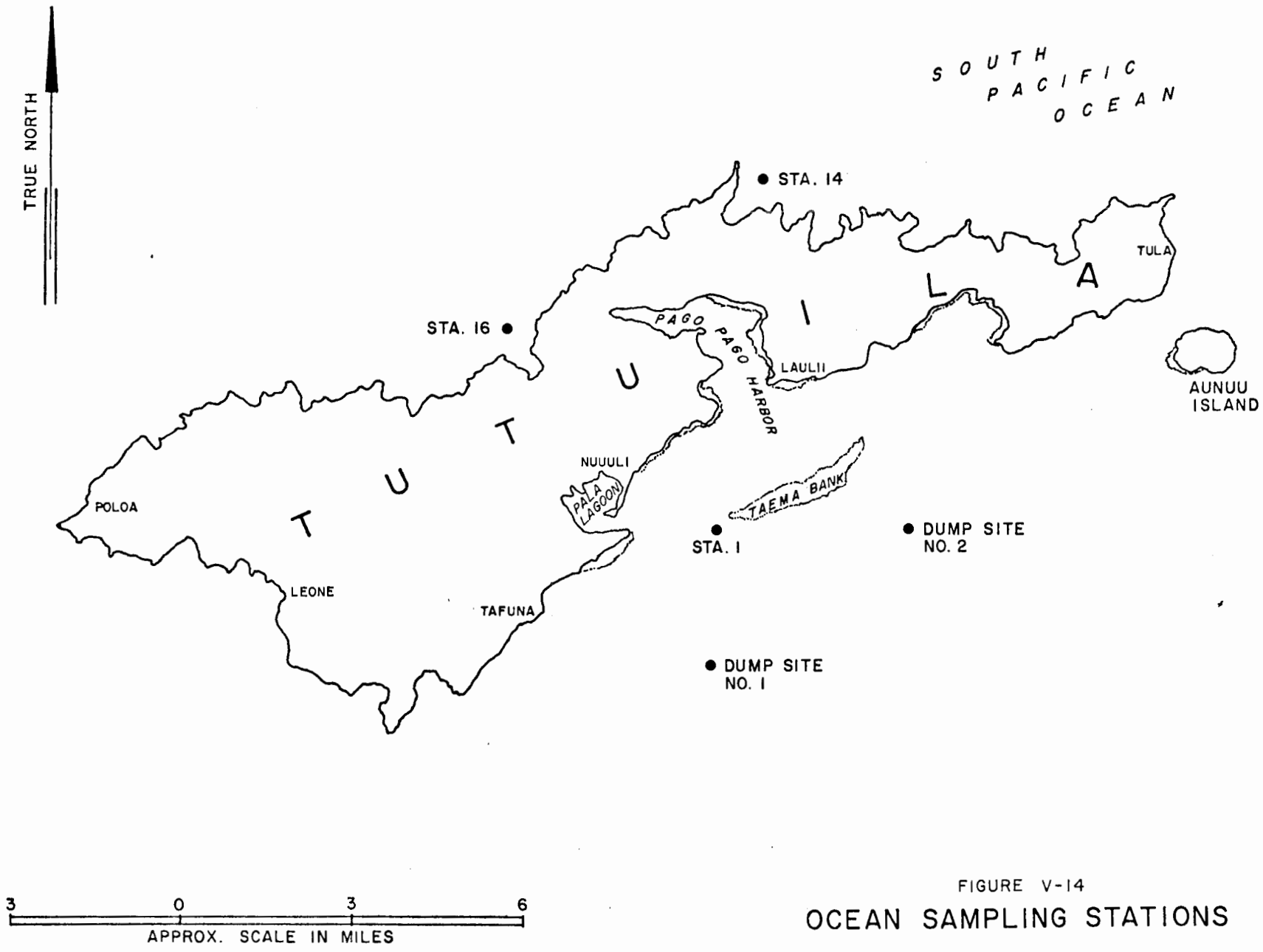


FIGURE V-14

OCEAN SAMPLING STATIONS

TABLE V-2

STATISTICAL SUMMARY OF OCEAN STATIONS

Parameter (Units)	Depth (feet)	Number of Points	Mean	Standard Deviation	Median	Geometric Mean	Geometric
Fecal Coliform (#/100 ml)	3	9	<1	0	<1	<1	1.00
pH	3	16	8.26	0.057	8.30	8.26	1.01
	60	16	8.26	0.059	8.28	8.26	1.01
Dissolved Oxygen (mg/l)	3	16	6.11	0.171	6.10	6.11	1.03
	50	16	5.98	0.163	6.00	5.98	1.03
Turbidity (NTU)	3	16	0.182	0.046	0.18	0.176	1.33
	60	16	0.199	0.092	0.17	0.185	1.47
Suspended Solids (mg/l)	3	11	1.51	0.485	1.40	1.44	1.37
	60	11	1.28	0.549	1.33	1.16	1.65
Irradiance (ft)	-	11	168	15	170	167	1.10
Total Kjedahl Nitrogen (ug/l-N)	3	17	103	51.6	87	92.7	1.59
	60	18	106	32.3	103	101	1.34
Nitrate & Nitrite (ug/l-N)	3	18	18.1	19.9	14.3	7.75	6.35
	60	18	15.6	16.8	11.1	6.38	6.88
Total Phosphorus (ug/l-P)	3	17	12.8	9.69	12	8.13	3.18
	60	17	11.2	6.18	9.9	9.45	1.91
Chlorophyll-a (ug/l)	3	14	0.211	0.154	0.203	0.163	2.16
	60	15	0.174	0.103	0.146	0.146	1.94

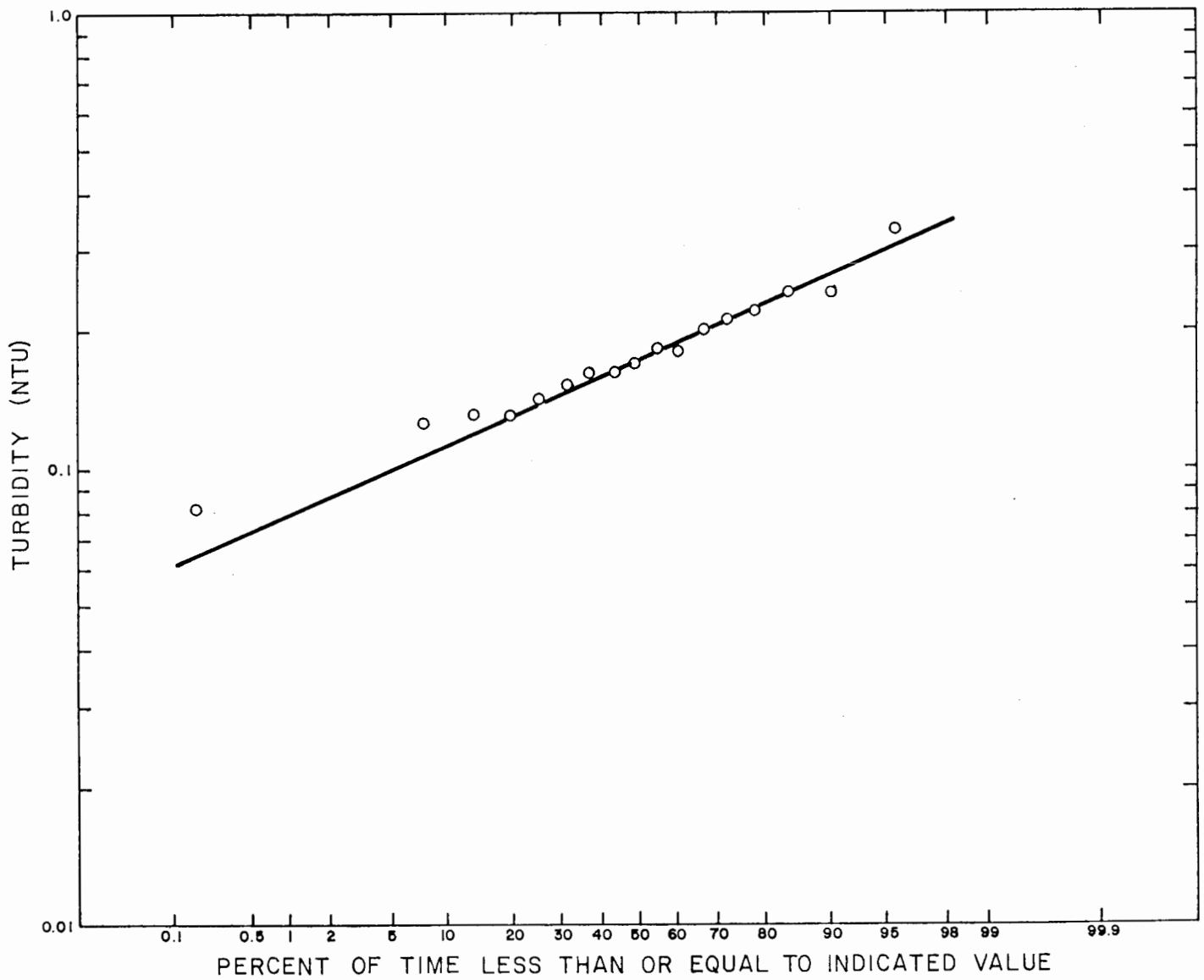


FIGURE V-15

TURBIDITY CUMULATIVE DISTRIBUTION FOR OCEAN STATIONS

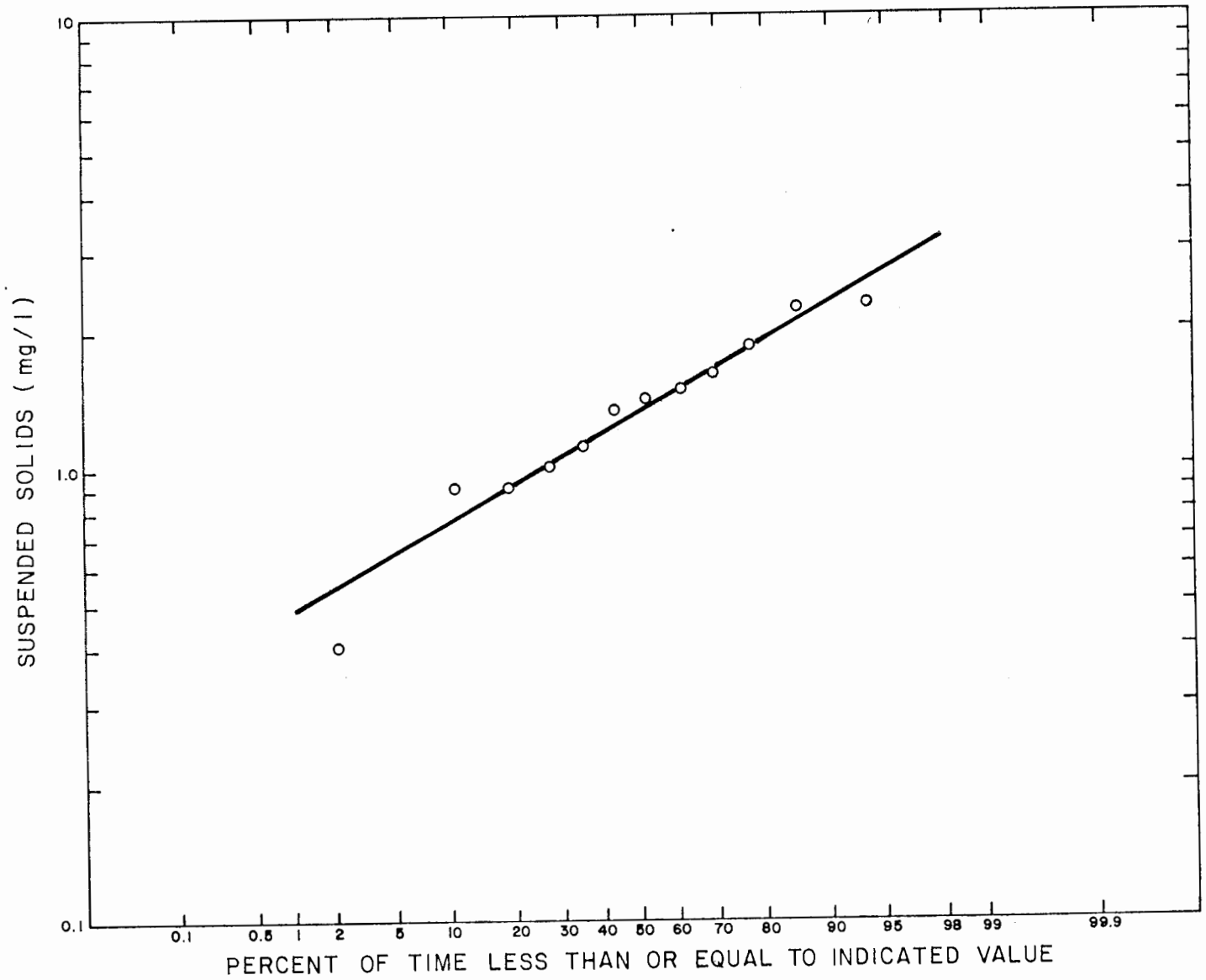


FIGURE V-16

SUSPENDED SOLIDS CUMULATIVE DISTRIBUTION FOR OCEAN STATIONS

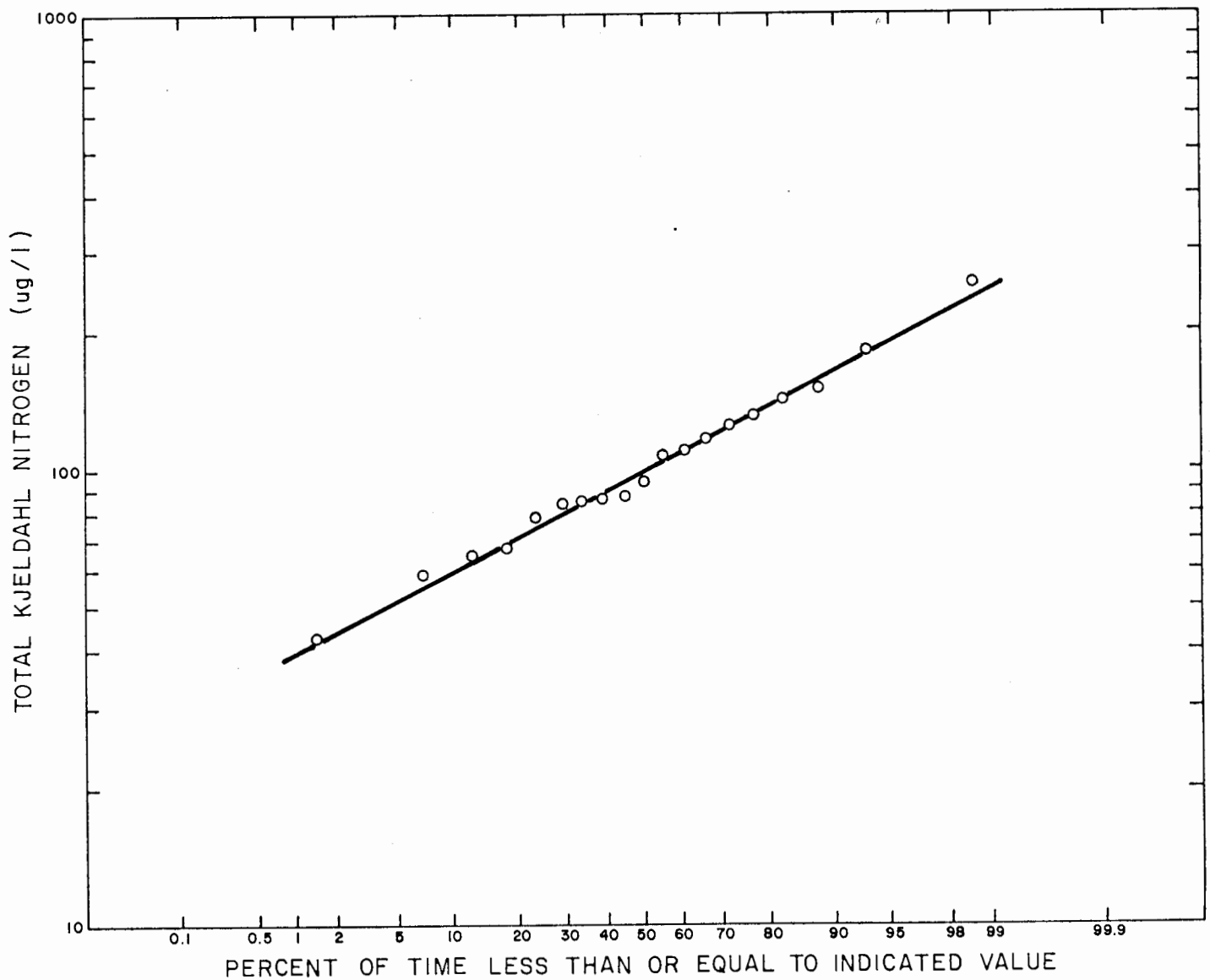


FIGURE V-17

TOTAL KJELDAHL NITROGEN CUMULATIVE DISTRIBUTION FOR OCEAN STATIONS

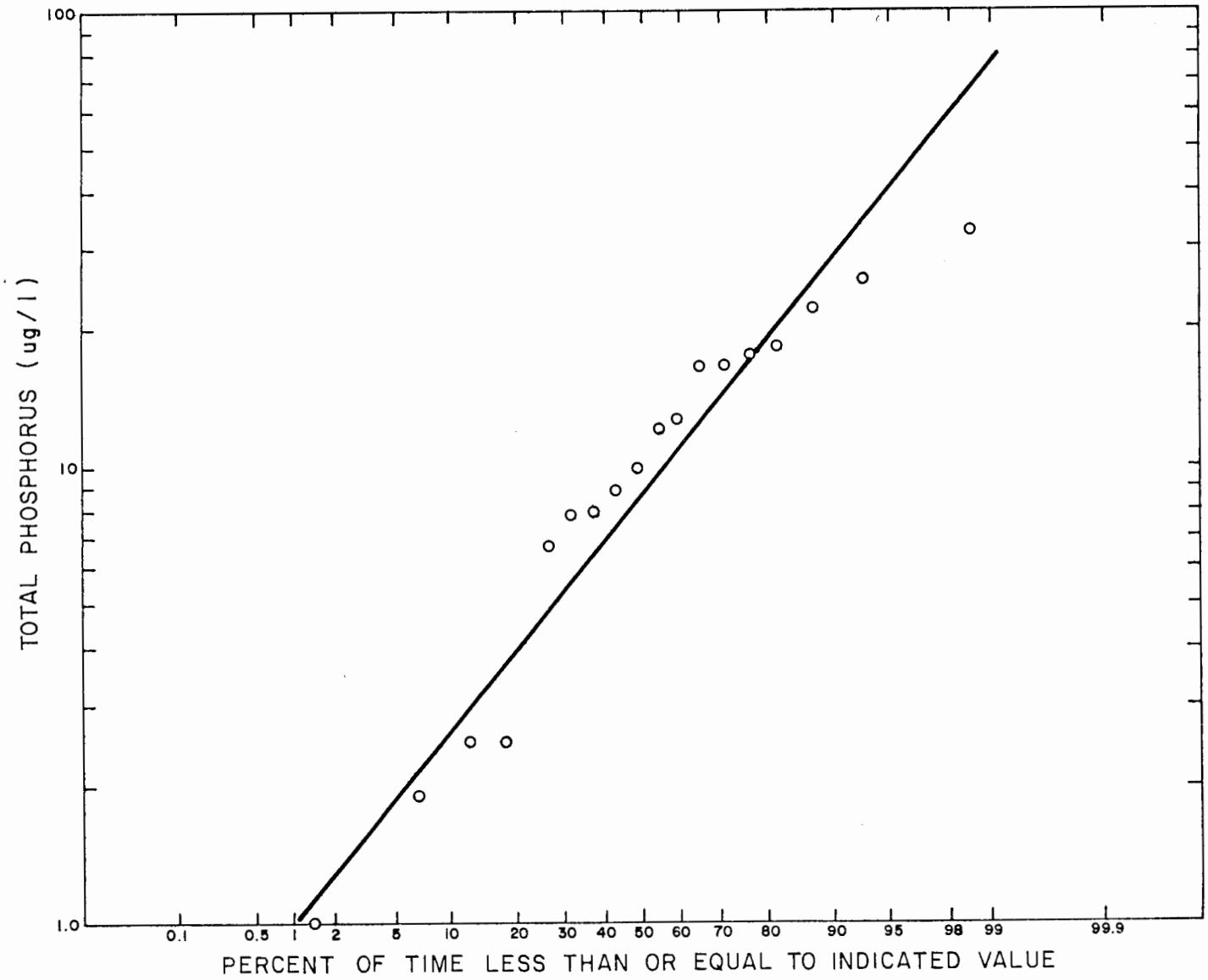


FIGURE V-18

TOTAL PHOSPHORUS CUMULATIVE DISTRIBUTION FOR OCEAN STATIONS

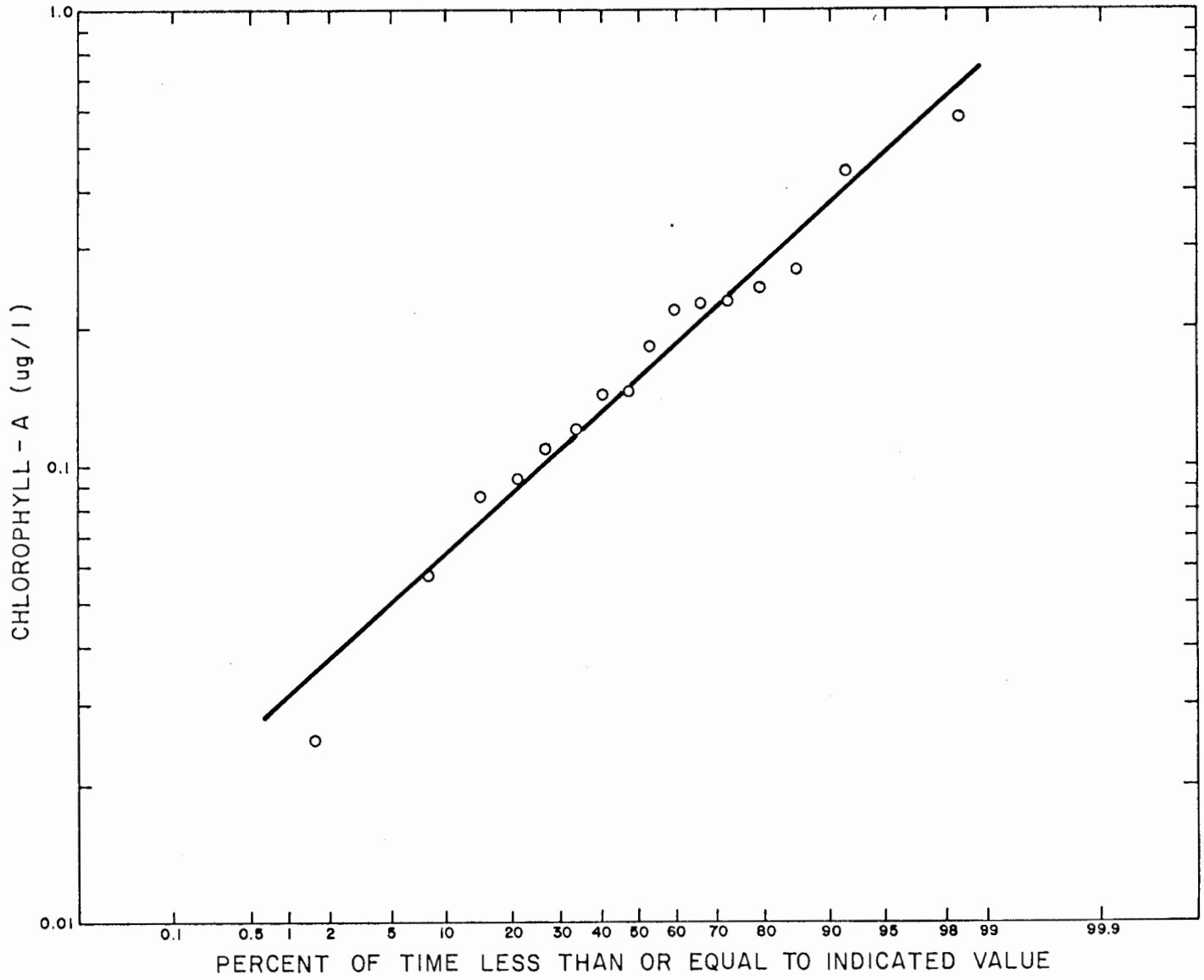


FIGURE V-19

CHLOROPHYLL-A CUMULATIVE DISTRIBUTION FOR OCEAN STATIONS

CHAPTER VI

EVALUATION OF POSSIBLE IMPACTS

Except for the addition of fresh water and nontoxic quantities of alum, NaOH, and polyelectrolytes, the origin of the sludge is the ocean in the vicinity of American Samoa. Because of the export of canned fish and other products, the effect of the fishing and canning operations is a net decrease in the nutrient content of the already nutrient poor waters around American Samoa. Similarly, these operations result in a net decrease in the amounts of metals and pesticides and other materials that may be contained in the fish caught. Considering the relative quantities of these materials in the surrounding ocean and in the fish caught, it is not likely that the net decrease is significant or even measurable; however, these considerations do show that the materials in the sludge are not alien to the ocean and, in fact, constitute only a small fraction of what was removed with the fish.

The potential difficulties with returning the sludge to the ocean are all related to the possibility of localized, long-term, high concentrations of materials in the water, on the surface, along the shoreline, or on the bottom. The potential effects are both concentration and time dependent. Consequently, alleviation of detrimental effects involves dispersion and transport as well as avoidance of concentrating areas.

The potential difficulties are clearly illustrated by considering the effects on inner Pago Pago Harbor when all the materials in the sludge were discharged into this concentrating area prior to the installation of the D.A.F. plants. Low dissolved oxygen, habitat change due to substrate smothering, shoreline grease collection, water column eutrophication, and generally aesthetically unpleasant conditions resulted. These effects are related to long-term, localized, high concentrations of oxygen demanding material, settleable solids, floatables, or nutrients. They are not indicative of direct toxic effects.

Two types of tests were conducted to evaluate and quantify the possible effects of ocean disposal of the cannery sludge. The first was a test release of sludge to determine the amount and character of floatables, the dispersion characteristics and the settling rate of the settleables. The second was a bioassay to measure the time-related response of

the predominant group of organisms at the disposal site, the plankton, to the most significant character of the sludge, the high concentration of organics.

TEST DISCHARGE RESULTS

Separate test discharges each of 30 gallons of Starkist and Van Camp sludges were conducted at Dump Site No. 1 under typical wind, sea, and current conditions. In order to facilitate observation and simulate worst case conditions, the releases were each made to the surface in a single batch with no artificial mixing. The two tests yielded essentially the same results.

Within two minutes after discharge, a small amount (estimated at about 100 ml) of floating "scum" separated from the cloudy sea water-sludge mixture and moved directly with the wind away from the initial discharge area. After some search in the downwind direction, this material could still be located, although somewhat dispersed, a half hour later.

Almost all of the remainder of the material mixed very readily with the sea water and dispersed horizontally in a manner similar to that observed with dye. The initial bubble structure of the sludge, which gave it its low bulk specific gravity, broke down almost immediately and the diluted sludge began to sink. Fifteen minutes after release, diver observations showed that the bottom of the expanding sludge "cloud" was at a depth of 40 feet, while the horizontal diameter was an estimated 30 to 35 feet. These observations would indicate an average initial sinking rate of about 40 cm per minute and an average dilution of around 9,000:1 within 15 minutes. Similar dilution rates have been observed with dye in open coastal areas.

Dissolved oxygen measurements made 15 to 20 minutes after release showed no discernible difference inside and outside the sludge "cloud"; both areas had DO concentrations of 6.3 mg/l.

The current pattern became visible as the diluting "cloud" sank downward. The portion near the surface moved downwind while the portion below 20 to 30 feet moved with the predominant current toward the east.

Around 30 to 45 minutes after the initial release the cloud had dispersed and moved downward to such an extent that it could no longer be definitely located. However, a readily discernible slick formed on the surface in a long narrow band extending downwind from the initial release area. After around three hours the slick was still visible but had spread out to the point where it no longer formed a contiguous pattern but rather consisted of a few streaks. It is expected that subsurface release at depths of fifty feet or more would significantly decrease both the scum and slick formation.

BIOASSAY

Possible effects of various concentrations of sludge on the short term photosynthesis and respiration rates of the plankton community were measured by means of changes in the dissolved oxygen (DO) concentration during three hours or less of exposure time. As noted in the methodology chapter, the plankton community in the surface waters of outer Pago Pago Harbor was selected as bioassay subject rather than the much more dilute open ocean community. The geometric mean chlorophyll-a concentration of the open ocean, 0.16 mg/l as well as the geometric mean of suspended solids of 1.3 mg/l indicate a community too dilute to respond measureably. The outer harbor plankton community has a higher concentration, as indicated by a geometric mean chlorophyll-a level of 1.80 mg/l, and would therefore be more likely to exhibit a measurable response.

It should be noted, however, that the addition of the biologically active sludge, with a solids content in the vicinity of 15 percent and a BOD_5 greater than 140,000 mg/l, would be expected to mask any planktonic response at low dilution factors with its own oxygen demand. Similarly, the high oxygen demand would mask any possible direct toxic effects that might be measured by acute fish or other macroorganism bioassays at relatively high sludge concentrations. If such bioassays are performed with constant sludge concentrations low enough to be able to alleviate the DO problem with a reasonable amount of aeration (e.g., 10,000:1) then the concentrations of the materials that might contribute to an acute response (such as MBAS, mercury, cadmium, ammonia or DDT) would all be at too low

concentrations to affect the fish. Consequently, the water column biological effects question related to the cannery sludge reduces to one of determining the time related dilution factor which would accommodate the oxygen demand. If that factor is met any lesser toxic effect will also be alleviated.

It might also be noted that, outside of the areas of a too low DO concentration, fish populations have been observed to respond to cannery sludge discharges by increasing in density since the sludge is a food source rather than one of direct toxicity.

The results of the test measurements of oxygen changes with the addition of various percentages of sludge at a constant incubation time are given in Figure VI-1. These results indicate that the DO uptake is linear with the percentage of sludge.

During the performance of these tests it was noted that there was no significant or consistent difference between light and dark bottle results. Evidently the phytoplankton in the surface layer of outer Pago Pago Harbor are not nutrient limited or, more likely, the oxygen demand of the sludge was much more significant at these concentrations than the oxygen production rate of phytoplankton photosynthesis. In any case, stimulation of phytoplankton is a population growth response which requires more time than three hours to become noticeable.

The results in Figure VI-1 show that the differences between the short term oxygen demand of Van Camp and Starkist sludges are not large but that the Van Camp sludge generally exhibited higher oxygen demands. This is in line with the somewhat higher TOC, BOD_5, and suspended solids of the Van Camp sludge.

It is evident from the decreasing oxygen demand shown in Figure VI-1 for the Van Camp data from July 20 through July 23 that there is significant bacteriological degradation of the organic material occurring during storage. The three hour DO demand of 0.1 percent Van Camp sludge decreases from about 4 mg/l with fresh sludge to about 1.7 mg/l with sludge that has been stored for three days. Similarly, it would require about a 3,050:1 dilution within three hours to meet the 80 percent DO saturation limitation

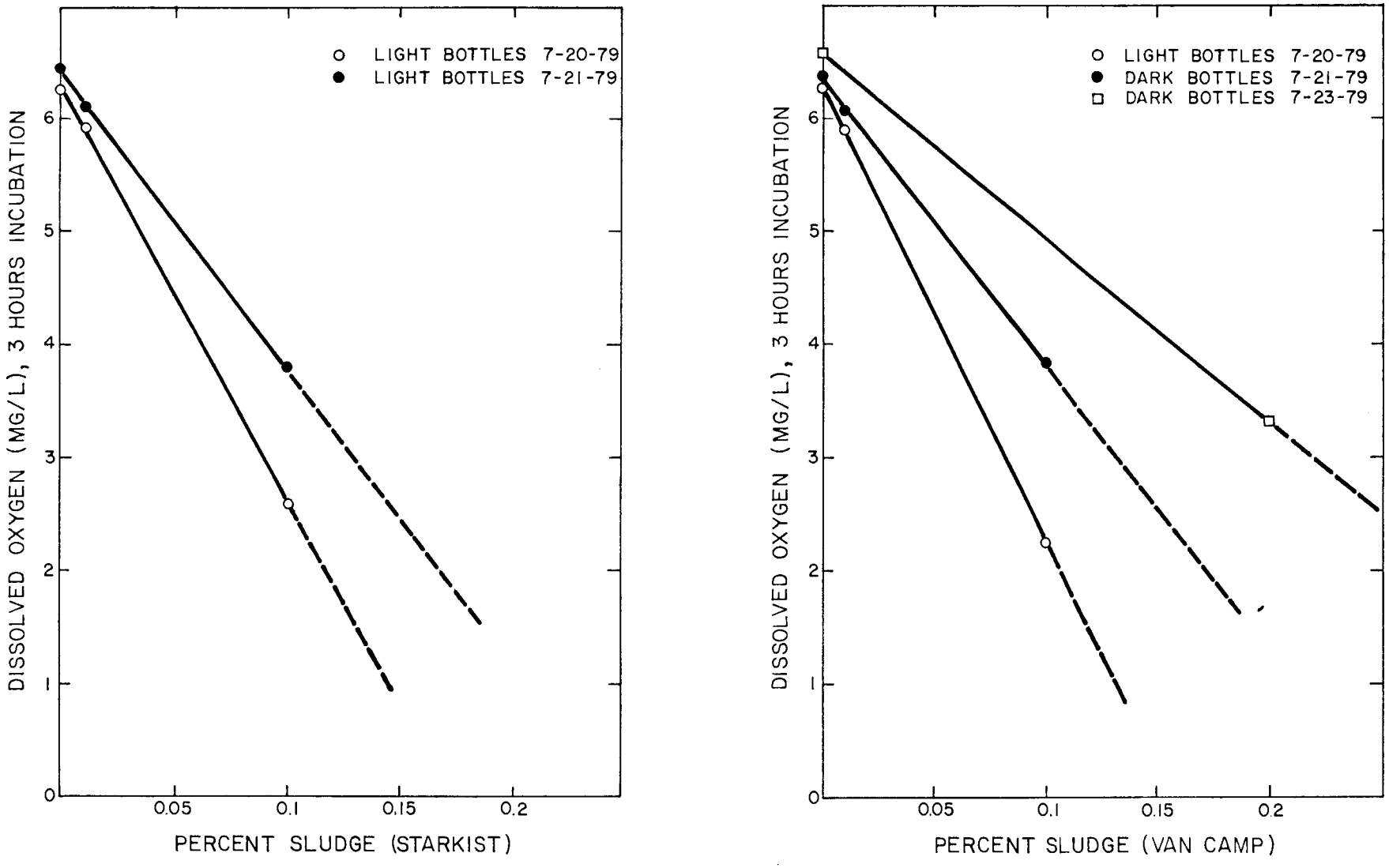


FIGURE VI-1

BIOASSAY RESPONSES TO SLUDGE ADDITIONS

of the standards (about 5 mg/l) while after three days storage it would only require around 1,050:1 dilution. Similar degradation would occur after discharge as aerobic bacteriological action oxidizes the organic content of the sludge.

The rate of change of DO with time is shown in Figure VI-2 for 0.2 percent of three-day old Van Camp sludge. Evidently, there is an initial DO demand which might be chemical in nature. This is followed by a constant rate of DO decline characteristic of biological action. The initial DO demand indicated in Figure VI-2 is about 550 mg/l per liter of sludge. The rate of biological oxygen demand under these conditions appears to be about 385 mg per hour per liter of sludge. Again, it should be noted that such vigorous biological activity is indicative of nontoxic conditions for these organisms. Extrapolating this rate back to the conditions with no storage yields a maximum oxygen demand rate of 1,267 mg per hour per liter of sludge.

In sum, increased sludge concentration and length of time of exposure increases total oxygen demand while the rate of biological oxygen demand decreases with time. These factors can be formulated to calculate the minimum dilution required to meet the DO standard:

$$\text{Dilution} = \frac{550 + (1,267)(t)\ e^{-kt}}{\Delta DO}$$

where: Dilution = dilution required to not exceed ΔDO

ΔDO = reduction in DO that can be tolerated before violating the sandard, in mg/l

t = time after discharge in hours

k = decay rate constant = 0.0167 per hour (from observed storage decay rate)

under the assumption of no initial storage and with ΔDO = 1.3 mg/l the above formulation was used to construct Figure VI-3. This approach is similar to an oxygen sag curve except the maximum oxygen sag is specified and the dilution is calculated. A required dilution of just under 22,000:1 after two and one half days is indicated by this conservative formulation. By achieving this dilution, designed to satisfy oxygen requirements, local biological effects can be minimized and no toxic responses are expected.

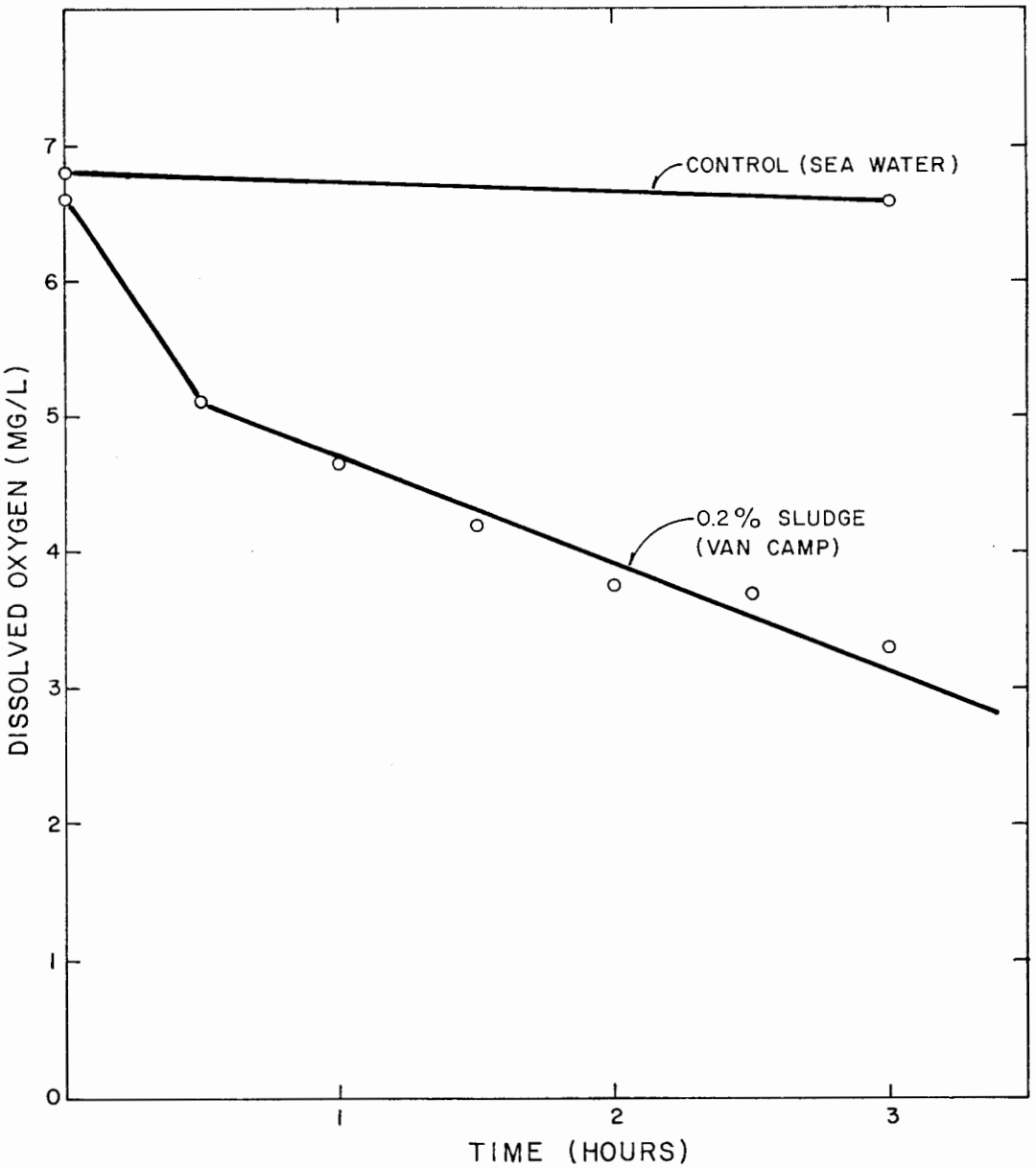


FIGURE VI-2

TIME RELATED DO DEMAND

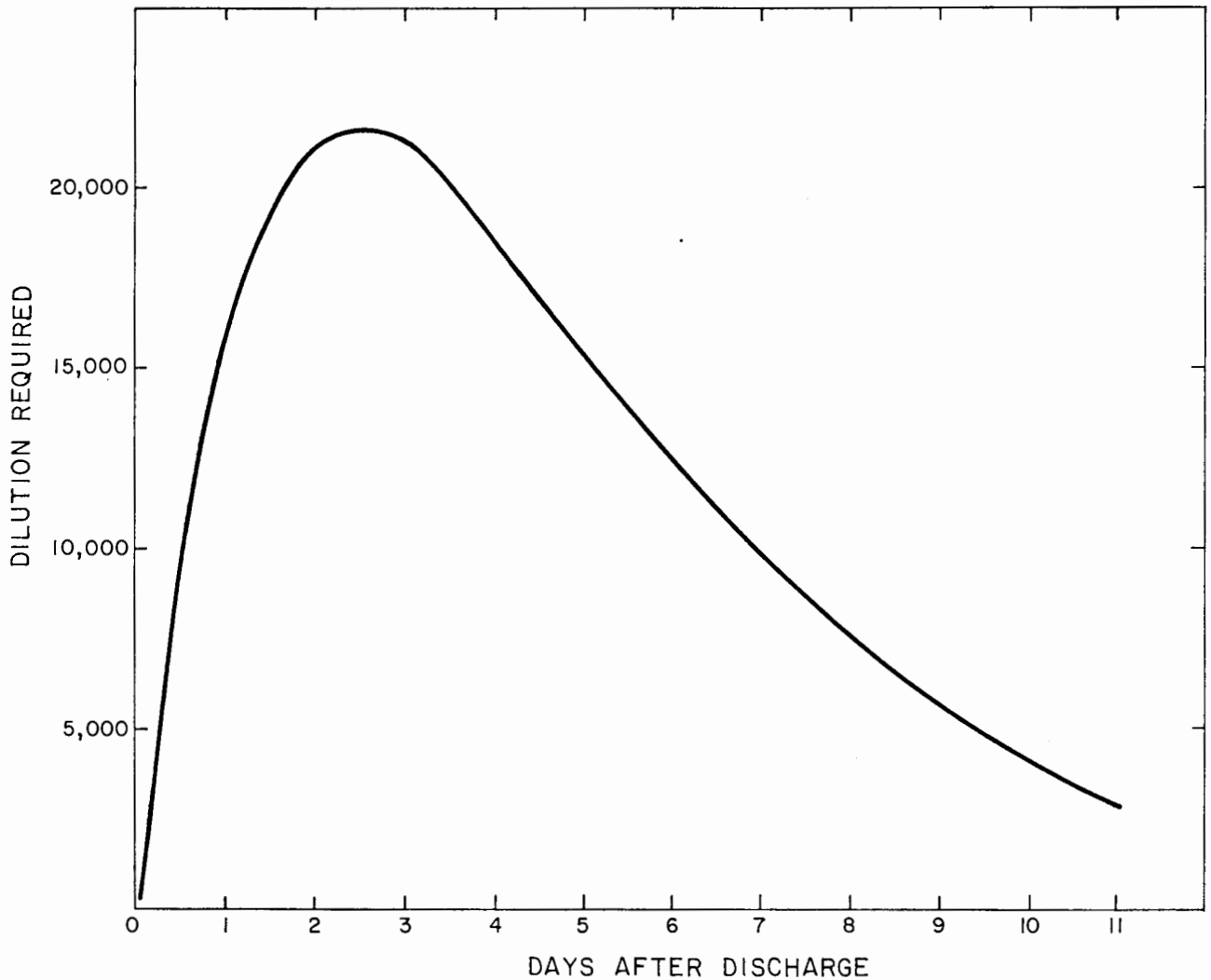


FIGURE VI-3

MINIMUM DILUTION REQUIRED TO MEET DO REQUIREMENTS

POSSIBLE EFFECTS AT DUMP SITE NO. 1

Dump Site No. 1 has open ocean conditions with respect to currents, mixing, depth and water quality. The biological community of importance is the plankton community and the associated pelagic fish population. The potential effects of the discharge of cannery sludge in this area are related to the oxygen demand, nutrient addition, and surface slick formation.

The formation of a surface slick will accompany the discharge of cannery sludge. However, this slick can be minimized by continuing to use alum treatment which ties up the slick forming materials and allows most of them to disperse and sink with the bulk of the sludge. Additionally, the slick can be minimized by discharging the sludge at least 50 feet below the surface at a controlled rate from a moving vessel. Under such discharge conditions the slick forming material would have to travel through the water column from an initially dilute condition and be subject to chemical and bacteriological alteration. The remaining slick would move downwind and may sometimes impinge on the shoreline of Tutuila. However, the distance to the shoreline will allow the biodegradable nature of the material as well as the dispersion characteristics of the wind and wave forces to greatly reduce the quantities and concentrations of the slick forming materials so that no detrimental shoreline accumulation of detrimental biological effects are expected.

The potential effect of nutrient addition at Dump Site No. 1 is not expected to be significant because most of the material being discharged will sink below the photic zone depth of around 170 feet. The strong bond between the aluminum and phosphate indicates that the phosphorus will not be quickly solubilized and will likely sink out of the photic zone. It is expected that some portion of the TKN will remain above the photic depth and may contribute to a slightly enhanced phytoplankton population. This effect, however, is not expected to be significant or even measurable because of the intermittent nature of the discharge over both time and space. Since growth responds to changes in the average condition rather than to isolated peaks no significant growth response is likely.

The effect of the discharge on the local oxygen content can be detrimental if adequate dilution is not achieved. Good initial dilution is the key to the prevention of potential problems since this is the only aspect of the dilution process that is directly under the control of the discharger. Subsequent dispersion in this area is as good as can be expected anywhere but is not enough without good initial dilution. Because most of the material sinks, there is additional dilution potential above that due to eddy dispersion.

The effect of this material on the bottom is expected to be small because of the great depth and the likelyhood that the sinking rate of the material will reduce greatly with the increasing water density at greater depths. It is possible that much of the material will end up, along with much of the other sinking natural organic material, at the minimum oxygen zone in the water column a considerable distance above the bottom.

POSSIBLE EFFECTS AT THE TAFUNA OUTFALL

The alternative of discharging the cannery sludge via the present or possible future Tafuna outfall has the advantages of not being affected by bad weather and of being able to continue using the already existing system of truck transport.

However, there are several significant environmental disadvantages to discharging sludge in the nearshore area. The slick and scum resulting from a discharge this close to shore would not be significantly dispersed or biologically degraded before being transported to the shoreline by the prevailing wind and breaking wave action. This material would likely accumulate and may result in detrimental biological effects and undesirable aesthetic conditions.

Because most of the material to be discharged sinks and because the transport in this area is parallel to the depth contours due to the alternating tide related currents it is likely that much of the material will accumulate on the bottom and detrimentally impact the coral based benthic community in the photic zone. This impact would result both from the organic loading and the change in the character of the substratum.

The third significant environmental disadvantage is related to the large oxygen demand of the sludge and the consequent large dilution requirement. It is very unlikely that this dilution requirement can be achieved even with an optimally designed diffuser system. In conventional municipal wastewater outfall diffuser design most of the initial dilution is achieved through the buoyancy of the plume. The sludge plume would not be particularly buoyant after the breakdwon of the residual DAF bubble matirx. This breakdown was observed to occur very rapidly during the test discharge. If adequate dilution is not achieved then there will be areas along the transport path of the sludge plume with low dissolved oxygen. This would have detrimental effects on both the water column and benthic communities.

CHAPTER VII

RECOMMENDATIONS

On the basis of the evaluation in the previous chapter of the possible environmental impacts at the two ocean disposal areas considered it is recommended that Dump Site No. 1 be chosen as the disposal area for the sludge being generated by the dissolved air flotation treatment processes at the Starkist and Van Camp tuna canneries in American Samoa.

In order to accommodate the maneuvering area necessary to provide the dilution required to meet the dissolved oxygen standard it is recommended that the designated disposal area be at least one nautical mile in diameter centered at 14°22' South latitude and 170°41' West longitude as shown in Figure VII-1.

The recommended disposal method to provide adequate initial dilution, minimize slick and floating scum formation, and achieve dispersal would involve controlled subsurface discharge from a vessel circling within the disposal area. A six-inch diameter flexible line discharging at below 50 feet at a rate of 500 gpm from a vessel moving at 5 knots would achieve an average dilution after about 15 minutes of about 9,000:1 based on the observed rate of dispersion during the test discharge. The subsequent dispersion will be more than adequate to meet the estimated 22,000:1 minimum dilution required two and one half days after discharge. This rate of discharge would require a suction lift sludge pump of around 35 horsepower. The discharge line should be noncollapsable with a control cable running from near the discharge end to a winch forward of where discharge line leaves the vessel. More detailed design and experience will show the best combination of discharge line length, amount of weight, and control cable length to control the discharge depth. It may also be possible to use an upside down "wing", rather than a weight, to help keep the discharge line submerged. The amount of dilution can be controlled by either the vessel speed or the discharge pump rate.

If the vessel has a working capacity of about 50,000 gallons then it will take about 100 minutes to discharge a full load. At the current

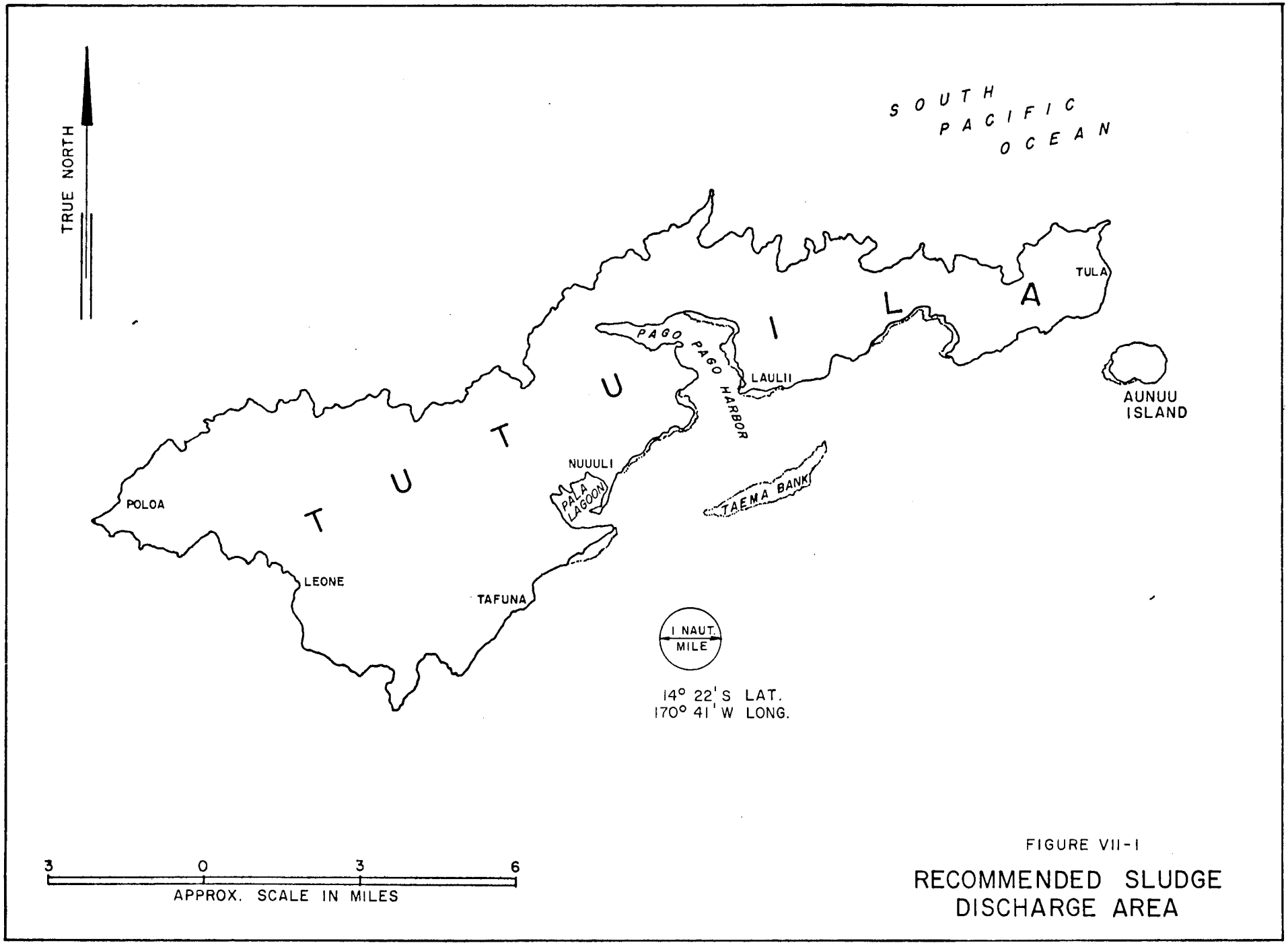


FIGURE VII-1

RECOMMENDED SLUDGE DISCHARGE AREA

production rate this would mean a disposal trip every three days on the average. Experience will show whether additional storage capacity is required to achieve acceptable reliability of the system.

It is recommended that an agreement be reached with the American Samoa government to allow for emergency land disposal of the sludge during periods of unusually long-term adverse weather or other conditions preventing the ocean disposal of the sludge. The exercise of such an option should, of course, be kept to a minimum.

Finally, it is recommended that a monitoring program of the discharge area be instituted to measure dissolved oxygen, turbidity and chlorophyll-a as well as to observe the extent and characteristics of any slick formation resulting from the sludge discharge. If adverse effects are detected these data can be used to beneficially alter the treatment or discharge practices or even relocate the discharge area.

REFERENCES

1. American Public Health Association, Standard Methods for the Examination of Water and Wastes, 14th Edition, 1974.

2. Brooks, N.H., "Diffusion of a Sewage Effluent in an Ocean Current," Proc. 1st Intl. Conf. on Waste Disposal in the Environment, Pergammon Press, 1960.

3. CH_2M Hill, Wastewater Facilities Plan for American Samoa, Volumes I and II, Public Works, American Samoa Government, 1976.

4. Hartline, B.K., "Polymode - Exploring the Undersea Weather," Science, Vol. 205, Aug. 10, 1979.

5. Strickland, J.D.H., and T.R. Parsons, A Manual of Sea Water Analyses, Fisheries Research Board of Canada, 1968.

6. U.S. Army Engineer Division, Baseline Water Quality Survey in American Samoa, 1979 (Draft Report subject to revision).

7. U.S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes, 1974 and 1979.

A P P E N D I X A

TABLE A-1

"WET SEASON" WATER QUALITY SAMPLING RESULTS IN AMERICAN SAMOA

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temperature (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Total Coliform (#/100 ml)	Fecal Coliform (#/100 ml)
2/13/79	1	SUR	50	34.38	28.90	6.1	0.23	8.30	-	< 1	< 1
	(Taema Bank)	5	-	-	-						
		10	20	34.35	-						
		15	-	-	28.64						
		20	10	-	-						
		30	10	-	-						
		40	10	-	-						
		50	5	34.40	28.60	5.8					
		60	5	-	-		0.24	8.30	-		
		70	4	-	-						
		80	4	-	-						
		90	4	-	-						
		100	4	34.40	28.70						
		110	4								
		120	3								
		150	2								
		170	1								
2/13/79	2	SUR	50	34.20	29.20	6.2	0.32	8.30	-	< 1	< 1
	(Tafuna)	10	20	34.30	29.10						
		20	10	34.40	29.00						
		30	10	34.40	28.90						
		40	9	34.40	28.90						
		50	5	34.40	28.80	5.8					
		60	5	34.40	28.80		0.18	8.30			
		70	5	34.40	28.80						
		80	5	34.45	28.75						
		90	-	34.45	28.75						
		100	4	34.50	28.70						
		110	3								
		120	2								
		140	1								

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temperature (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Total Coliform (#/100 ml)	Fecal Coliform (#/100 ml)
2/13/79	3	SUR	50	33.80	29.40	6.4	0.26	8.33	-	<2	<2
	(Tafuna)	5	-	34.00	29.40						
		10	20	34.30	29.10						
		20	20	34.40	28.90						
		30	20	34.40	28.90						
		40	15	34.40	28.90						
		50	15	34.40	28.80	6.0					
		60	10	34.40	28.75		0.22	8.33	-		
		70	10	34.40	28.70						
2/13/79	4	SUR	50	33.80	29.40	6.3	0.27	8.32	-	<2	<2
	(Tafuna)	10	30	34.40	29.00						
		20	30	34.40	20.00						
		30	25	34.40	28.90						
		40	25	34.40	28.90						
		50	15	34.40	28.90	6.0					
		60	15	34.40	28.90		0.29	8.33	-		
2/15/79	14	SUR	50	34.40	29.00	6.3	0.21	8.25	-	4	<1
	(Vatia off-shore)	10	30	34.40	29.00						
		20	30	34.45	29.00						
		30	20	34.45	28.95						
		40	15	34.45	28.90						
		50	15	34.45	28.90	6.1					
		60	5	34.50	28.90		0.17	8.25	-		
		70	5	34.50	28.80						
		80	4	34.50	28.80						
		90	4	34.50	28.80						
		100	4	34.50	28.80						
		110	2								
		120	1.5								
		130	1.5								
		140	1								

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temperature (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Total Coliform (#/100 ml)	Fecal Coliform (#/100 ml)
2/15/79	16	SUR	50	34.50	29.20	6.3	0.18	8.30	-	<1	<1
	(Fagasa	10	30	34.50	29.10						
	Offshore)	20	20	34.60	29.00						
		30	10	34.60	29.00						
		40	10	34.60	28.90						
		50	10	34.60	28.90	6.1					
		60	10	34.60	28.90		0.16	8.30	-		
		70	10	34.60	28.90						
		80	10	34.60	28.80						
		90	9	34.60	28.80						
		100	8	34.60	28.80						
		110	6								
		120	5								
		130	3.5								
		140	3								
		150	2								
		160	2								
		170	2								
		180	1								
2/21/79	14	SUR	-	34.30	28.80	6.2	0.22	8.30	1.07	-	-
	(Vatia	10		34.30	28.80						
	Off Shore)	20		34.35	28.60						
		30		34.40	28.60						
		40		34.45	28.60						
		50		34.45	28.50	6.1					
		60		34.45	28.50		0.33	8.31	1.33		
		70		34.45	28.50						
		80		34.45	28.50						
		90		34.46	28.50						
		100		34.45	28.50						
2/21/79	16	SUR	-	34.40	29.00	6.1	0.22	8.31	1.27	-	-
	(Fagasa	10		34.40	28.90						
	Off Shore)	20		34.50	28.80						
		30		34.50	28.70						
		40		34.50	28.50						
		50		34.50	28.50	6.0					
		60		34.50	28.50		0.47	8.32	1.60		
		70		34.50	28.50						
		80		34.54	28.50						
		90		34.55	28.50						
		100		34.55	28.50						

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temperature (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Total Coliform (#/100 ml)	Fecal Coliform (#/100 ml)
2/22/79	1	SUR	-	34.60	28.80	6.03	0.20	8.29	1.47	-	-
	(Taema Bank)	10		34.60	28.75						
		20		34.65	28.70						
		30		34.65	28.75						
		40		34.65	28.70						
		50		34.65	28.60	6.00					
		60		34.65	28.60		0.15	8.29	1.73		
		70		34.65	28.60						
		80		34.65	28.60						
		90		34.65	28.60						
		100		34.65	28.60						
2/22/79	Dump	SUR	-	34.60	28.70	6.0	0.15	8.31	2.13	-	-
	Site No. 1	10		34.60	28.60						
		20		34.60	28.60						
		30		34.60	28.60						
		40		34.64	28.60						
		50		34.65	28.56	5.9					
		60		34.65	28.55		0.24	8.32	1.87		
		70		34.65	28.50						
		80		34.65	28.50						
		90		34.65	28.50						
		100		34.65	28.50						
2/22/79	Dump	SUR	-	34.50	28.80	6.0	0.17	8.33	2.27	-	-
	Site No. 2	10		34.60	28.80						
		20		34.55	28.70						
		30		34.60	28.70						
		40		34.60	28.65						
		50		34.62	28.60	5.9					
		60		34.64	28.60		0.15	8.32	1.47		
		70		34.64	28.60						
		80		34.65	28.60						
		90		34.65	28.60						
		100		34.65	28.60						

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temperature (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Total Coliform (#/100 ml)	Fecal Coliform (#/100 ml)
2/22/79	4	SUR	-	34.42	28.90	6.1	0.17	8.32	2.00	-	-
	(Tauna)	10		34.46	28.90						
		20		34.46	28.90						
		30		34.50	28.80						
		40		34.50	28.80						
		50		34.50	28.68	5.9	0.21	8.33	2.33	-	-
		60		34.50	28.65						
		70		34.50	28.60						
		80		34.55	28.60						
		90		34.57	28.60						
		100		34.57	28.60						
2/22/79	3	SUR	-	34.40	29.00	6.1	0.15	8.33	2.67	-	-
	(Tafuna)	10		34.38	29.00						
		20		34.45	28.70						
		30		34.45	28.70						
		40		34.48	28.60						
		50		34.52	28.60	5.95					
		60		34.52	28.60		0.16	8.33	2.33		
2/22/79	2	SUR	-	34.40	28.90	5.95	0.19	8.30	2.47	-	-
	(Tafuna)	10		34.50	28.85						
		20		34.54	28.70						
		30		34.60	28.60						
		40		34.60	28.64						
		50		34.60	28.60	5.90	0.17	8.33	2.60		
		60		34.60	28.60						
		70		34.60	28.60						
		80		34.60	28.60						
		90		34.60	28.60						
		100		34.60	28.60						

TABLE A-2

"DRY SEASON" WATER QUALITY SAMPLING RESULTS IN AMERICAN SAMOA

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temp. (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Fecal Coliform (#/100 ml)
7/3/79	Dump Site No. 1	Sur	50	33.37	28.10	5.75	0.16	8.19	2.2	1
		5	40	33.42	28.10					
		10	30	33.42	28.10					
		20	30	33.42	28.10					
		30	30	33.42	28.10					
		40	20	33.42	28.10					
		50	20	33.47	28.10	5.75				
		60	20	33.47	28.05		0.12	8.20	2.2	
		70	15	33.47	28.05					
		80	10	33.47	28.05					
		90	7	33.47	28.05					
		100	7	33.47	28.05					
		110	7							
		120	7							
		130	6							
		140	5							
		150	4							
		160	3							
		170	1							
		300	–				0.13	8.22	2.5	
7/3/79	1 (Taema Bank)	Sur	60	33.42	28.20	5.85	0.08	8.23	1.0	1
		5	50	33.45	28.20					
		10	40	33.42	28.20					
		20	40	33.42	28.20					
		30	40	33.42	28.20					
		40	30	33.42	28.15					
		50	25	33.42	28.15	5.75				
		60	17	33.47	28.10		0.13	8.23	0.9	
		70	12	33.47	28.10					
		80	9	33.47	28.10					
		90	7	33.47	28.10					
		100	5	33.47	28.10					
		110	3							
		120	2.5							
		130	2.0							
		140	1.0							

Table A-2, Cont.

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temp. (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Fecal Coliform (#/100 ml)
7/3/79	2	Sur	50	33.37	28.20	6.20	0.13	8.23	1.7	1
	(Tafuna)	5	40	33.42	28.15					
		10	40	33.42	28.15					
		20	30	33.42	28.15					
		30	30	33.42	28.15					
		40	25	33.42	28.15					
		50	20	33.42	28.00	5.90				
		60	15	33.42	28.01		0.11	8.24	0.8	
		70	13	33.42	28.00					
		80	10	33.42	28.05					
		90	8	33.42	28.00					
		100	7	33.42	28.00					
		110	5	33.42						
		120	3	33.42						
		130	3	33.42						
		140	1	33.42						
7/3/79	3	Sur	50	33.27	28.20	6.45	0.23	8.24	2.2	1
	(Tafuna)	5	40	33.37	28.20					
		10	40	33.37	28.15					
		20	30	33.42	28.15					
		30	25	33.42	28.15					
		40	20	33.40	28.15					
		50	15	33.47	28.00	5.95	0.16	8.23	4.4	
		60	Bottom							

Table A-2 Cont.

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temp. (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Fecal Coliform (#/100 ml)
7/3/79	4	Sur	50	33.37	28.20	6.00	0.18	8.22	2.2	1
	(Tafuna)	5	40	33.42	28.20					
		10	30	33.42	28.20					
		20	25	33.42	28.20					
		30	20	33.42	28.15					
		40	20	33.42	28.15					
		50	16	33.42	28.10	5.85				
		60	14	33.42	28.10		0.18	8.25	2.1	
		70	11	33.42	28.10					
		80	9	33.42	28.10					
		90	7	33.42	28.10					
		100	5	33.42	28.10					
		110	4							
		120	3							
		130	3							
		140	3							
		150	1							
7/6/79	14	Sur	40	33.37	28.30	6.20	0.13	8.25	1.4	1
	(Vatia - Offshore)	5	20	33.47	28.30					
		10	20	33.47	28.25					
		20	20	33.47	28.20					
		30	20	33.47	28.20					
		40	18	33.47	28.20					
		50	15	33.51	28.20	5.90				
		60	10	33.51	28.20		0.11	8.25	1.0	
		70	9	33.52	28.20					
		80	7	33.52	28.20					
		90	5	33.57	28.20					
		100	4.5	33.57	28.20					
		110	3.5							
		120	3							
		130	2.5							
		140	2							
		150	1.5							
		160	1.3							
		170	1							

Table A-2, Cont.

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temp. (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Fecal Coliform (#/100 ml)
7/10/79	1 (Taema Bank)	Sur	70	33.47	28.10	6.30	0.18	8.18	0.9	1
		5	50	33.47	28.10					
		10	50	33.47	28.10					
		20	40	33.52	28.10					
		30	35	33.52	28.00					
		40	30	33.52	28.00					
		50	25	33.52	28.00	6.30				
		60	19	33.47	28.00		0.19	8.19	0.4	
		70	15	33.47	28.00					
		80	13	33.47	28.00					
		90	10	33.47	28.00					
		100	8.5	33.47	28.00					
		110	7							
		120	5.5							
		130	4.5							
		140	4							
		150	3							
		160	2							
		170	1							

Table A-2 Cont.

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temp. (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Fecal Coliform (#/100 ml)
7/6/79	16	Sur	60	33.27	28.10	6.00	0.16	8.25	1.5	1
	(Fagasa - Offshore)	5	50	33.47	28.20					
		10	35	33.52	28.20					
		20	30	33.57	28.15					
		30	20	33.57	28.10					
		40	15	33.57	28.10					
		50	15	33.57	28.10	5.80				
		60	9	33.57	28.10		0.14	8.23	0.9	
		70	7	33.62	28.10					
		80	6	33.62	28.10					
		90	3	33.62	28.10					
		100	2	33.62	28.10					
		110	2							
		120	1.5							
		130	1.5							
		140	1.5							
		150	1.5							
		160	1.5							
		170	1.5							
		180	1.0							

Table A-2, Cont.

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temp. (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Fecal Coliform (#/100 ml)
7/10/79	2 (Tafuna)	Sur	50	33.32	28.15	6.30	0.17	8.19	0.6	1
		5	35	33.47	28.15					
		10	30	33.47	28.10					
		20	25	33.47	28.10					
		30	17	33.47	28.05					
		40	17	33.47	28.05					
		50	15	33.47	28.05	6.20				
		60	12	33.47	28.05		0.16	8.19	1.0	
		70	9.5	33.47	28.05					
		80	7.5	33.47	28.00					
		90	6	33.47	28.00					
		100	5	33.47	28.00					
		110	4							
		120	3							
		130	2.5							
		140	2							
		150	1.8							
		160	1.5							
		170	1.3							
		180	1							

Table A-2, Cont.

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temp. (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/1)	Fecal Coliform (#/100 ml)
7/10/79	3	Sur	50	32.97	28.15	6.30	0.18	8.19	0.2	1
	(Tafuna)	5	35	33.27	28.10					
		10	25	33.47	28.10					
		20	20	33.47	28.10					
		30	14	33.47	28.10					
		40	10	33.47	28.10					
		50	9	33.47	28.05	6.30	0.18	8.19	0.8	
		55	Bottom							
7/10/79	4	Sur	55	32.97	28.20	6.30	0.15	8.22	0.7	1
	(Tafuna)	5	50	33.47	28.20					
		10	35	33.47	28.20					
		20	30	33.47	28.15					
		30	22	33.47	28.10					
		40	18	33.47	28.10					
		50	10	33.47	28.10	6.10				
		60	12	33.47	28.05		0.13	8.22	0.4	
		70	12	33.47	28.05					
		80	9	33.47	28.05					
		90	7	33.47	28.05					
		100	5	33.47	28.05					
		110	4							

Table A-2, Cont.

Date	Station No. (Location)	Depth (ft)	Relative Irradiance (%)	Salinity (o/oo)	Temp. (°C)	D.O. (ppm)	Turbidity (NTU)	pH	Suspended Solids (mg/l)	Fecal Coliform (#/100 ml)
7/10/79	Dump Site No. 1	Sur	60	33.47	28.10	6.30	0.14	8.13	1.4	1
		5	50	33.47	28.10					
		10	40	33.47	28.10					
		20	35	33.47	28.05					
		30	30	33.47	28.05					
		40	25	33.47	28.05					
		50	20	33.47	28.05	6.20				
	Dump Site No. 1	60	15	33.47	28.00		0.17	8.11	0.7	
		70	13	33.47	28.00					
		80	8.5	33.47	28.00					
		90	7	33.47	28.00					
		100	5.5	33.47	28.00					
		110	4.5							
		120	3.8							
		130	3							
		140	2.5							
		150	2							
		160	1.8							
		170	1.5							
		180	1							
		300	-				0.13	8.10	1.1	

TABLE A-3

NUTRIENT, CHLOROPHYLL-A, AND OIL AND GREASE
RESULTS FOR AMERICAN SAMOA WET SEASON SAMPLING

Station No. (Location)	Depth (ft)	Date Sampled	Total Kjeldahl Nitrogen (ug/l-N)	Total Phosphorus (ug/l-P)	NO_2+NO_3 (ug/l-N)	Chlorophyll-a (mg/m^3)	Oil and Grease (mg/l)
1	Surface	2/13	141.5	1.9	24.4	0.444	--
(Taema Bank)	60 ft		107.7	9.6	26.0	0.221	
2	Surface	2/13	133.1	8.9	20.9	0.508	--
(Tafuna)	60 ft		105.8	16.9	14.3	0.556	
3	Surface	2/13	76.4	16.9	34.0	0.790	--
(Tafuna)	60 ft		105.8	3.8	26.1	0.141	
4	Surface	2/13	74.6	13.6	125.9	0.441	--
(Tafuna)	60 ft		25.8	4.2	15.1	0.442	
16	Surface	2/15	86.3	2	12.9	0.239	--
(Fagasa-Offshore)	60 ft		80.2	7.5	13.7	0.204	
14	Surface	2/15	137.6	12.0	17.9	0.109	--
(Vatia-Offshore)	60 ft		97.7	5.4	15.4	0.242	

Station No. (Location)	Depth (ft)	Date Sampled	Total Kjeldahl Nitrogen (ug/l-N)	Total Phosphorus (ug/l-P)	NO_2+NO_3 (ug/l-N)	Chlorophyll-a (mg/m^3)	Oil and Grease (mg/l)
1 (Taema Bank)	Surface	2/22	123.9	48.0	4.4	0.227	--
	60 ft		110.3	26.0	1.9	0.457	
2 (Tafuna)	Surface	2/22	147.0	17.2	11.5	ND	
	60 ft		128.1	3.8	2.8	0.340	
3 (Tafuna)	Surface	2/22	85.1	22.2	47.6	0.228	--
	60 ft		112.4	10.4	7.8	0.277	
4 (Tafuna)	Surface	2/22	143.9	29.9	7.1	0.267	--
	60 ft		99.8	2	21.1	0.290	
14 (Vatia-Offshore)	Surface	2/21	81.9	32.5	2.5	0.334	--
	60 ft		104.0	98.2	1.6	0.146	
16 (Fagasa -Offshore)	Surface	2/21	43.1	22.2	0.04		-
	60 ft		149.1	17.2	ND	0.088	
Dump Site #1	Surface	2/22	141.6	25.5	25.2	0.050	
	60 ft		181.7	12.5	8.4	0.025	
Dump Site #2	Surface	2/22	143.9	2	1.6	0.077	
	60 ft		158.6	17.9	2.4	0.066	

TABLE A-4

NUTRIENT, CHLOROPHYLL-A, OIL AND GREASE

RESULTS FOR AMERICAN SAMOA - DRY SEASON SAMPLING

Date	Station (Stream Name)	Depth (ft)	Total Kjeldahl Nitrogen (ug/l-N)	Total Phosphorus (ug/l-P)	NO_2+NO_3 (ug/l-N)	Chlorophyll-a (mg/m^3)	Oil and Grease (mg/l)
7/3/79	1	Surface		8.0	28.9	0.085	
	(Taema Bank)	60		6.7	24.0	0.141	
	2	Surface		6.4	40.0	0.161	
	(Tafuna)	60		5.8	26.8	0.056	
	3	Surface		4.9	38.4	0.202	
	(Tafuna)	60		5.8	37.0	0.212	
	4	Surface		5.5	31.9	0.035	
	(Tafuna)	60		4.9	30.5	0.141	
7/6/79	14	Surface	59	18.1	28.8	0.142	
	(Vatia Offshore)	60	79	16.6	25.4	0.270	
	16	Surface	87	16.6	29.0	0.224	
	(Fagasa Offshore)	60	85	16.9	26.4	0.119	
7/10/78	1	Surface	130	8.8	85.5	0.182	
	(Taema Bank)	60	110	9.9	68.8	0.093	
	2	Surface	88	7.8	62.9	0.146	
	(Tafuna)	60	117	11.9	76.3	0.111	
	3	Surface	120	7.1	85.4	0.106	
	(Tafuna)	60	134	8.5	118.4	0.092	
	4	Surface	118	6.1	57.5	0.416	
	(Tafuna)	60	99	9.5	52.6	0.139	

A P P E N D I X B

STUDY AREA AMERICAN SAMOA
LOCATION OCEAN STATIONS
PARAMETER PH

NUMBER OF DATA POINTS	34
MEDIAN	8.28
SMALLEST NUMBER	8.1
LARGEST NUMBER	8.33
MEAN	8.25676
STANDARD DEVIATION	6.20711E-02
COEF. OF VARIANCE	7.51761E-03
GEOMETRIC MEAN	8.25651
GEOMETRIC STANDARD DEVIATION	1.00758
84.1% FREQUENCY VE	8.31906
15.9% FREQUENCY VE	8.19443

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	8.100	.015
2	8.110	.044
3	8.130	.074
4	8.180	.103
5	8.190	.132
6	8.190	.162
7	8.200	.191
8	8.220	.221
9	8.230	.250
10	8.230	.279
11	8.230	.309
12	8.250	.338
13	8.250	.368
14	8.250	.397
15	8.250	.426
16	8.250	.456
17	8.270	.485
18	8.290	.515
19	8.290	.544
20	8.300	.574
21	8.300	.603
22	8.300	.632
23	8.300	.662
24	8.300	.691
25	8.300	.721
26	8.300	.750
27	8.300	.779
28	8.310	.809
29	8.310	.838
30	8.310	.868
31	8.320	.897
32	8.320	.926
33	8.320	.956
34	8.330	.985

STUDY AREA AMERICAN SAMOA
LOCATION OCEAN STATIONS
PARAMETER DISSOLVED OXYGEN (MG/L)

NUMBER OF DATA POINTS	32
MEDIAN	6.065
SMALLEST NUMBER	5.75
LARGEST NUMBER	6.3
MEAN	6.04781
STANDARD DEVIATION	.177596
COEF. OF VARIANCE	2.93653E-02
GEOMETRIC MEAN	6.04526
GEOMETRIC STANDARD DEVIATION	1.02987
84.1% FREQUENCY VE	6.22584
15.9% FREQUENCY VE	5.86991

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	5.750	.016
2	5.750	.047
3	5.750	.078
4	5.800	.109
5	5.800	.141
6	5.850	.172
7	5.900	.203
8	5.900	.234
9	5.900	.266
10	6.000	.297
11	6.000	.328
12	6.000	.359
13	6.000	.391
14	6.000	.422
15	6.000	.453
16	6.030	.484
17	6.100	.516
18	6.100	.547
19	6.100	.578
20	6.100	.609
21	6.100	.641
22	6.100	.672
23	6.100	.703
24	6.200	.734
25	6.200	.766
26	6.200	.797
27	6.300	.828
28	6.300	.859
29	6.300	.891
30	6.300	.922
31	6.300	.953
32	6.300	.984

STUDY AREA AMERICAN SAMOA
LOCATION
PARAMETER SUSPENDED SOLIDS (MG/L)

NUMBER OF DATA POINTS	24
MEDIAN	1.4
SMALLEST NUMBER	.4
LARGEST NUMBER	2.5
MEAN	1.42958
STANDARD DEVIATION	.548876
COEF. OF VARIANCE	.383941
GEOMETRIC MEAN	1.31984
GEOMETRIC STANDARD DEVIATION	1.5356
84.1% FREQUENCY VE	2.02675
15.9% FREQUENCY VE	.859491

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.400	.021
2	.700	.063
3	.900	.104
4	.900	.146
5	.900	.188
6	1.000	.229
7	1.000	.271
8	1.070	.313
9	1.100	.354
10	1.270	.396
11	1.330	.438
12	1.400	.479
13	1.400	.521
14	1.470	.563
15	1.470	.604
16	1.500	.646
17	1.600	.688
18	1.730	.729
19	1.870	.771
20	2.130	.813
21	2.200	.854
22	2.200	.896
23	2.270	.938
24	2.500	.979

STUDY AREA	AMERICAN SAMOA
LOCATION	OCEAN STATIONS
PARAMETER	TURBIDITY (NTU)

NUMBER OF DATA POINTS	34
MEDIAN	.17
SMALLEST NUMBER	.08
LARGEST NUMBER	.47
MEAN	.187059
STANDARD DEVIATION	7.12881E-02
COEF. OF VARIANCE	.3811
GEOMETRIC MEAN	.176663
GEOMETRIC STANDARD DEVIATION	1.39501
84.1% FREQUENCY VE	.246446
15.9% FREQUENCY VE	.12664

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.080	.015
2	.110	.044
3	.120	.074
4	.130	.103
5	.130	.132
6	.130	.162
7	.130	.191
8	.140	.221
9	.140	.250
10	.150	.279
11	.150	.309
12	.150	.338
13	.160	.368
14	.160	.397
15	.160	.426
16	.170	.456
17	.170	.485
18	.170	.515
19	.180	.544
20	.180	.574
21	.180	.603
22	.190	.632
23	.200	.662
24	.210	.691
25	.210	.721
26	.220	.750
27	.220	.779
28	.230	.809
29	.240	.838
30	.240	.868
31	.240	.897
32	.270	.926
33	.330	.956
34	.470	.985

STUDY AREA AMERICAN SAMOA
LOCATION OCEAN STATIONS
PARAMETER TOTAL KJELDAHL NITROGEN (UG/L)

NUMBER OF DATA POINTS	37
MEDIAN	94
SMALLEST NUMBER	43
LARGEST NUMBER	255
MEAN	107
STANDARD DEVIATION	44.83
COEF. OF VARIANCE	.418972
GEOMETRIC MEAN	99.0676
GEOMETRIC STANDARD DEVIATION	1.48408
84.1% FREQUENCY VE	147.025
15.9% FREQUENCY VE	66.7534

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	43.000	.014
2	45.000	.041
3	59.000	.068
4	59.000	.095
5	65.000	.122
6	66.000	.149
7	67.000	.176
8	74.000	.203
9	79.000	.230
10	80.000	.257
11	84.000	.284
12	85.000	.311
13	85.000	.338
14	86.000	.365
15	86.000	.392
16	87.000	.419
17	87.000	.446
18	91.000	.473
19	94.000	.500
20	98.000	.527
21	107.000	.554
22	108.000	.581
23	110.000	.608
24	112.000	.635
25	117.000	.662
26	117.000	.689
27	126.000	.716
28	130.000	.743
29	131.000	.770
30	138.000	.797
31	142.000	.824
32	144.000	.851
33	148.000	.878
34	159.000	.905
35	181.000	.932
36	214.000	.959
37	255.000	.986

STUDY AREA AMERICAN SAMOA
LOCATION OCEAN STATIONS
PARAMETER NITRATE + NITRITE (UG/L)

NUMBER OF DATA POINTS	38
MEDIAN	13.3
SMALLEST NUMBER	.02
LARGEST NUMBER	85.5
MEAN	17.0516
STANDARD DEVIATION	17.8317
COEF. OF VARIANCE	1.04575
GEOMETRIC MEAN	7.4122
GEOMETRIC STANDARD DEVIATION	6.23462
84.1% FREQUENCY VE	46.2123
15.9% FREQUENCY VE	1.18888

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.020	.013
2	.040	.039
3	.400	.066
4	.500	.092
5	1.600	.118
6	1.600	.145
7	1.900	.171
8	2.400	.197
9	2.500	.224
10	2.700	.250
11	3.100	.276
12	4.400	.303
13	6.600	.329
14	7.600	.355
15	8.400	.382
16	8.600	.408
17	12.300	.434
18	12.500	.461
19	12.900	.487
20	13.700	.513
21	15.400	.539
22	15.700	.566
23	17.900	.592
24	22.700	.618
25	23.900	.645
26	24.000	.671
27	24.400	.697
28	25.200	.724
29	25.400	.750
30	26.000	.776
31	26.400	.803
32	26.500	.829
33	28.800	.855
34	28.900	.882
35	29.000	.908
36	29.700	.934
37	68.800	.961
38	85.500	.987

STUDY AREA AMERICAN SAMOA
LOCATION OCEAN STATIONS
PARAMETER TOTAL PHOSPHORUS (UG/L)

NUMBER OF DATA POINTS	36
MEDIAN	10.2
SMALLEST NUMBER	1
LARGEST NUMBER	32.5
MEAN	11.8028
STANDARD DEVIATION	7.97864
COEF. OF VARIANCE	.675996
GEOMETRIC MEAN	8.57838
GEOMETRIC STANDARD DEVIATION	2.5284
84.1% FREQUENCY VE	21.6896
15.9% FREQUENCY VE	3.39281

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	1.000	.014
2	1.000	.042
3	1.900	.069
4	2.500	.097
5	2.500	.125
6	2.500	.153
7	2.500	.181
8	2.500	.208
9	5.400	.236
10	6.700	.264
11	7.500	.292
12	7.800	.319
13	7.900	.347
14	8.000	.375
15	8.300	.403
16	8.800	.431
17	9.600	.458
18	9.900	.486
19	10.500	.514
20	12.000	.542
21	12.000	.569
22	12.500	.597
23	14.100	.625
24	16.500	.653
25	16.600	.681
26	16.600	.708
27	16.900	.736
28	17.500	.764
29	17.900	.792
30	18.100	.819
31	18.200	.847
32	22.200	.875
33	23.000	.903
34	25.500	.931
35	26.000	.958
36	32.500	.986

STUDY AREA	AMERICAN SAMOA
LOCATION	OCEAN STATIONS
PARAMETER	CHLOROPHYLL-A (UG/L)

NUMBER OF DATA POINTS	31
MEDIAN	.163
SMALLEST NUMBER	.025
LARGEST NUMBER	.578
MEAN	.192097
STANDARD DEVIATION	.125638
COEF. OF VARIANCE	.654036
GEOMETRIC MEAN	.156133
GEOMETRIC STANDARD DEVIATION	1.98889
84.1% FREQUENCY VE	.310531
15.9% FREQUENCY VE	7.85022E-02

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.025	.016
2	.050	.048
3	.057	.081
4	.060	.113
5	.085	.145
6	.088	.177
7	.093	.210
8	.106	.242
9	.109	.274
10	.115	.306
11	.119	.339
12	.141	.371
13	.142	.403
14	.143	.435
15	.146	.468
16	.163	.500
17	.182	.532
18	.204	.565
19	.219	.597
20	.221	.629
21	.224	.661
22	.227	.694
23	.227	.726
24	.239	.758
25	.242	.790
26	.245	.823
27	.270	.855
28	.334	.887
29	.444	.919
30	.457	.952
31	.578	.984

STUDY AREA	AMERICAN SAMOA
LOCATION	OCEAN STATIONS
PARAMETER	IRRADIANCE (FT)

NUMBER OF DATA POINTS	11
MEDIAN	170
SMALLEST NUMBER	140
LARGEST NUMBER	180
MEAN	167.727
STANDARD DEVIATION	14.7247
COEF. OF VARIANCE	8.77898E-02
GEOMETRIC MEAN	167.094
GEOMETRIC STANDARD DEVIATION	1.09722
84.1% FREQUENCY VE	183.34
15.9% FREQUENCY VE	152.288

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	140.000	.045
2	140.000	.136
3	165.000	.227
4	170.000	.318
5	170.000	.409
6	170.000	.500
7	170.000	.591
8	180.000	.682
9	180.000	.773
10	180.000	.864
11	180.000	.955

STUDY AREA	AMERICAN SAMOA
LOCATION	OPEN COASTAL NEARSHORE, SURFACE
PARAMETER	FECAL COLIFORM (NO./100ML)

NUMBER OF DATA POINTS	9
MEDIAN	.5
SMALLEST NUMBER	.5
LARGEST NUMBER	1
MEAN	.611111
STANDARD DEVIATION	.220479
COEF. OF VARIANCE	.360794
GEOMETRIC MEAN	.583265
GEOMETRIC STANDARD DEVIATION	1.35751
84.1% FREQUENCY VE	.791786
15.9% FREQUENCY VE	.429659

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.500	.056
2	.500	.167
3	.500	.278
4	.500	.389
5	.500	.500
6	.500	.611
7	.500	.722
8	1.000	.833
9	1.000	.944

STUDY AREA	AMERICAN SAMOA
LOCATION	OPEN COASTAL NEARSHORE, SURFACE
PARAMETER	PH

NUMBER OF DATA POINTS	12
MEDIAN	8.27
SMALLEST NUMBER	8.19
LARGEST NUMBER	8.33
MEAN	8.26583
STANDARD DEVIATION	5.36707E-02
COEF. OF VARIANCE	6.73504E-03
GEOMETRIC MEAN	8.26563
GEOMETRIC STANDARD DEVIATION	1.00676
84.1% FREQUENCY VE	8.32151
15.9% FREQUENCY VE	8.21013

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	8.190	.042
2	8.190	.125
3	8.220	.208
4	8.220	.292
5	8.230	.375
6	8.240	.458
7	8.300	.542
8	8.300	.625
9	8.320	.708
10	8.320	.792
11	8.330	.875
12	8.330	.958

STUDY AREA	AMERICAN SAMOA
LOCATION	OPEN COASTAL NEARSHORE, 60 FT DEPTH
PARAMETER	PH

NUMBER OF DATA POINTS	12
MEDIAN	8.275
SMALLEST NUMBER	8.19
LARGEST NUMBER	8.33
MEAN	8.2727
STANDARD DEVIATION	5.80163E-02
COEF. OF VARIANCE	7.01316E-03
GEOMETRIC MEAN	8.27229
GEOMETRIC STANDARD DEVIATION	1.00704
84.1% FREQUENCY VE	8.33055
15.9% FREQUENCY VE	8.21443

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	8.190	.042
2	8.190	.125
3	8.220	.208
4	8.230	.292
5	8.240	.375
6	8.250	.458
7	8.300	.542
8	8.300	.625
9	8.330	.708
10	8.330	.792
11	8.330	.875
12	8.330	.958

STUDY AREA	AMERICAN SAMOA
LOCATION	OPEN COASTAL NEARSHORE, SURFACE
PARAMETER	DISSOLVED OXYGEN (MG/L)

NUMBER OF DATA POINTS	12
MEDIAN	6.25
SMALLEST NUMBER	5.95
LARGEST NUMBER	6.45
MEAN	6.21667
STANDARD DEVIATION	.154200
COEF. OF VARIANCE	2.48096E-02
GEOMETRIC MEAN	6.21488
GEOMETRIC STANDARD DEVIATION	1.02522
84.1% FREQUENCY VE	6.37161
15.9% FREQUENCY VE	6.062

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	5.950	.042
2	6.000	.125
3	6.100	.208
4	6.100	.292
5	6.200	.375
6	6.200	.458
7	6.300	.542
8	6.300	.625
9	6.300	.708
10	6.300	.792
11	6.400	.875
12	6.450	.958

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, 50 FT DEPTH
PARAMETER DISSOLVED OXYGEN (MG/L)

NUMBER OF DATA POINTS	12
MEDIAN	5.95
SMALLEST NUMBER	5.8
LARGEST NUMBER	6.3
MEAN	5.9875
STANDARD DEVIATION	.146357
COEF. OF VARIANCE	2.44438E-02
GEOMETRIC MEAN	5.98386
GEOMETRIC STANDARD DEVIATION	1.02449
84.1% FREQUENCY VE	6.13247
15.9% FREQUENCY VE	5.84277

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	5.800	.042
2	5.850	.125
3	5.900	.208
4	5.900	.292
5	5.900	.375
6	5.950	.458
7	5.950	.542
8	6.000	.625
9	6.000	.708
10	6.100	.792
11	6.200	.875
12	6.300	.958

LOCATION OPEN COASTAL NEARSHORE, SURFACE
PARAMETER TURBIDITY (NTU)

NUMBER OF DATA POINTS	12
MEDIAN	.18
SMALLEST NUMBER	.13
LARGEST NUMBER	.22
MEAN	.2
STANDARD DEVIATION	5.75247E-02
COEF. OF VARIANCE	.287623
GEOMETRIC MEAN	.193106
GEOMETRIC STANDARD DEVIATION	1.31248
84.1% FREQUENCY VE	.233447
15.9% FREQUENCY VE	.147151

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.130	.042
2	.150	.125
3	.150	.208
4	.170	.292
5	.170	.375
6	.180	.458
7	.180	.542
8	.190	.625
9	.230	.708
10	.240	.792
11	.270	.875
12	.320	.958

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, 60 FT DEPTH
PARAMETER TURBIDITY (NTU)

NUMBER OF DATA POINTS	12
MEDIAN	.175
SMALLEST NUMBER	.11
LARGEST NUMBER	.29
MEAN	.179167
STANDARD DEVIATION	4.60174E-02
COEF. OF VARIANCE	.25683
GEOMETRIC MEAN	.174148
GEOMETRIC STANDARD DEVIATION	1.28032
84.1% FREQUENCY VE	.222965
15.9% FREQUENCY VE	.136019

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.110	.042
2	.130	.125
3	.160	.208
4	.160	.292
5	.160	.375
6	.170	.458
7	.180	.542
8	.180	.625
9	.180	.708
10	.210	.792
11	.220	.875
12	.290	.958

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, SURFACE
PARAMETER SUSPENDED SOLIDS (MG/L)

NUMBER OF DATA POINTS	9
MEDIAN	2
SMALLEST NUMBER	.2
LARGEST NUMBER	2.67
MEAN	1.68778
STANDARD DEVIATION	.904778
COEF. OF VARIANCE	.552441
GEOMETRIC MEAN	1.27834
GEOMETRIC STANDARD DEVIATION	2.41569
84.1% FREQUENCY VE	3.08806
15.9% FREQUENCY VE	.529182

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.200	.056
2	.600	.167
3	.700	.278
4	1.700	.389
5	2.000	.500
6	2.200	.611
7	2.200	.722
8	2.470	.833
9	2.670	.944

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, 60 FT DEPTH
PARAMETER SUSPENDED SOLIDS (MG/L)

NUMBER OF DATA POINTS	9
MEDIAN	2.1
SMALLEST NUMBER	.4
LARGEST NUMBER	4.4
MEAN	1.86222
STANDARD DEVIATION	1.25588
COEF. OF VARIANCE	.674374
GEOMETRIC MEAN	1.47669
GEOMETRIC STANDARD DEVIATION	2.14539
84.1% FREQUENCY VE	3.16807
15.9% FREQUENCY VE	.688308

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.400	.056
2	.500	.167
3	.800	.278
4	1.800	.389
5	2.100	.500
6	2.330	.611
7	2.330	.722
8	2.600	.833
9	4.400	.944

STUDY AREA	AMERICAN SAMOA
LOCATION	OPEN COASTAL NEARSHORE
PARAMETER	IRRADIANCE (FT)

NUMBER OF DATA POINTS	4
MEDIAN	145
SMALLEST NUMBER	140
LARGEST NUMBER	180
MEAN	152.5
STANDARD DEVIATION	18.9297
COEF. OF VARIANCE	.124129
GEOMETRIC MEAN	151.67
GEOMETRIC STANDARD DEVIATION	1.12603
84.1% FREQUENCY VE	170.736
15.9% FREQUENCY VE	134.694

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	140.000	.125
2	140.000	.375
3	150.000	.625
4	180.000	.875

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, SURFACE
PARAMETER TOTAL KJELDAHL NITROGEN (UG/L)

NUMBER OF DATA POINTS	9
MEDIAN	107
SMALLEST NUMBER	75
LARGEST NUMBER	133
MEAN	101.333
STANDARD DEVIATION	20.9643
COEF. OF VARIANCE	.206884
GEOMETRIC MEAN	99.3733
GEOMETRIC STANDARD DEVIATION	1.23489
84.1% FREQUENCY VE	122.715
15.9% FREQUENCY VE	80.4716

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	75.000	.056
2	76.000	.167
3	85.000	.278
4	88.000	.389
5	107.000	.500
6	110.000	.611
7	118.000	.722
8	120.000	.833
9	133.000	.944

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, 60 FT DEPTH
PARAMETER TOTAL KJELDAHL NITROGEN (UG/L)

NUMBER OF DATA POINTS	9
MEDIAN	100
SMALLEST NUMBER	26
LARGEST NUMBER	134
MEAN	95
STANDARD DEVIATION	30.4672
COEF. OF VARIANCE	.320708
GEOMETRIC MEAN	87.9098
GEOMETRIC STANDARD DEVIATION	1.62099
84.1% FREQUENCY VE	142.501
15.9% FREQUENCY VE	54.2322

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	26.000	.056
2	76.000	.167
3	91.000	.278
4	99.000	.389
5	100.000	.500
6	106.000	.611
7	106.000	.722
8	117.000	.833
9	134.000	.944

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, SURFACE
PARAMETER NITRATE + NITRITE (UG/L)

NUMBER OF DATA POINTS	12
MEDIAN	39.2
SMALLEST NUMBER	7.1
LARGEST NUMBER	125.9
MEAN	46.925
STANDARD DEVIATION	33.1839
COEF. OF VARIANCE	.707276
GEOMETRIC MEAN	36.3157
GEOMETRIC STANDARD DEVIATION	2.24423
84.1% FREQUENCY VE	81.501
15.9% FREQUENCY VE	16.1818

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	7.100	.042
2	11.500	.125
3	20.900	.208
4	31.900	.292
5	34.000	.375
6	38.400	.458
7	40.000	.542
8	47.600	.625
9	57.500	.708
10	62.900	.792
11	85.400	.875
12	125.900	.958

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, 60 FT DEPTH
PARAMETER NITRATE + NITRITE (UG/L)

NUMBER OF DATA POINTS	12
MEDIAN	26.45
SMALLEST NUMBER	2.8
LARGEST NUMBER	118.4
MEAN	35.7333
STANDARD DEVIATION	32.952
COEF. OF VARIANCE	.921603
GEOMETRIC MEAN	24.0404
GEOMETRIC STANDARD DEVIATION	2.73576
84.1% FREQUENCY VE	65.7818
15.9% FREQUENCY VE	8.78794

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	2.800	.042
2	7.800	.125
3	14.300	.208
4	15.100	.292
5	21.100	.375
6	26.100	.458
7	26.800	.542
8	30.500	.625
9	37.800	.708
10	52.600	.792
11	76.300	.875
12	118.400	.958

STUDY AREA	AMERICAN SAMOA
LOCATION	OPEN COASTAL NEARSHORE, SURFACE
PARAMETER	TOTAL PHOSPHORUS (UG/L)

NUMBER OF DATA POINTS	12
MEDIAN	7.45
SMALLEST NUMBER	1.2
LARGEST NUMBER	29.9
MEAN	11.5417
STANDARD DEVIATION	8.47237
COEF. OF VARIANCE	.734086
GEOMETRIC MEAN	8.66948
GEOMETRIC STANDARD DEVIATION	2.37377
84.1% FREQUENCY VE	20.5793
15.9% FREQUENCY VE	3.6522

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	1.200	.042
2	4.900	.125
3	5.500	.208
4	6.100	.292
5	6.400	.375
6	7.100	.458
7	7.800	.542
8	13.600	.625
9	16.900	.708
10	16.900	.792
11	22.200	.875
12	29.900	.958

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, 60 FT DEPTH
PARAMETER TOTAL PHOSPHORUS (UG/L)

NUMBER OF DATA POINTS	12
MEDIAN	5.8
SMALLEST NUMBER	1
LARGEST NUMBER	11.9
MEAN	6.54167
STANDARD DEVIATION	3.23812
COEF. OF VARIANCE	.478057
GEOMETRIC MEAN	5.56861
GEOMETRIC STANDARD DEVIATION	1.96124
84.1% FREQUENCY VE	10.9214
15.9% FREQUENCY VE	2.83933

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	1.000	.042
2	3.800	.125
3	3.800	.208
4	4.200	.292
5	4.900	.375
6	5.800	.458
7	5.800	.542
8	8.500	.625
9	8.700	.708
10	9.500	.792
11	10.400	.875
12	11.900	.958

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, SURFACE
PARAMETER CHLOROPHYLL-A (UG/L)

NUMBER OF DATA POINTS	12
MEDIAN	.215
SMALLEST NUMBER	.02
LARGEST NUMBER	.79
MEAN	.276667
STANDARD DEVIATION	.22469
COEF. OF VARIANCE	.812133
GEOMETRIC MEAN	.184729
GEOMETRIC STANDARD DEVIATION	2.74483
84.1% FREQUENCY VE	.340996
15.9% FREQUENCY VE	5.27299E-02

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.020	.042
2	.035	.125
3	.106	.208
4	.146	.292
5	.161	.375
6	.202	.458
7	.228	.542
8	.267	.625
9	.416	.708
10	.441	.792
11	.508	.875
12	.790	.958

STUDY AREA AMERICAN SAMOA
LOCATION OPEN COASTAL NEARSHORE, 60 FT DEPTH
PARAMETER CHLOROPHYLL-A (UG/L)

NUMBER OF DATA POINTS	12
MEDIAN	.1765
SMALLEST NUMBER	.056
LARGEST NUMBER	.556
MEAN	.233083
STANDARD DEVIATION	.152635
COEF. OF VARIANCE	.655708
GEOMETRIC MEAN	.190252
GEOMETRIC STANDARD DEVIATION	1.97364
84.1% FREQUENCY VE	.376383
15.9% FREQUENCY VE	9.61677E-02

NO. POINTS	INDIVIDUAL POINTS	F(I)
1	.056	.042
2	.092	.125
3	.111	.208
4	.139	.292
5	.141	.375
6	.141	.458
7	.212	.542
8	.277	.625
9	.290	.708
10	.340	.792
11	.442	.875
12	[illegible]	[illegible]

A P P E N D I X C

TAFIINA (DRY SEASON)

SAMPLE SIZE = 513

THIS IS A EBB SDPT

X =-6.33453 Y =-1.81726 RESULTANT = 6.59004 ANGLE = 16.0072

% OF TIME

SEC	0CM	1CM	2CM	3CM	4CM	5CM	6CM	7CM	8CM	9CM	10CM	11CM	12CM	13CM	14CM	15CM	16CM	17CM	18CM	19CM	20CM	21CM	22CM	23CM	24CM	25CM	26CM	VSUM
1	.0	.0	.0	.0	.2	.4	.2	.0	.2	.4	1.0	.2	.4	.2	.0	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.31189
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
10	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
11	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
12	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
13	.0	.0	.0	.0	.0	.2	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.02339
14	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.4	.6	.0	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.13060
15	.0	.0	.0	.0	.4	.4	.8	.2	1.4	1.0	1.8	1.4	.6	.8	.0	.2	.0	.2	.0	.0	.0	.2	.0	.0	.0	.0	.0	.89279
16	.0	.0	.0	.0	.6	1.6	1.9	3.5	2.1	3.7	4.5	3.5	1.9	2.3	1.0	.8	.6	.0	.6	.0	.0	.0	.0	.0	.0	.0	.0	2.79337
17	.0	.0	.0	.0	.4	.4	2.3	3.1	2.7	2.5	2.1	1.9	1.4	1.6	.6	.2	.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.81092
18	.0	.2	.0	.0	.8	.4	2.5	2.3	1.2	.4	.0	1.0	.2	.2	.4	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.73879
19	.0	.0	.0	.0	.6	.6	1.0	.8	.4	.4	.8	.4	.2	.6	.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.50877
20	.0	.0	.0	.2	.2	.0	1.4	.6	.6	.2	.4	.0	.2	.4	.2	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.37232
21	.0	.0	.4	.0	.4	.0	.4	.6	.2	.0	.0	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.12671
22	.0	.0	.2	.2	.4	.0	.2	.2	.2	.2	.2	.0	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.12865
23	.0	.0	.0	.2	.2	.0	.0	.2	.4	.0	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.07992
24	.0	.0	.0	1.0	1.8	2.1	1.8	2.3	.8	1.4	.8	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.76023
25	.0	.2	.6	1.6	5.8	6.0	12.5	14.0	10.1	10.1	11.9	9.4	5.1	6.2	2.5	1.4	1.4	.4	.6	.0	.0	.2	.0	.0	.0	.0	.0	.00000

TAFUNA (DRY SEASON)

SAMPLE SIZE = 466

THIS IS A FLOOD SORT

X =-4.37705 Y = .40516 RESULTANT = 4.39576 ANGLE =-5.28847

% OF TIME

SEC	0CM	1CM	2CM	3CM	4CM	5CM	6CM	7CM	8CM	9CM	10CM	11CM	12CM	13CM	14CM	15CM	16CM	17CM	18CM	19CM	20CM	21CM	22CM	23CM	24CM	25CM	26CM	VSUM
1	.0	.0	.2	.2	.4	.0	.9	.6	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.2	.0	.0	.0	.19313
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
10	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
11	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
12	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
13	.0	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00429
14	.0	.0	.0	.0	.0	.0	.2	.6	.0	.2	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.10086
15	.0	.0	.6	.0	.4	.2	.9	.9	1.9	.6	2.1	.2	1.3	.4	.9	.6	.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.10086
16	.0	.0	.0	.2	.4	1.1	1.3	1.7	1.9	3.0	2.4	.6	1.1	.6	1.1	.9	.0	.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	1.57296
17	.0	.0	.6	.2	1.1	1.7	1.1	2.8	.9	1.7	.6	.6	1.3	.2	.9	.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.13519
18	.0	.0	.0	.2	.6	.9	1.5	.4	.9	.9	.9	.2	.4	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.53004
19	.0	.0	.0	.2	.4	1.1	.2	.0	.4	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.14378
20	.0	.0	.0	.2	.2	1.3	.0	.4	.4	.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.18455
21	.0	.0	.2	.0	.2	.6	.0	.9	.2	.0	.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.14592
22	.0	.0	.0	.4	.4	.4	.2	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.09442
23	.0	.0	.0	.6	.6	.6	.4	.6	.0	.2	.0	.4	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.26609
24	.0	.4	.6	1.7	4.3	4.9	5.2	5.2	3.2	1.5	1.5	1.1	.9	.9	.2	.2	.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	2.16524
25	.0	.4	2.6	4.1	9.2	12.9	11.8	14.6	9.9	8.8	7.7	3.6	5.4	2.4	3.0	1.9	.6	.6	.2	.0	.0	.0	.0	.2	.0	.0	.0	.00000

TAFUNA (DRY SEASON)

SAMPLE SIZE = 979

THIS IS A OVERALL SORT

X =-5.40278 Y =-.759397 RESULTANT = 5.45588 ANGLE = 8.00088

% OF TIME

SEC	0CM	1CM	2CM	3CM	4CM	5CM	6CM	7CM	8CM	9CM	10CM	11CM	12CM	13CM	14CM	15CM	16CM	17CM	18CM	19CM	20CM	21CM	22CM	23CM	24CM	25CM	26CM	VSUM
1	.0	.0	.1	.1	.3	.2	.5	.3	.1	.3	.5	.1	.2	.1	.0	.0	.1	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0	.85536
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
10	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
11	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
12	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00000
13	.0	.0	.1	.0	.0	.1	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.01430
14	.0	.0	.0	.0	.0	.0	.1	.3	.0	.1	.2	.4	.0	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.11645
15	.0	.0	.3	.0	.4	.3	.8	.5	1.6	.8	1.9	.8	.9	.6	.4	.4	.1	.2	.0	.0	.0	.1	.0	.0	.0	.0	.0	.99183
16	.0	.0	.0	.1	.5	1.3	1.6	2.7	2.0	3.4	3.5	2.1	1.5	1.5	1.0	.8	.3	.1	.4	.0	.0	.0	.0	.0	.0	.0	.0	2.21246
17	.0	.0	.3	.1	.7	1.0	1.7	3.0	1.8	2.1	1.4	1.3	1.3	.9	.7	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.48928
18	.0	.1	.0	.1	.7	.6	2.0	1.4	1.0	.6	.4	.6	.3	.2	.2	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.63943
19	.0	.0	.0	.1	.5	.8	.6	.4	.4	.3	.4	.2	.1	.3	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.33504
20	.0	.0	.0	.2	.2	.6	.7	.5	.5	.2	.3	.0	.1	.2	.1	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.28294
21	.0	.0	.3	.0	.3	.3	.2	.7	.2	.0	.0	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.13585
22	.0	.0	.1	.3	.4	.2	.2	.3	.1	.1	.1	.0	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.11236
23	.0	.0	.0	.4	.4	.3	.2	.4	.2	.1	.0	.3	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.16854
24	.0	.2	.3	1.3	3.0	3.5	3.4	3.7	1.9	1.4	1.1	.6	.4	.4	.1	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.42901
25	.0	.3	1.5	2.8	7.5	9.3	12.2	14.3	10.0	9.5	9.9	6.6	5.2	4.4	2.8	1.6	1.0	.5	.4	.0	.0	.1	.0	.1	.0	.0	.0	.00000

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WTR-RRC-451

A REPORT ON OCEAN DISPOSAL OF FISH PROCESSING WASTES OFF PAGO PAGO, AMERICAN SAMOA

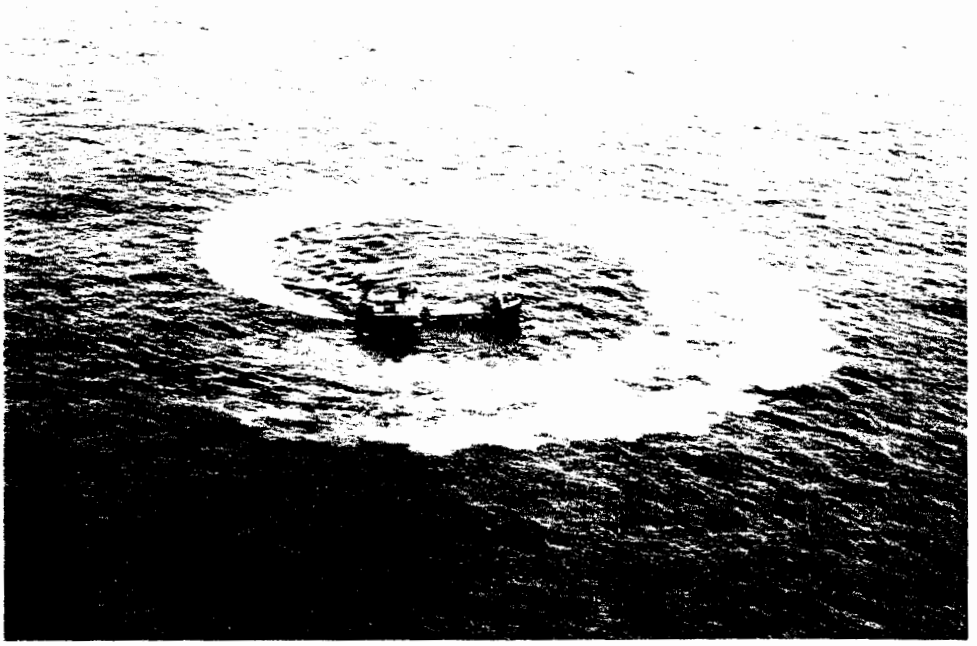
Prepared for The

U.S. ENVIRONMENTAL PROTECTION AGENCY

REGION IX, SAN FRANCISCO, CALIFORNIA

And

NOAA, DEPARTMENT OF COMMERCE



On Behalf Of Star-Kist Foods, Inc., And

Van Camp Seafood Division, Ralston Purina Co.

by Dorothy F. Soule and Mikihiko Oguri

Los Angeles, California

June, 1983

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BY

DOROTHY F. SOULE AND MIKIHIKO OGURI
LOS ANGELES, CALIFORNIA

JUNE 1983

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SUMMARY

The present report documents the field and laboratory research on ocean disposal of fish processing wastes in American Samoa. It is directed toward several general objectives, including the following:

- For the fish processors, the objectives are is ensure an adequate and environmentally acceptable waste disposal site capacity within feasible economic and logistic capabilities; and to have that site designated for permanent use by the EPA Office of Marine Protection.
- For the federal and local regulatory agencies, the objective is to insure that disposal occurs in the mode least damaging to the environment, commensurate with the available alternatives and with protection of living resources--in this case through compliance with ocean disposal permit conditions; and
- For the Office of Marine Assessment (NOAA, Department of Commerce), the objective is to investigate the basic premise that ocean disposal of non-toxic, biodegradable wastes can provide the best alternative for management of fish processing wastes.

An interim site designation off Tutuila Island, American Samoa, for an ocean dumping permit was issued by the Environmental Protection Agency (CFR 40, 24 November 1980),

based in part on an EIS submitted in September 1979 by the local Star-Kist Samoa, Inc. and the Van Camp Seafood Division of Ralston Purina Co. tuna processors. The permit was in part contingent upon conducting a Trend Assessment study to be based on a scope of work submitted by the canners to EPA for approval. The scope of the NOAA/OMPA investigation, with its somewhat broader goals, was accepted by EPA, Region IX as fulfilling the Trend Assessment requirement for American Samoa. Two field monitoring periods, in January 1982 and July 1982 were selected to represent the wet and dry (or Trade Wind) periods respectively.

Semi-annual monitoring of the designated disposal site, at 14° 22' S and 170° 41' W, included the following parameters (see Table 1 for methods):

Temperature	pH
Salinity	NH3
Dissolved Oxygen	BOD
% Light Transmittance	TOC
Light Penetration	Color
Winds, Sea State	Currents
Biota (visual observations)	

Field and laboratory results and analyses of data are discussed in the main body of the present report, while field logs and data are presented in Appendix A and B for January and July 1982 respectively.

Salient results of the of semi-annual trend assessment surveys are as follows:

o No evidence of deleterious environmental stress has been

observed during ocean disposal monitoring.

- Although a visible plume remained for several hours, it did not appear as an oily slick but formed a suspensate of fine particulates which showed as a light blue-turquoise patch on the cobalt, deep sea waters.
- Much of the material sank within minutes of dumping, as shown by changes in percent light transmittance (Figures 5, 7, 21).
- Five-day Biochemical Oxygen Demand (BOD 5) rose rapidly as dumping proceeded, but returned to background levels after dumping ceased, within minutes to several hours, depending on dispersion due to wind and sea state (Figures 9, 22).
- Dissolved Oxygen (DO) dropped rapidly as dumping proceeded but did not fall below 5.5 ppm, which is well above levels that would produce even temporary stress on pelagic fishes (Figures 10, 23 and 24). In some cases the DO returned to afternoon ambient (control) levels, but in others it did not during the post-dump monitoring periods. Variability is, no doubt, dependent on weather conditions and sea state.
- Ammonia levels were low in ambient waters and increased immediately to as much as 20 ug-at/l NH3 (= 0.34mg/l). Ammonia levels in the undiluted sludge vary; there were 50,000 ug-at/l (850 mg/l) in the July sludge sample, indicating that a dilution of 2500 times had occurred by

the time it passed the propellor wash, at the first sampling in the field. Levels of up to 220,000 ug-at/l NH3 (3740 mg/l) have been recorded in undiluted sludge in southern California, but this was from sludge that had been stored for several days.

- There was close correlation between ammonia values and BOD 5 values, suggesting that the simpler, less time consuming ammonia technique could be used for future monitoring of the plume.
- Statistically significant differences between values in the plume and at control sites were found at least part of the time for the following: percent light transmittance, dissolved oxygen, ammonia and BOD 5.
- Significant diffferences were not found with suspended solids, total organic carbon, oil and grease, or temperture. Natural sediment transport from storm turbulence or upwelling affects suspended solids controls, while very fine suspended particulates tend to skew TOC values. Oil and grease levels were too low in water samples to give meaningful separation between the plume and controls.
- When material is dumped on site, the plume moves offshore, or moves parallel to the coast with the longshore currents. If it were accidentally dumped considerably short of the site, it could move onto the reefs and shoreline where it might create an esthetically displeasing or

harmful residue at the edge of the surf zone. The dilutions are such that fish or invertebrate kills would not occur unless the dumping occurred very close to shore at a time of extreme low tides.

- There is no evidence that dumped materials have reached nearshore areas since dumping began under the permit in October 1980.
- The possibility of marking the site with a fish aggregation device (FAD) should be explored. The American Samoa Office of Marine Resources has deployed several such devices elsewhere off Tutuila Island under the auspices of the National Marine Fisheries Service, and fish recruitment has resulted. This would, in turn, enhance utilization of the nutritional ingredients of the waste by providing a new, habitat in the deep water area.

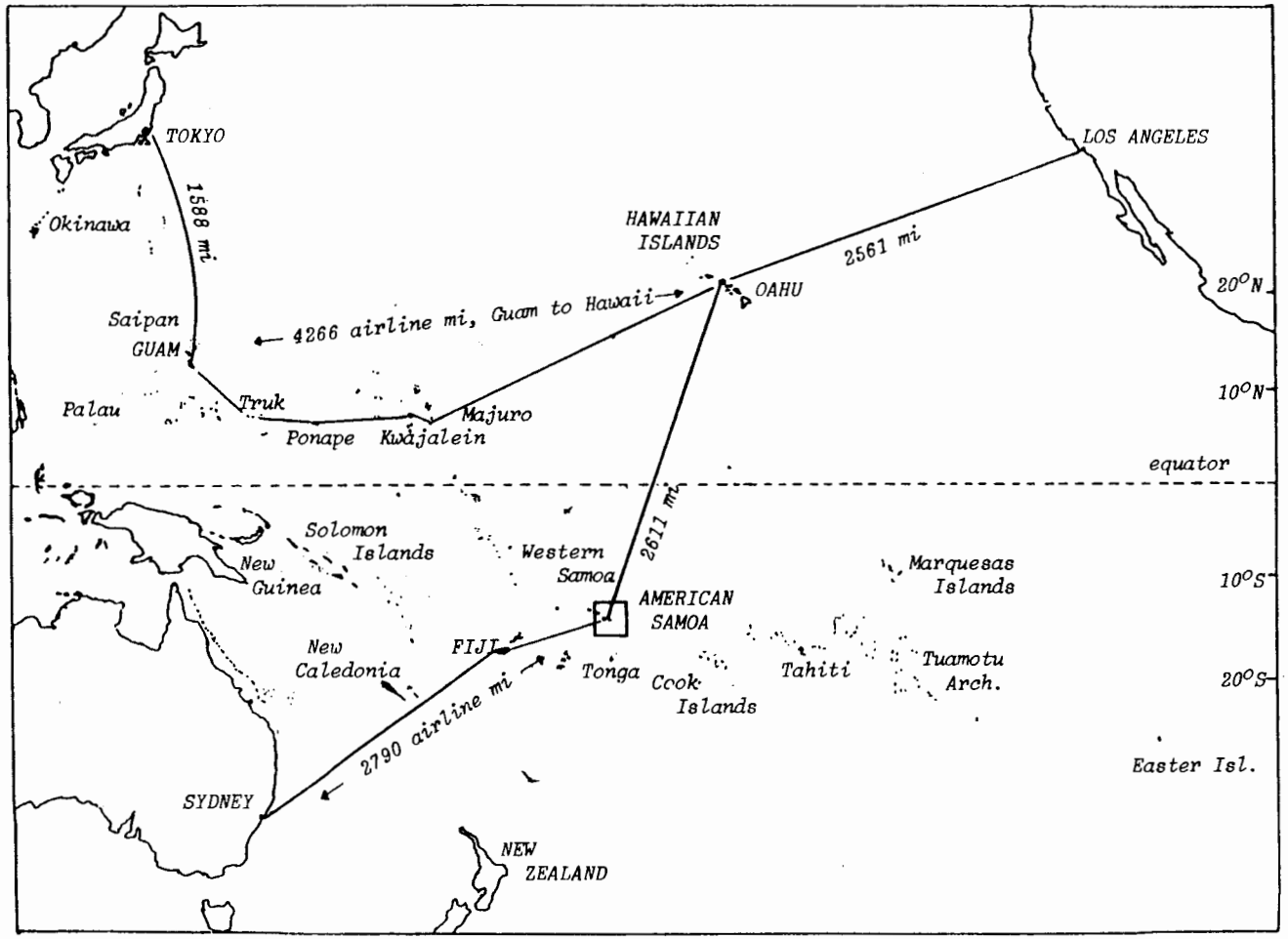


Figure 1. Location of American Samoa, Site of Ocean Disposal Investigations (see box)

I. INTRODUCTION

HISTORICAL BACKGROUND

The main island of American Samoa is Tutuila, located some 2600 mi (4160 km) south-southwest of Hawaii (Figure 1). The islands of Samoa are part of the Samoan ridge, a deep water formation from which volcanic peaks rise steeply to elevations up to 3000 feet (914 m) above sea level. Pago Pago Harbor is formed from the drowned caldera of a large volcano which was subsequently eroded by riverine flow (American Samoa Dept. of Public Works, 1976). The harbor now has roughly the configuration of a "bird's head," with the capital, Pago Pago, and associated villages located on the narrow silty margins of the harbor, backed by steeply rising peaks (Figure 2).

Fish processors in American Samoa have been located along the narrow margin of the "upper beak" near Anua (Figure 2) since part of a World War II naval installation was converted into a tuna processing facility by IBEC. Van Camp succeeded IBEC, and Star-Kist opened their plant in 1963 (Vincent Evich, Star-Kist Foods; pers. comm).

Because the inner harbor is poorly flushed, waste loading became a severe environmental problem concomitant with increased fish processing. The imposition of regulatory controls followed the sequence of requirements under the National Environmental Policy Act (NEPA) in 1970 and the Federal Water

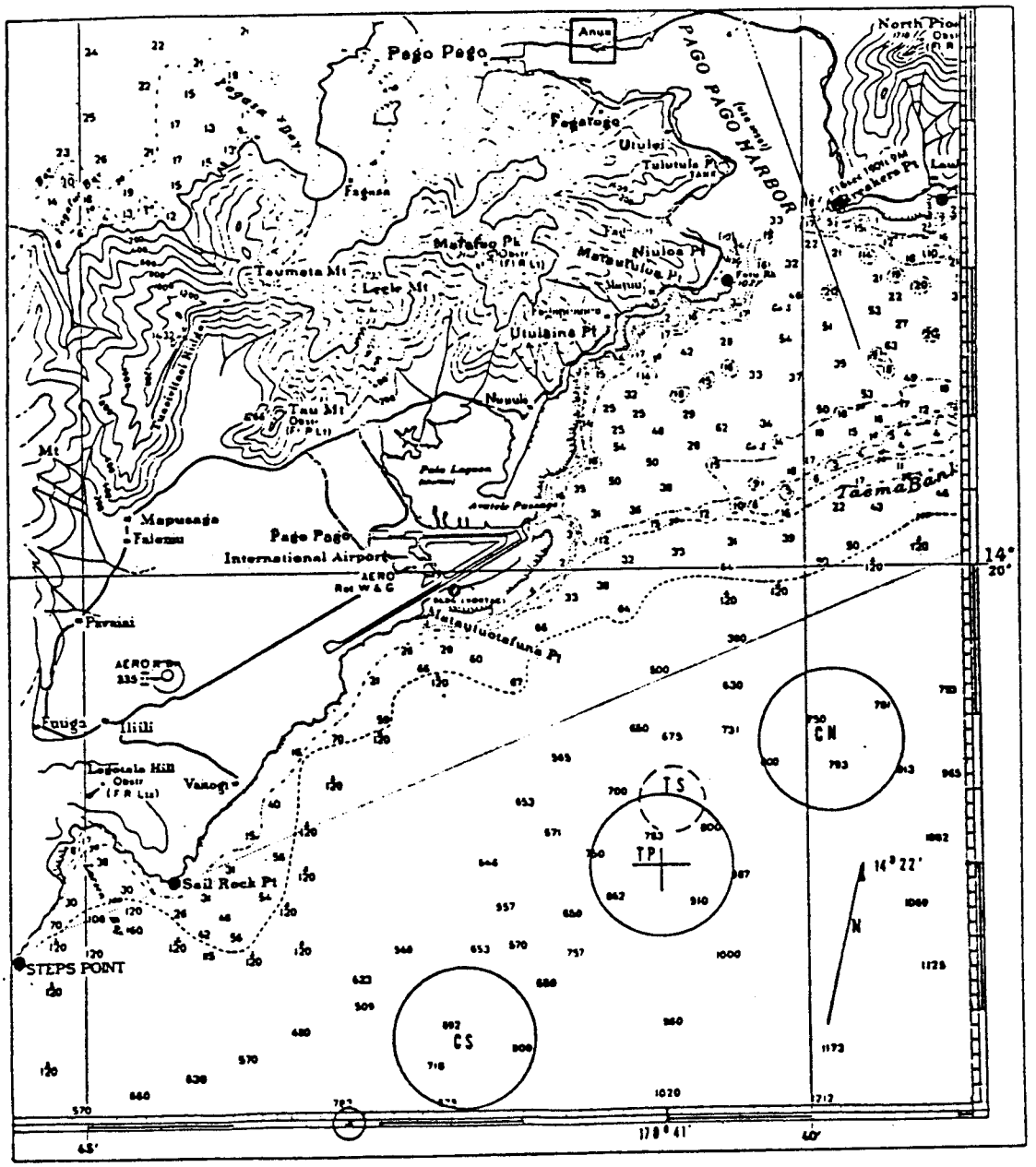


Figure 2. Fish Waste Disposal Sites, American Samoa. Control South (CS), Control North (CN), Primary Test Site (TP), Secondary Test Site (TS), Pago Pago Harbor Fish Processors (Box).

Pollution Control Act Amendments of 1972. Whereas all particulates, solid wastes, and liquid wastes from the fish processors had gone directly into the harbor, screening was instituted along with installation of facilities for scrap reduction to fish meal. The Dissolved Air Flotation (DAF) process, introduced for tuna waste treatment in 1974 under a requirement of the NPDES permit program, greatly reduced the waste loadings to the harbor but in turn created a different problem. The DAF process created a semi-solid sludge, odoriferous, saline and containing various coagulants.

Because EPA policy at that time precluded ocean disposal of the sludge, land disposal of the semi-solid material was mandated when DAF treatment was begun.

There is a very limited amount of land for habitation and cultivation on the peripheral shoreline and fringing reef structures of the island or on the plains near the airport. The very porous nature of the soil and the associated problems of percolation thus make land-based disposal of solid wastes a significant problem for American Samoa. The disposal of the wet cannery wastes in local landfill was objectionable to nearby residents, attracted vermin, and increased public health hazards. Trucking of the wastes to the landfill from the canneries required passing through the downtown area on the only road --- a road shared as well by pedestrians (and by events such as the parade pictured in frontispieces). Thus, a

permit for ocean disposal was sought from EPA Region IX in 1979, at the recommendation of EPA staff from the National Enforcement Investigations Center in Denver.

INTERIM SITE DESIGNATION

In accordance with provisions of the Marine Protection, Research and Sanctuaries Act of 1972 (Pl 92-532, 33 USC 1401 et seq.), permit No. OD 79-01/02 was issued jointly to Star-Kist Samoa, Inc. and the Van Camp Seafood Division of the Ralston Purina Co. An interim site was designated by the Environmental Protection Agency in the Federal Register, Vol. 45, No. 228, Mon. November 24, 1980.

As stated therein, under 40 CFR Part 228, Ocean Dumping; Final Designation of Site:

> "...EPA today designates a fish cannery waste site in the Pacific Ocean as an EPA approved interim ocean site. This action is necessary to provide a site for the dumping of fish cannery waste originating in American Samoa which can no longer be accommodated on land...."

The site designated lies off Tutuila Island, American Samoa in the South Pacific (Figure 2). The center point of the one nautical mile - diameter dumpsite is located at 170°41'W and 14°22'S. (CFR 228.12, Delegation of management authority for interim ocean dumping sites; opt. cit.).

Transportation of wastes to the dumpsite is by the 125 ft vessel Misimoa, which has a capacity of approximately 41,000 gals (155,202 l) and discharges through hull ports forward of the propellors at a rate no greater than 500 gpm when moving at 5 knots, so that optimum initial mixing is obtained.

Disposal under the permit is limited to 130,000 tons per year of fish cannery waste generated on the island of Tutuila, American Samoa, but amounts have been far less than that (Table 2, p . 35).

The application for permit and site selection included the items of information required in the Federal Register, Vol. 42, No. 7, Title 40, Part 221, January 11, 1979 (See Appendix C). The issuance of the interim site designation was based in part on data contained in the "Evaluation of Ocean Disposal of Cannery Sludge in American Samoa", prepared for Star-Kist Foods, Inc. and Ralston Purina Co. by M&E Pacific, Inc. (September 1979). That report included data on Pago Pago Harbor, the Tafuna sewage treatment plant outfall site and adjacent coastal waters. In addition, responses to the criteria for site selection, listed in Part 228.6 of the above Federal Register, were filed with EPA Region IX by a letter and attachment dated March 10, 1980 (see Appendix C).

As a condition for issuance of the permit, certain laboratory analyses of the wastes were required to be performed quarterly. (See Section VI, Federal Regulatory

Compliance). A monitoring plan to define the fate of wastes dumped under various climatic and sea conditions and a scope of work for environmental assessment of the impact of site use for disposal were required, in consultation with EPA Region IX, to be carried out during the three-year interim permit period. The monitoring parameters are summarized in Table 1, p 34.

NOAA-OMPA INVESTIGATIONS

In 1981, the Office of Marine Pollution Assessment (NOAA, Department of Commerce) funded a grant to the principal investigators at the University of Southern California entitled "Assessment of the Ocean Disposal Alternative for Management of Fish Processing Wastes" to include research in southern California and American Samoa. Partial matching effort was provided by Star-Kist Foods in the southern California investigations, and by Star-Kist Samoa and Van Camp Seafood Division of Ralston Perina Co. in American Samoa.

The objective of the fish processors are to insure an adequate disposal site capacity within feasible economic and logistic capabilities of the industry and to have that site designated for permanent use by the EPA Office of Marine Protection.

The responsibility of the federal and local regulatory agencies is to insure that disposal occurs in the mode least damaging to the environment, commensurate with available

alternatives and with protection of living resources.

The objective of the Office of Marine Pollution Assessment (NOAA-Department of Commerce) grant is to investigate the basic premise that ocean disposal of non-toxic, biodegradable wastes can provide the best alternative for management of fish processing wastes.

Thus the needs of the processors for documentation of trend assessment in American Samoa were concurrent with implementation of the NOAA investigations. The field and laboratory programs were designed to fulfill the objectives of both programs.

Information for the EPA permit renewal must include an environmental trend assessment of the impact of the use of the site for disposal. The present report is directed toward that requirement.

IMPACT ASSESSMENT RESEARCH

FIELD INVESTIGATIONS

Field investigations were carried out during two periods in American Samoa, one from 15 to 23 Janaury 1982, representing the rainy season, and the other from 16 to 30 July 1982, representing the dry or Trade Wind season. The parameters selected for measurement were similar to those used in southern California studies (Soule and Oguri, 1982) with a few exceptions. Benthic sampling was not included in American Samoa due to the great depths (exceeding 1200m) at the disposal site which would

inhibit the dumped material from reaching the bottom. Fish surveys were made on a visual basis, since no fathometer or SONAR gear are available in American Samoa. Navigation is based entirely on visual sightings, using sextant and compass, but good landmarks such as the airport VORTAC tower, Breakers Point, Fatu Rock, and Matafao Peak, (Figure 2), are usually visible for triangulation.

Table 1 (p 34) lists the parameters measured and the methods used for analysis. The instruments were all transported by air as passenger baggage to American Samoa for safer handling, and recalibrated upon arrival. Laboratory equipment was installed in the Rainmaker Hotel, and the American Samoa Marine Resources Center (MRC) provided other logistical support. The MRC research vessels Sausauimoana or Autele were made available by Dr. Richard Wass and Mr. Henry Sesepesara. Dr. Wass and William Pedro assisted with field navigation and sample collection. Senator Peter Reid and Mr. Brant Judy made commercial refrigeration space available for holding samples when the cannery freezer facilities were not operating. Cooperation of the Star-Kist and Van Camp laboratory and plant facilities personnel was noteworthy during field efforts.

Quantities of waste dumped between 1 October 1981 and 31 December 1982 by the two processors are listed in Table 2, (p 35), while quantities dumped during the field monitoring are listed in Table 3, (p 36).

II. JANUARY FIELD RESEARCH

CRUISES

The first cruise on 18 January 1982 on the R.V. Sausauimoana with Paul Pedro, skipper, was short due to a very rough seas and rainstorms. It was scheduled in the afternoon along with a demonstration dump for a visiting Congressional committee which was on a sport-fishing cruise off Tutuila. The remote probe battery was unable to hold sufficient charge during that period so on subsequent cruises, on the R.V. Autele, leads were attached to the onboard batteries. The dump was started on the 18th before control stations could be sampled, and the dump vessel Misimoa could not be contacted by the sampling vessel due to communication difficulties.

On 20 January, water samples were taken from on board the R.V. Autele before, during and after dumping operations for determination of ammonia, five-day biochemical oxygen demand (BOD 5), total organic carbon (TOC) and oil and grease. In addition, the transmissometer and Secchi disc were used to determine the turbidity associated with the dump on the surface and at 2m, 3m, 6m, and 10m, and the Forel-Ule scale was used for color evaluation.

On 21 January, the parameters of temperature, salinity, dissolved oxygen (DO) and pH were measured by Martek instrument, before, during and after dumping. Additional BOD 5 samples were taken as well as water samples for oxygen determi-

nation by the Winkler method for comparison. Winkler values tended to be slightly lower than Martek values. (See Appendix A for field and laboratory data).

Water samples for BOD and TOC determination were refrigerated after acidification to pH2 with sulfuric acid, and packed in ice for transporting to the USC Environmental Engineering Laboratories in Los Angeles.

Tracking the Plumes and Sampling

Drogues were deployed on each cruise in order to follow surface current movements. Drogues consisted of colored plastic plates, each pierced by a Kahl Scientific plastic drogue wand with weighted tip and cork ball float. Various colored streamers of surveyors tape were used to code the place of deployment and identify the plume movement upon resighting.

The locations of the various January sampling stations are plotted in Figure 3. The navigation of the dump vessel by visual sightings suggests that its position within the dump circle at the start of disposal may be somewhat imprecise, but dumping did begin each day well within the test prime (TP, Figure 2) circle, as designated by the Ocean Dumping Permit. The research vessel began sampling in the test secondary (TS) circle at the start of the dump as planned, and monitored the plume as it spread. It also sampled the control north (CN) and control south (CS) sites. Stations A-F were sampled on 18

January 1982, G-T on 20 January, and 2-10 on 21 January.

The spread of the plumes on the three days differed for each day, as illustrated in Figure 4; this is in contrast to the limited information published previously in studies by the Government of American Samoa Department of Public Works (CH2M Hill, 1976) and the study "Evaluation of Ocean Disposal of Cannery Sludge in American Samoa" (M&E Pacific, 1979). On 18 January,the plume was almost static in spite of south winds of 4-7 mph and rough water. On 20 January, the plume moved to the southwest with the wind from the east-northeast, but the plume remained almost entirely within the dumpsite circle except at the southwest edge. On the 21 January, however, the plume split. Winds were at first light, increasing to 16 mph from the northeast. The wind varied in direction and the incoming tide may have carried some drogues and patches of slick to the north-east while others traveled almost at right angles to the wind, to the southeast. At control south (CS), conversely, the drogues traveled southwest in strongly wind-driven movement parallel to the coast. This is more in keeping with the earlier studies mentioned above, and may be typical of the nearshore area to the southwest of the airport. Results in July 1982 also differed, with drogue movement at the surface, 10m and 20m trending toward the north-northwest or north-north-east under strong winds from the south, as will be discussed later.

Turbidity

Tracking the turbidity of the plume on the surface and at depth was done by Secchi disc, and by the inverse measurement of percent light transmittance (%T) using a Hydroproducts transmissometer with a self-contained light source and a 10 cm path. The depth profiles of %T for January dates are presented in Figures 5, 6 and 7.

Two phenomena are clearly seen; one is that a surficial depression of transmittance occurs immediately after dumping, followed by recovery. The other is that as surface recovery progresses, transmittance decreases through the water column for 3-6m and sometimes deeper. A difficulty in interpreting data is that natural turbidity seemed to increase as the day progressed. Upwelling seemed to occur at the control south (CS) location although that phenomenon has not previously been suggested as occurring off Tutuila, so that comparisions with disposal plume turbidity are less easily interpreted. Thus, the apparent decrease in transmittance due to dumping must be weighed statistically.

The tropical waters off oceanic islands are generally low in phytoplankton productivity, tending to negate that as an explanation. The chlorophyll a data for Pago Pago Harbor and along the south coast (M&E Pacific, 1979) are similar to values found elsewhere in the tropical Pacific (Doty and Oguri, unpubl.), but are 2 to 3 orders of magnitude lower than those

from Los Angeles Harbor (Soule and Oguri, 1980), for example.

Biochemical Oxygen Demand

The five-day BOD samples were acidified on board and refrigerated for transport to Los Angeles. The BOD 5 levels in samples for 21 January increased from ambient levels immediately at the start of the dump (Figure 8) and began to decline as soon as dumping was completed (center vertical line, Figure 8). The low readings from station 08 samples were probably not representative, since they were from the periphery of the plume (Figures 3, 4); those at station 10 were probably more representative. Lack of afternoon controls makes comparison less certain as to whether BOD 5 levels returned to ambient at the surface during the two hour period.

Comparison of BOD 5 and Ammonia

The BOD 5 surface values for 20 January were plotted (Figure 9) against surface ammonia (NH_3) readings and proved to be remarkably similar in configuration, except that initially the ammonia level increased from morning ambient values as soon as dumping began (Station K), whereas BOD levels declined from control levels. Both parameters then continued parallel in a steep decline, suggesting initial inhibition, and then both rose rapidly. The sample at Station N was distinctly in the plume, as shown by light transmittance (Figure 6). Both NH_3 and BOD declined below afternoon control

south (CS) levels by 1400 hours.

The parallel results of BOD 5 and NH_3 suggest that NH_3 analysis, which can be done much more easily then BOD 5, may be the parameter of choice for assessing impacts of the plume in such a remote site.

Dissolved Oxygen

Control North (CN) values for dissolved oxygen (DO) were high at the surface, 3m, 6m and 10m in the morning of 21 January (Figure 10); all were at 6.1 ppm, as measured by the Martek probe. Winkler DO values tended to be slightly lower (e.g., 0.3 ppm less). Control surface values at TP and CS were higher but the other depths had lower readings. Oxygen levels declined swiftly after dumping began, especially at 3m, but recovery was quicker at that depth as well. All readings were close to control values by the end of the monitoring period, but surface values did not return to morning levels. Surface DO levels tend to drop naturally during the hotter part of the day.

Secchi Disc and Sea Color

The measurement of water transparency and color are visual, and are thus highly subjective. It is best if one person performs these tasks throughout the period to minimize variations. As illustrated in Figure 11, the white Secchi disc

was visible to more than 20m at controls. Visibility plummeted to less than 4m after dumping started and then gradually recovered but not to control levels during monitoring. The pattern tends to differ slightly from the metered transmittance (Figure 6) which shows more sensitivity.

The Forel-Ule color scale did not indicate as great a variation, although there is considerable difference on the scale from FU 1, a cobalt blue, to the brownish green seen in the plume and the turquoise of the plume after dispersion and degradation have begun.

Computer Analysis

Principal Component Analysis (PCA), a type of factor analysis (Figure 12) develops vectors (scaled, directional arrows) to express the relationships among the parameters. Vectors that are similarly directed are correlated, while those that point in opposite directions are inversely related. If vectors are perpendicular to one another, parameters are presumed not to be related. The Figures actually represent 3-dimensional space.

In the factor analysis, several parameters are grouped into three principal factors. The dominant combination in the January analysis includes in Factor 1, depth, percent light transmittance (%T) and ammonia. The second factor includes the parameters of distance from the dump and BOD 5, and the third is time of day. Together the three factors account for 74

percent of the variance in the entire array of measurements (See Table 4).

From the factors shown as vectors in Figure 12, it would appear that ammonia was inversely related to depth, while percent transmittance was directly related to depth. The BOD 5 was directly related to distance from the dump; it also appeared to be related to time in factors 1 and 2, and in 1 and 3, but was not related to time in 2 and 3, so the rotational changes in vectors suggests that the time relationship is not valid.

Testing the data by ANOVA (Analysis of Variance) produced some statistically significant information (Table 5). As illustrated in the following bar graphs (Figures 13-18), the single horizontal lines represent the ranges (extremes), and the central vertical lines, the means; the double bar lines represent 2 Standard Errors.

In Figures 13 and 14, percent light transmittance can be seen to vary significantly with depth as well as with dumping and post-dumping conditions. The difference in %T between controls and the surface values at the time of dump was statistically significant, but there was considerable overlapping of data at depths. There was a marked reduction in %T at the surface immediately following the dump. In the post-dump period, some depression in %T remained, but there was substantial recovery as material disappeared, by sinking,

dispersing and dilution.

Ammonia values (Figure 15) showed statistically significant increases during dumping and post-dump periods only and the surface through 3m depths, but values were not significantly different from controls at 6m and 10m depths. This suggested that the ammonia-containing material was in the fraction which tended to float rather than sink.

On 20 January, the lowest BOD values (Figure 16) occurred at the 6m and 10m depths during dumping and differed significantly from all other values. The post-dump data overlapped values at controls. The 21 January data produced a different picture (Figure 17). The BODs were high in the dump and post-dump periods at virtually all depths, but the variation was so great that there were no statistically significant differences from controls.

Differences in surface oxygen values (Figure 18) as determined by Martek probe were significant between controls at both dump and post-dump periods. However, there were no significant differences among the other depths. Analysis of Winkler DO measurements showed a similar surface difference but it was not significant.

Apparently, disposal had no discernible effect on temperature, salinity or pH. The difficulties of sampling through the water column while the slick and the boat are drifting, and some dump material is sinking, make the potential great for erratic results. Yet statistically significant differences were found in light transmittance, ammonia and BOD 5.

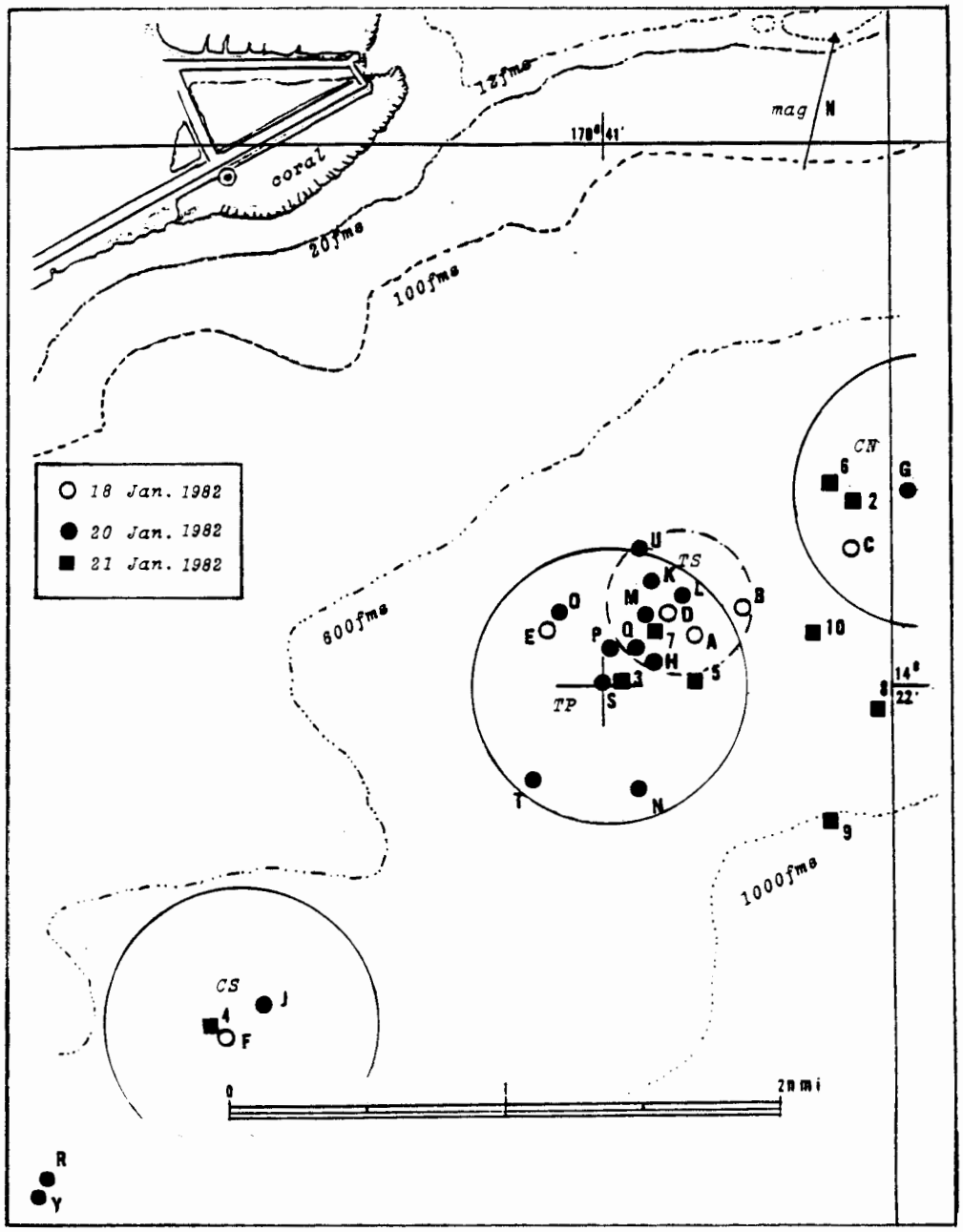


Figure 3. Monitoring Stations, 18, 20, 21 January 1982. Control North (CN), Control South (CS), Prime Test (Dump) Site (TP), Secondary Test (Plume) Site (TS).

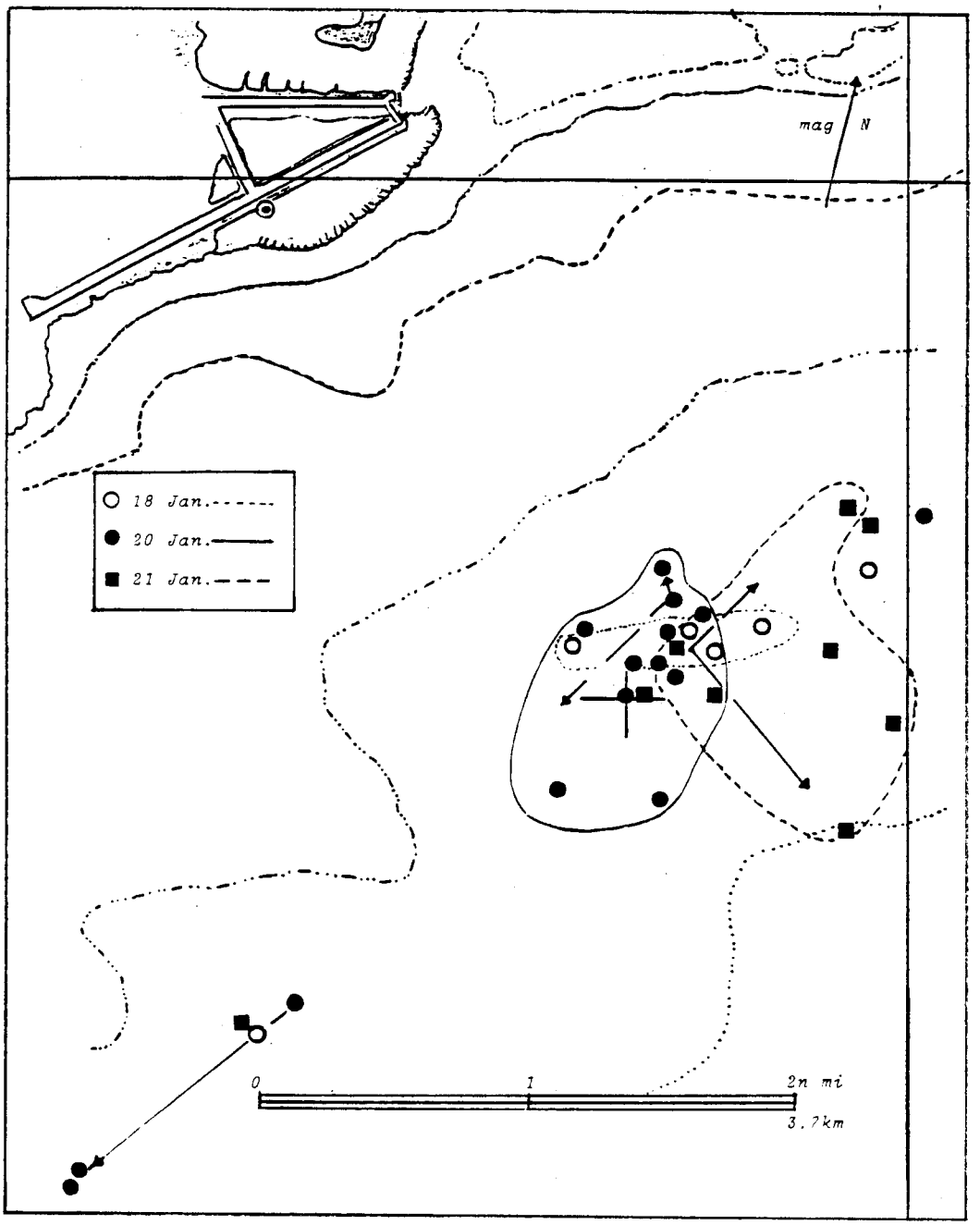


Figure 4. Movement of Waste Plumes Tracked by Drogues, American Samoa, 18, 20, 21 January 1982.

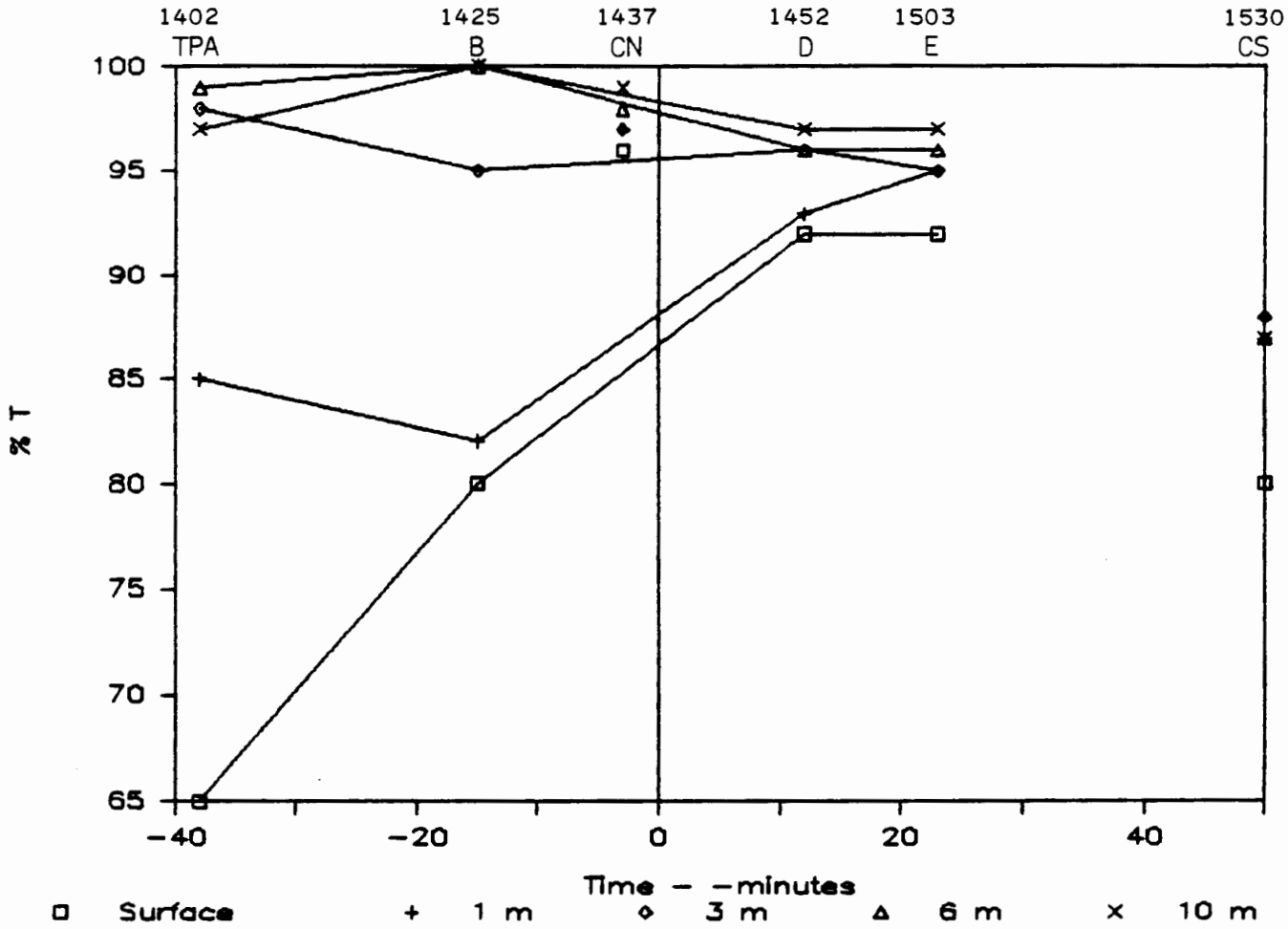


FIGURE 5. PERCENT LIGHT TRANSMITTANCE (%T), 18 JANUARY 1982.

DUMP WAS UNDERWAY WHEN MONITORING STARTED AT 1402. ZERO VERTICAL LINE MARKS END OF DUMP. NOTE THAT DEPRESSION IS PRIMARILY LIMITED TO UPPER 3 METERS. FINAL CONTROL SOUTH (CS) VALUES WERE CONSIDERABLY LOWER THAN TRANSPARENCY VALUES IN THE DISPERSING PLUME.

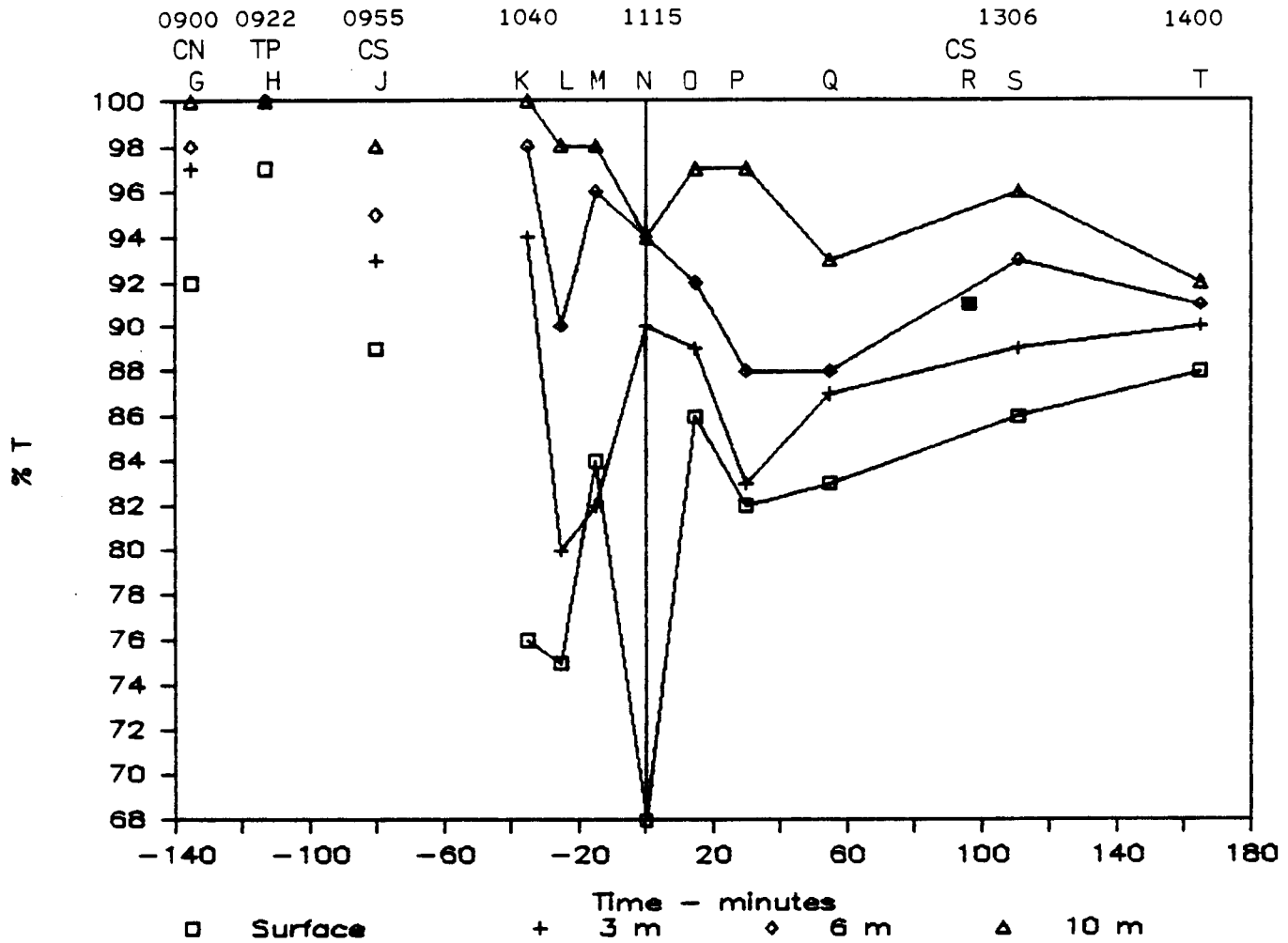


FIGURE 6. PERCENT LIGHT TRANSMITTANCE, (%T) 20 JANUARY 1982.

CONTROL MEASUREMENTS WERE TAKEN PRIOR TO DUMP, WHICH WAS STARTED AT 1040 (K) AND FINISHED AT 1115 (VERTICAL LINE). NOTE LOWER VALUES FOR CONTROL SOUTH (CS) COMPARED WITH CONTROL NORTH (CN). THE SURFACE AND 3 METER VALUES WERE STRONGLY DEPRESSED INITIALLY, WHILE 6 AND 10 METER VALUES WERE LESS SO, WITH 10 METER VALUES REMAINING WITHIN CS RANGE.

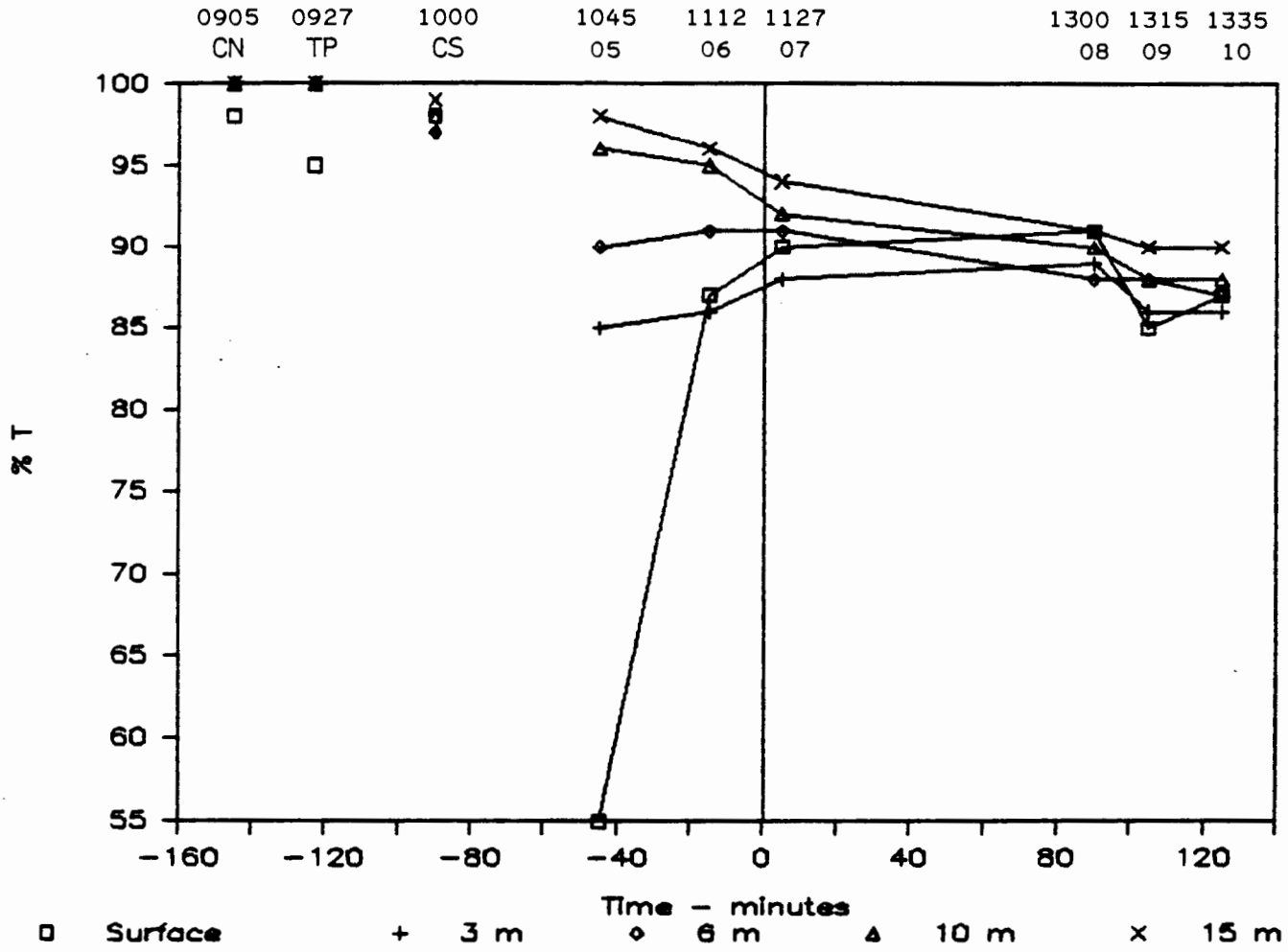


FIGURE 7. PERCENT LIGHT TRANSMITTANCE (%T), 21 JANUARY 1982.

CONTROL VALUES IN THE MORNING WERE HIGH, AND SURFACE VALUES WERE QUITE DEPRESSED AT THE START OF DUMPING (05 AT 1045). SURFACE VALUES ROSE RAPIDLY DURING DUMPING AND VALUES FOR ALL DEPTHS WERE SIMILAR AFTER DUMPING STOPPED (1127, VERTICAL LINE). WINDS WERE GUSTING TO OVER 16 MPH SO THAT MIXING APPARENTLY WAS MORE PRONOUNCED THAN IT WAS ON THE 18TH OR 20TH, BUT TRANSPARENCY VALUES DID NOT RETURN TO MORNING CONTROL VALUES.

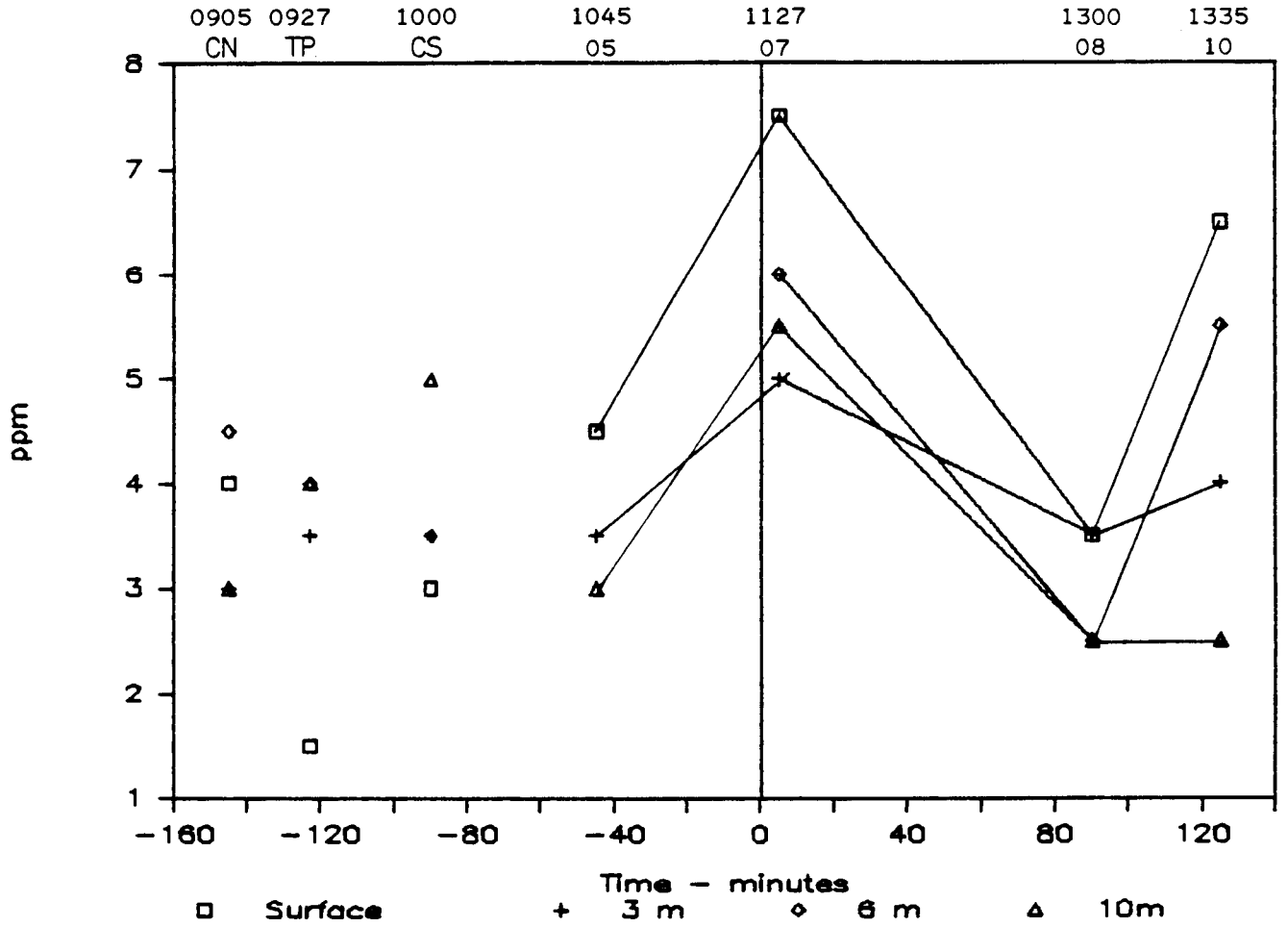


FIGURE 8. FIVE-DAY BIOCHEMICAL OXYGEN DEMAND (BOD 5), 21 JANUARY 1982.

BOD VALUES ROSE FROM AMBIENT LEVELS DURING DUMPING AND DECREASED AFTER DUMPING WAS CONCLUDED. STATION 8 WAS ON THE EDGE OF THE PLUME AND SO PROBABLY WAS NOT AS REPRESENTATIVE OF BOD LEVEL AS STATION 10.

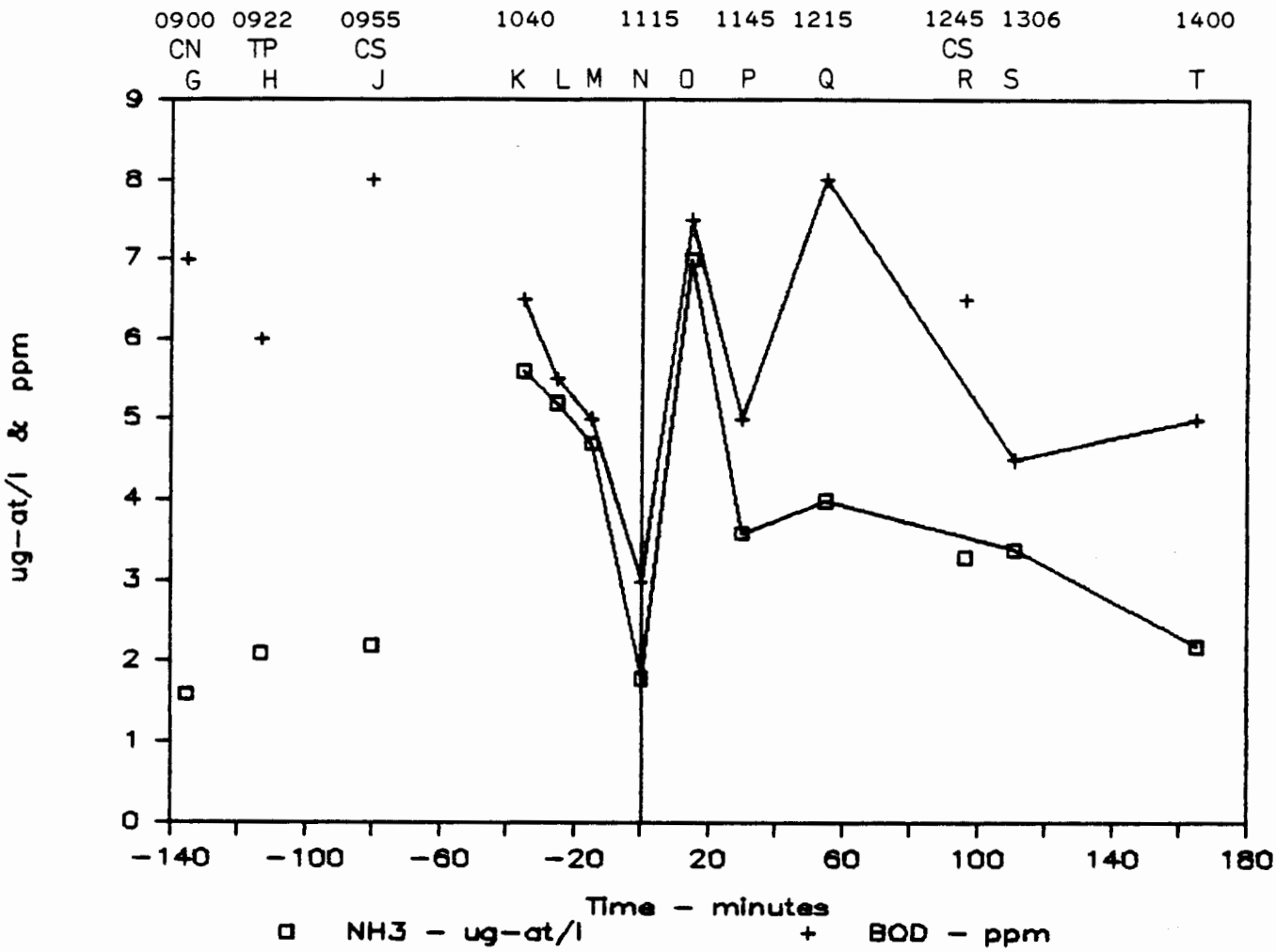


FIGURE 9. COMPARISON OF SURFACE AMMONIA (NH_3) CONCENTRATIONS AND FIVE-DAY BIOCHEMICAL OXYGEN DEMAND (BOD 5), ON 20 JANUARY 1982.

AMMONIA LEVELS AT MORNING CONTROL SITES WERE LOW AND BOD LEVELS RELATIVELY HIGH PRIOR TO THE DUMP. AMMONIA WAS HIGH AT THE START OF THE DUMP (K) AND DECLINED DURING DISPOSAL, AS DID BOD, SUGGESTING INITIAL INHIBITION OF BOD. BOTH PARAMETERS ROSE AFTER DUMPING CEASED (N), AND DEPENDING ON THE POSITION IN THE SLICK, DECLINED TO AMBIENT OR LOWER VALUES WITH TIME. *(1 µg.at NH_3/l = 0.017mg NH_3/l)*

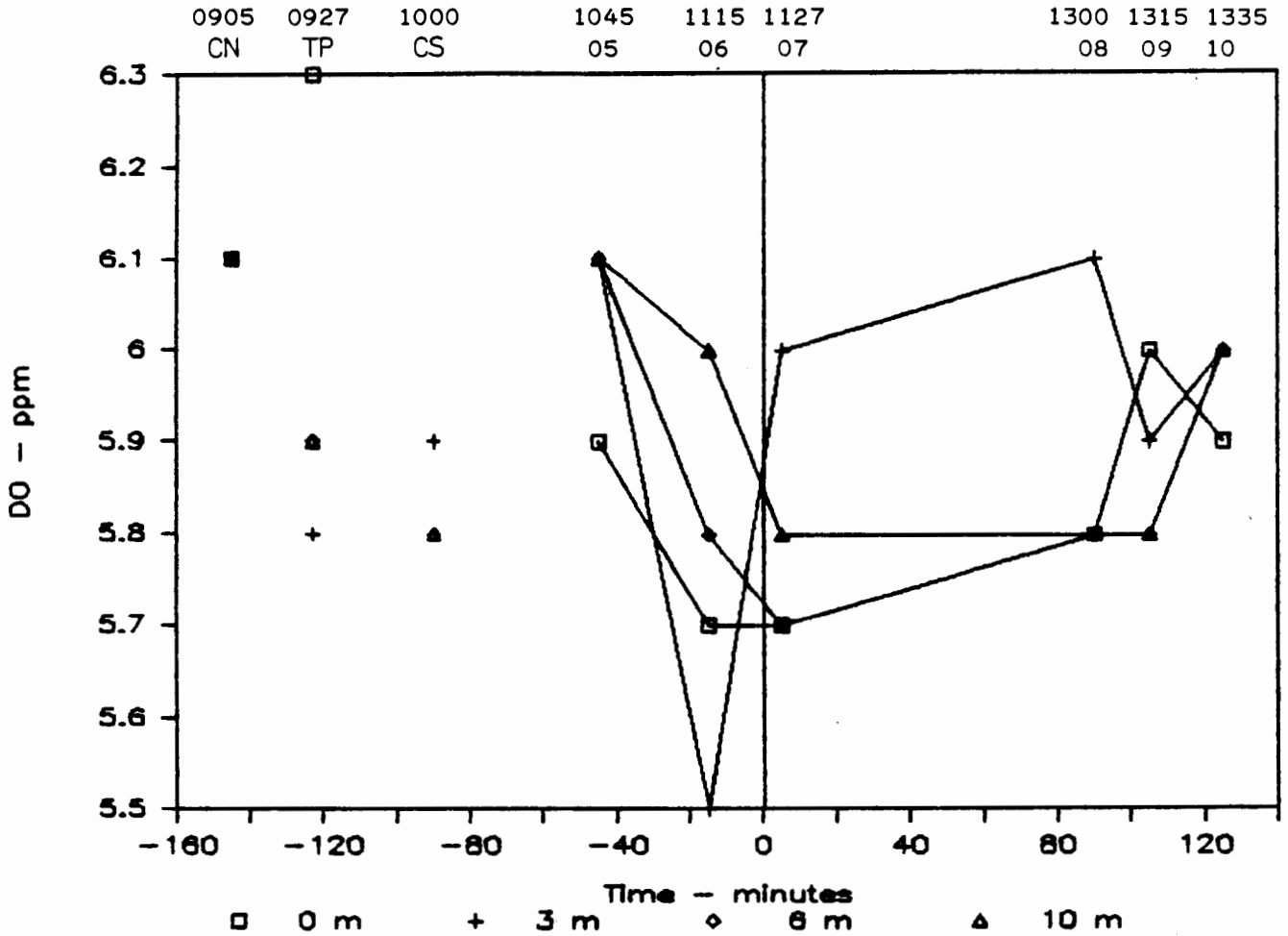


FIGURE 10. DISSOLVED OXYGEN, 21 JANUARY 1982.

MORNING CONTROL SAMPLES SHOWED UNIFORM LEVELS AT 6.1 PPM FOR ALL FOUR DEPTHS MEASURED AT CONTROL NORTH (CN). LOWER LEVELS AT TP AND CONTROL SOUTH (CS) WERE FOUND AT 3, 6 AND 10 METERS, BUT SURFACE VALUES RECORDED WERE 6.3 AT TP AND AN ANOMALOUS HIGH AT 6.8 PPM AT CS (NOT SHOWN). AT THE START OF DUMPING AT 1045, DISSOLVED OXYGEN DROPPED RAPIDLY. RECOVERY TO APPROXIMATELY AMBIENT CONTROL LEVELS OCCURRED FOLLOWING COMPLETION OF THE DUMP, ALTHOUGH SURFACE DISSOLVED OXYGEN TENDS TO BECOME LOWER DURING THE HOTTER PART OF THE DAY.

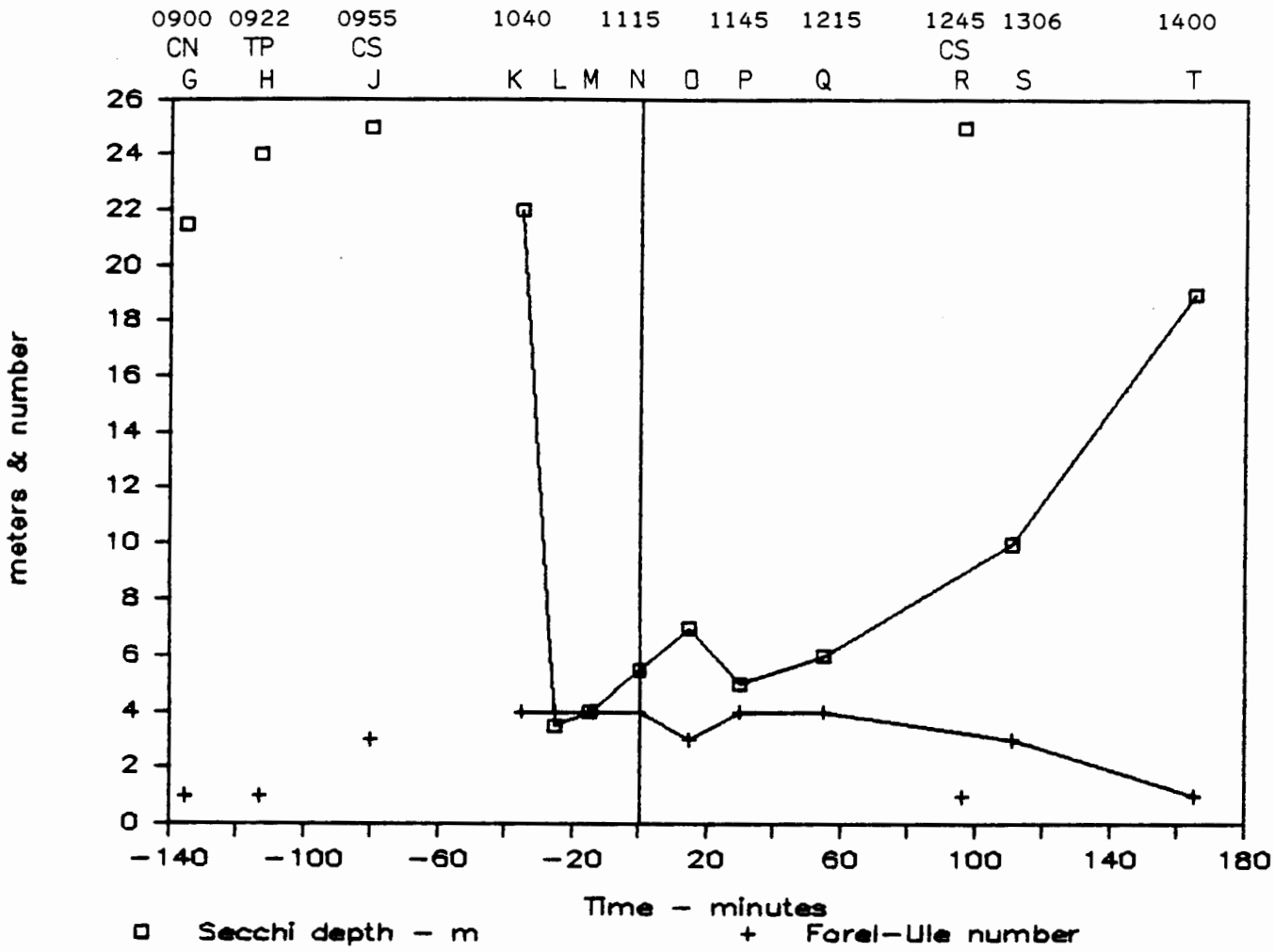
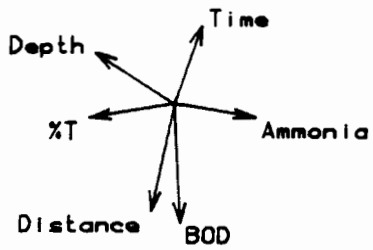


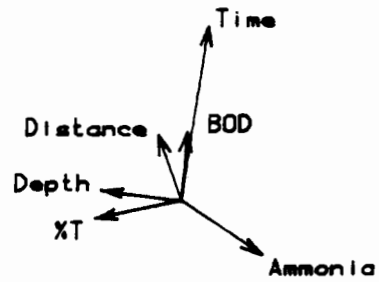
FIGURE 11. WATER TRANSPARENCY MEASURED BY SECCHI DISC AS COMPARED WITH COLOR MEASURED BY FOREL-ULE COLOR SCALE, 20 JANUARY 1982.

BOTH VALUES ARE MEASURED VISUALLY AND ARE THUS SUBJECTIVE. SECCHI DISC VALUES DID NOT RETURN COMPLETELY TO CONTROL LEVELS, BUT FOREL-ULE COLOR SCALE DID. THE COLOR SCALE AT FU 1 IS COBALT BLUE; INCREASING NUMBERS PROGRESS THROUGH TURQUOISE SHADES TO DARK GREENS INCREASING TO 15, AND BROWNISH SHADES TO 21. (DUMP STARTED AT K AND WAS COMPLETED AT N, AS SHOWN BY VERTICAL LINE AT TIME ZONE).

FACTORS 1 & 2



FACTORS 1 & 3



FACTORS 2 & 3

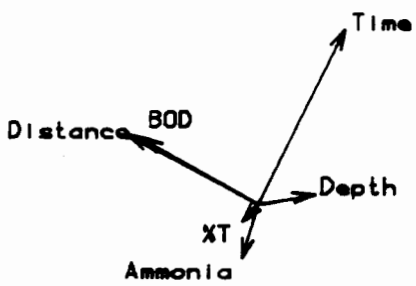


FIGURE 12. PRINCIPAL COMPONENT ANALYSIS (PCA) SHOWING RELATIONSHIPS BETWEEN PARAMETERS, JANUARY 1982

PARAMETERS EXPRESSED AS THREE-DIMENSIONAL VECTORS ARE DIRECTLY CORRELATED IF SIMILARLY DIRECTED AND INVERSELY CORRELATED IF POINTED IN OPPOSITE DIRECTIONS. PERPENDICULAR VECTORS ARE PRESUMABLY UNRELATED. FACTOR 1 INCLUDES DEPTH, PERCENT LIGHT TRANSMITTANCE (%T) AND AMMONIA. FACTOR 2 INCLUDES DISTANCE FROM DUMP AND BOD, AND FACTOR 3 IS TIME OF DAY. (SEE TABLE 4 FOR CORRELATION MATRIX)

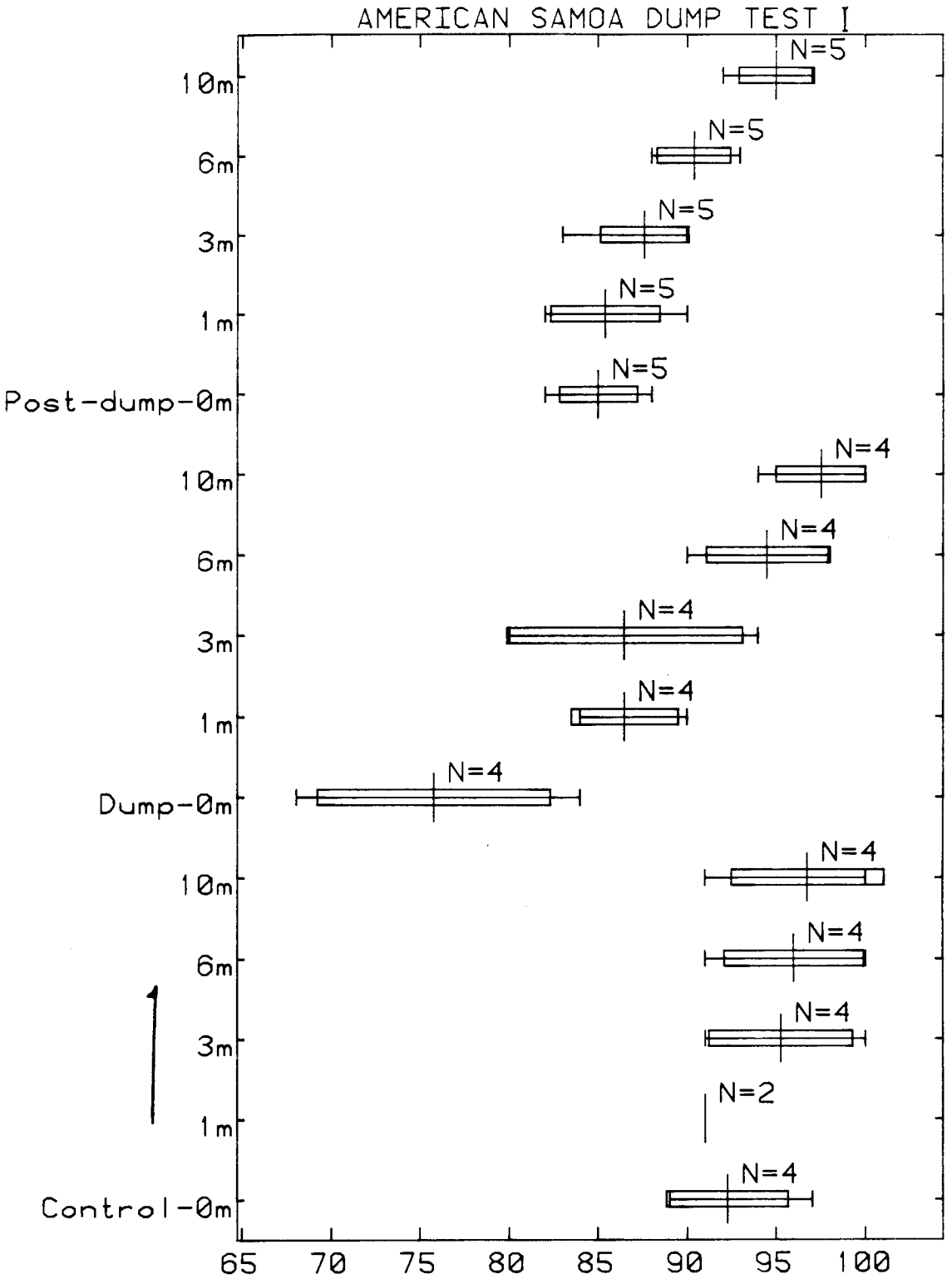


FIGURE 13. PERCENT LIGHT TRANSMITTANCE (%T), 20 JANUARY 1982.

* The difference is significant (by anova, P< 0.001). Range & mean ± 2 S.E. are shown. Homogeneity of variances requirement realized without transformation. (C=0.2066).

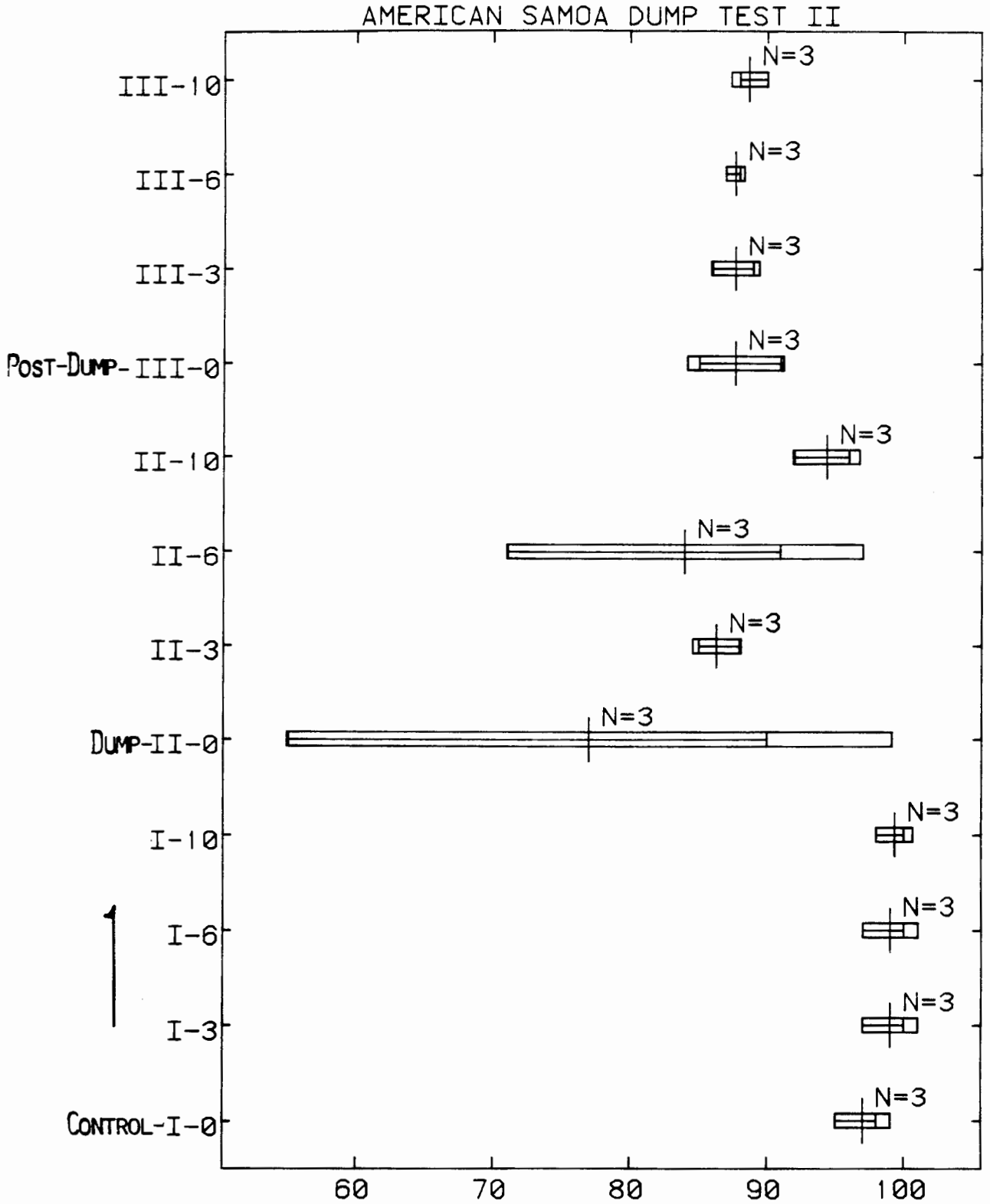


FIGURE 14. PERCENT LIGHT TRANSMITTANCE (%T), 21 JANUARY 1982.

* The difference is significant (by anova, P= 0.006).
Range & mean ± 2 S.E. are shown.
Data processed without transformation.

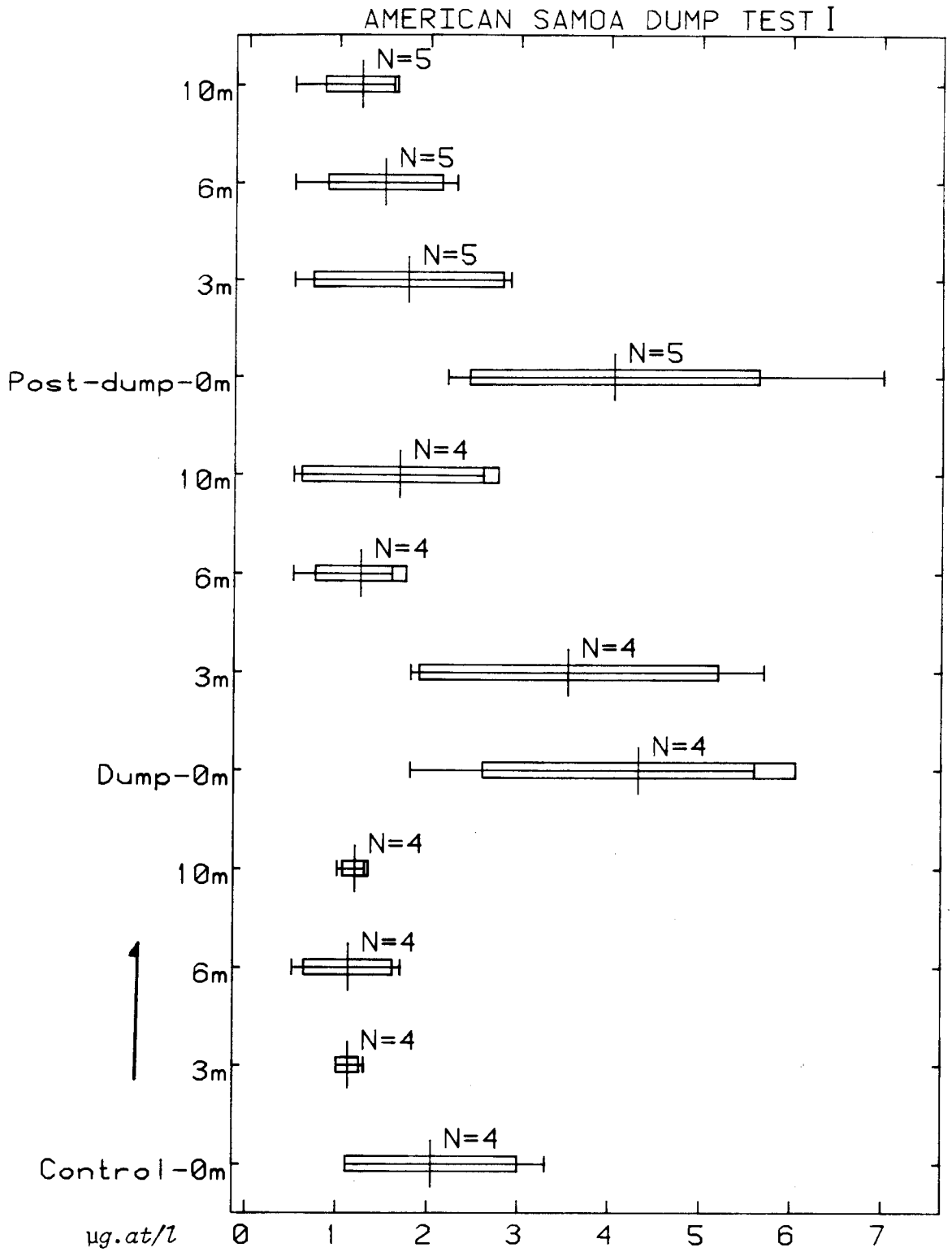


FIGURE 15. AMMONIA, JANUARY 20, 1982. *(1 µg.at NH_3/l = 0.017mg NH_3/l)*

* The difference is significant (by anova, P< 0.001).
Range & mean ± 2 S.E. are shown.
Homogeneity of variances requirement realized without transformation. (C=0.2350).

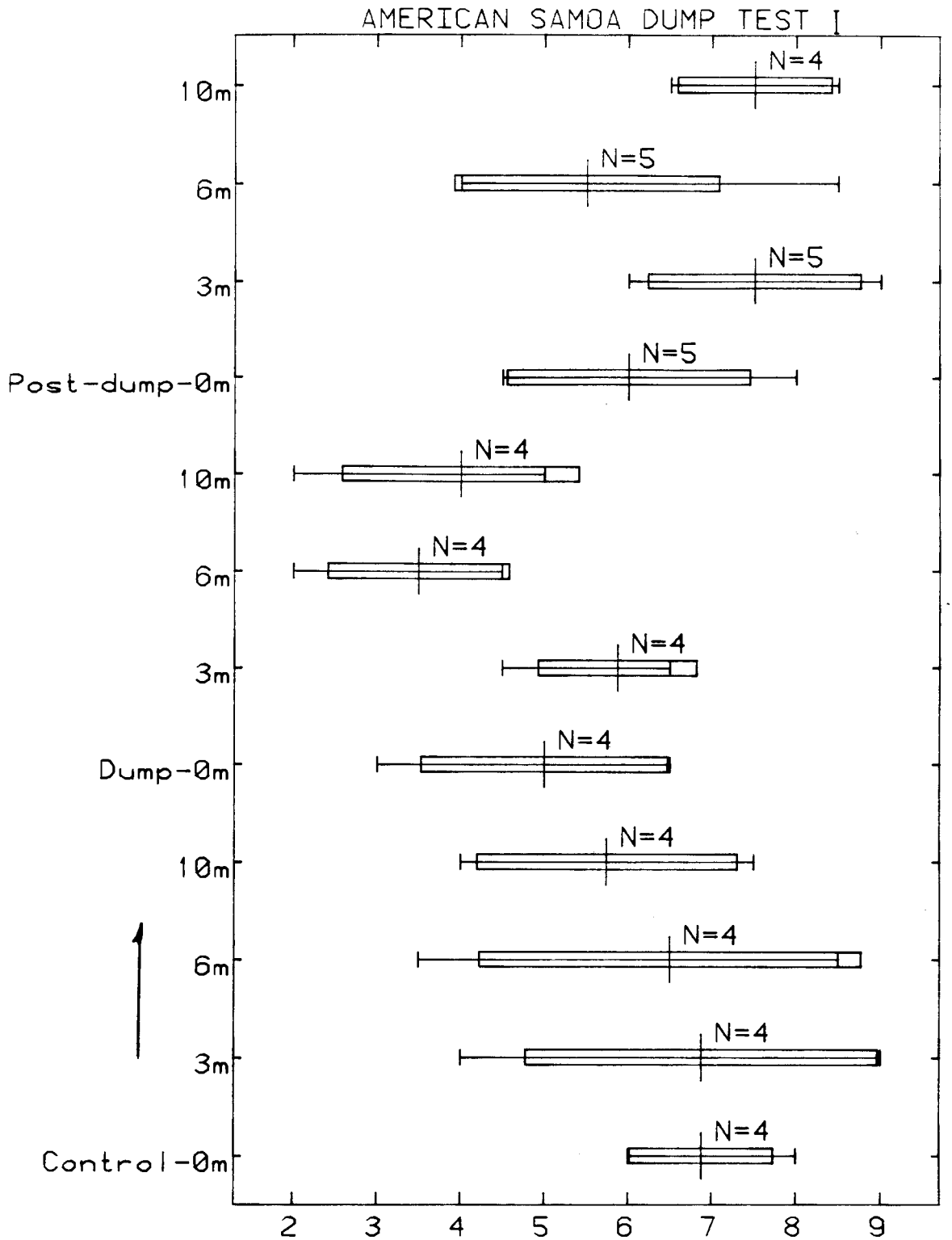


FIGURE 16. FIVE-DAY BOD (*mg/l*), 20 JANUARY 1982.

* The difference is significant (by anova, P= 0.007).
Range & mean ± 2 S.E. are shown.
Homogeneity of variances requirement realized without transformation. (C=0.1877).

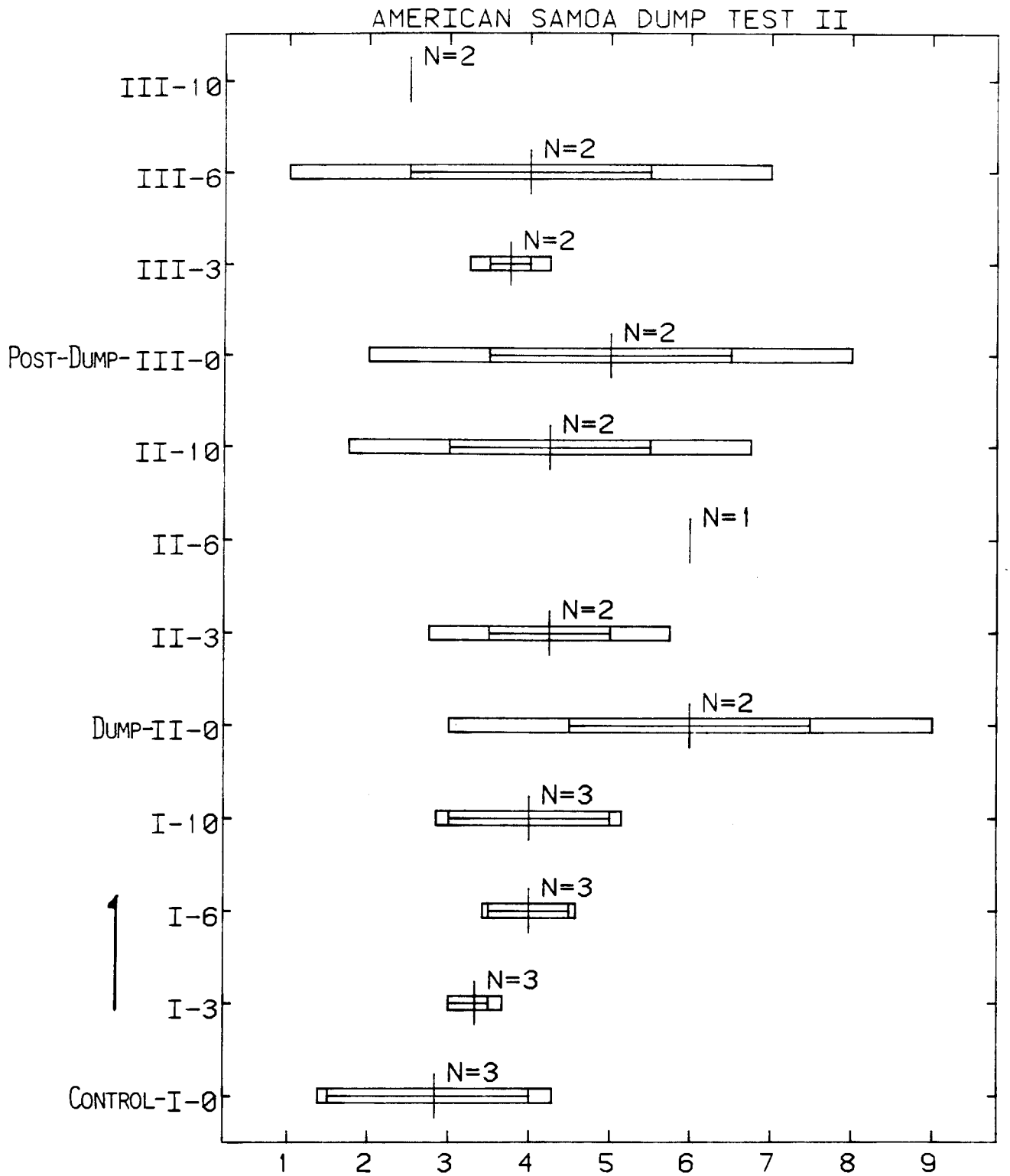


FIGURE 17. FIVE-DAY BOD (*mg/l*), 21 JANUARY 1982.

* The difference is not significant (by anova, P= 0.274). Range & mean ± 2 S.E. are shown. Homogeneity of variances requirement realized without transformation. (C=0.2164).

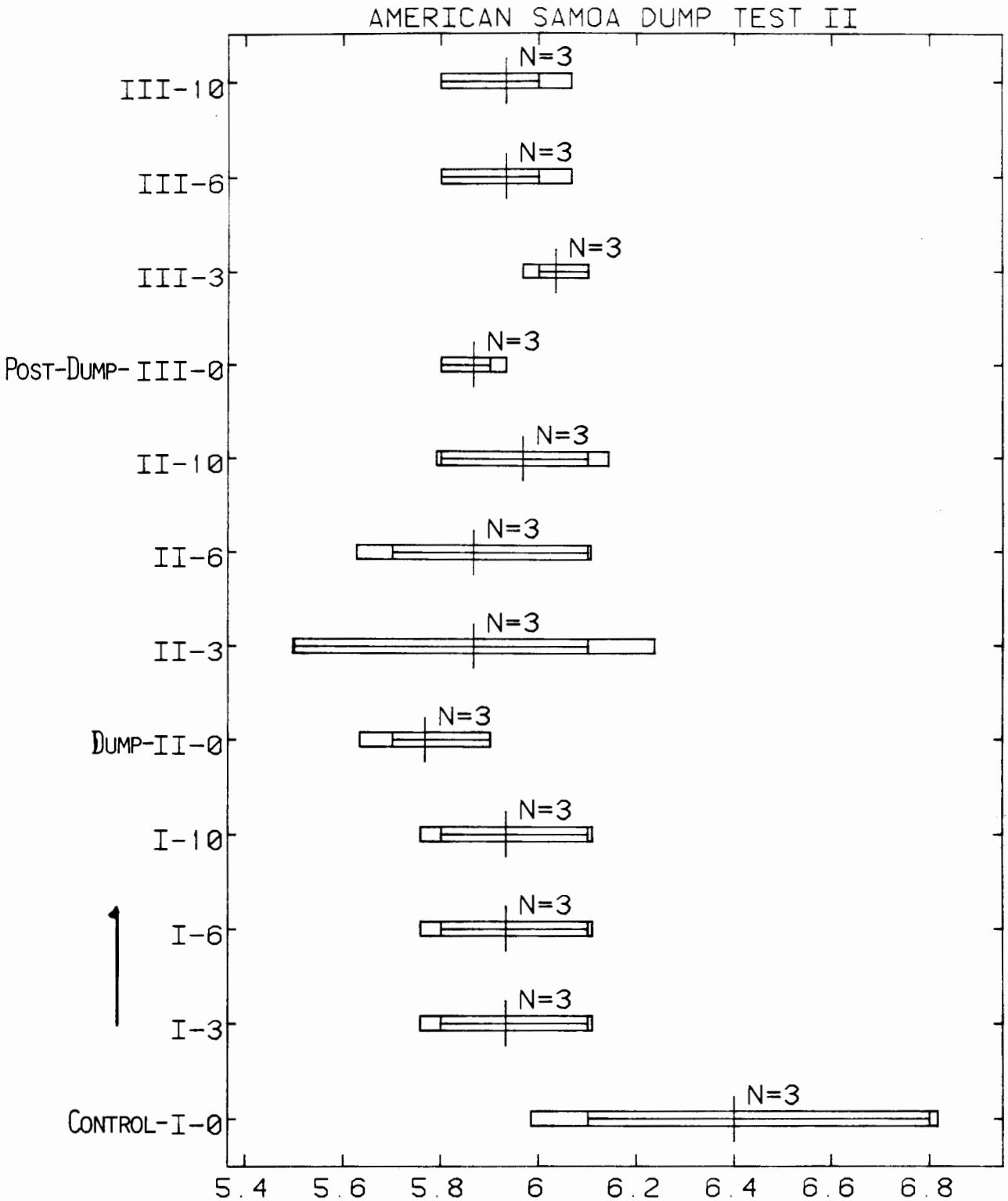


FIGURE 18. DISSOLVED OXYGEN (*ppm*), 21 JANUARY 1982.

* The difference is not significant (by anova, P= 0.064).
Range & mean ± 2 S.E. are shown.
Homogeneity of variances requirement realized without transformation. (C=0.3120).

Table 1. Parameters Monitored in American Samoa at Control and Test Sites, January and July, 1982.

Parameters	Field Method	Lab Method/Calibration
Temperature	Martek Electronic Probe	Thermometer
Salinity	"	Known Solution
pH	"	Standard Buffers
Dissolved Oxygen	"	Air Calibration
Light		
Transmittance	Hydroproducts Transmissometer	
Penetration	Secchi Disc	
Color	Forel-Ule Scale	
NH_3	Water Sampler	Specific ion Probe
BOD	Water Sampler	Standard Methods (APHA 1981) Modified for Sea Water; Electronic Probe
TOC	Water Sampler	Oceanography International Model 0524B Total Carbon System
Wind	Hand Gauge	
Currents	Drogue Visual Sightings	
Biota	Direct Observation	
Visual Observation	Solids Dispersion, Slick	

Table 2. Quantities of Wastes Dumped Under Permit No. OD79-01/02
1 October 1980 - 31 December 1982.

Period	Reported by Waste Producers: Van Camp gallons/ tons	Reported by Waste Producers: Star-Kist gallons/ tons	Reported by Waste Carriers: Inter-Island Shipping Total Reported
1 Oct-31 Dec 80		86,700 260	86,700 260
1980 TOTALS gallons tons			86,700 260
1 Jan-31 Mar 81	594,125 2,150	839,300 2,552.5	1,433,425 4,702.5
1 Apr-30 Jun 81	901,625 3,721.9	840,700 2,395.3	1,742,325 6,117.2
1 Jul-30 Sept 81	925,410 3,820.4	1,021,200 2,769.8	1,946,610 6,590.2
1 Oct-31 Dec 81	811,500 3,350.3	821,800 2,529.8	1,633,300 5,880.11
1981 TOTALS gallons tons	3,232,660 13,042.6	3,523,000 10,247.4	6,755,660 23,290.01
1 Jan-31 Mar 82	401,125 1,656	701,000 2,058	1,102,125 3,713
1 Apr-30 Jun 82	830,500 3,428	651,050 1,941.9	1,481,550 5,369.88
1 Jul-30 Sept 82	565,811 2,336	696,000 2,060.26	1,261,811 4,396.26
1 Oct-31 Dec 82	804,077 3,319	681,926 2,021.45	1,486,003 5,340.45
1982 TOTALS gallons tons	2,601,513 10,739.0	2,729,976 8,081.61	5,331,489 18,820.59

Table 3. Quantities of Waste Disposed at Sea in American Samoa During Field Monitoring in 1982.

Date		Gals	Tons
18 January	SK	16,800	52,50
19 January	SK	21,000	61.21
20 January	SK	21,000	61.21
21 January	SK	16,800	52.50
19 July	SK	16,800	46.94
	VC	24,375	101.00
20 July	SK	21,000	62.17
	VC	6,250	26.00
22 July	SK	29,400	85.82
	VC	12,500	
23 July	SK	25,200	73.56
	VC	5,000	21.00

TABLE 4. PRINCIPAL COMPONENT ANALYSIS JANUARY 1982

(SEE FIGURE 12)

AMERICAN SAMOA DUMP TEST

6 variables:
1 - Time
2 - Distance
3 - Depth
4 - %T
5 - Ammonia
6 - BOD

51 sets of observations.

--

Variable correlation matrix (R):

	1	2	3	4	5	6
1	1.00	-0.10	-0.06	-0.29	0.03	-0.02
2	-0.10	1.00	0.01	0.13	-0.20	0.11
3	-0.06	0.01	1.00	0.64	-0.55	-0.14
4	-0.29	0.13	0.64	1.00	-0.61	0.06
5	0.03	-0.20	-0.55	-0.61	1.00	0.06
6	-0.02	0.11	-0.14	0.06	0.06	1.00

Determinant of R = 0.2551
For Sperricity test, Chi-square = 64.435, df = 15

--

Eigenvectors (axis loadings)
-factors are columns, variables are rows-

	1	2	3
1	0.19	0.42	0.85
2	-0.16	-0.58	0.31
3	-0.54	0.27	0.05
4	-0.59	-0.08	-0.08
5	0.54	-0.08	-0.26
6	0.04	-0.64	0.33

V'V=

1.00	0.00	0.00
0.00	1.00	0.00
0.00	0.00	1.00

TABLE 4, CONTINUED. JANUARY 1982

AMERICAN SAMOA DUMP TEST

--

Factor	Eigen-value	%	Cum %	df	Chi-square
1	2.281	38	38	15	64.435
2	1.182	20	58	10	33.036
3	0.971	16	74	6	24.580

--

Factor Pattern (factor-variable correlations)
-factors are columns, variables are rows-

	1	2	3
1	0.28	0.45	0.83
2	-0.24	-0.63	0.31
3	-0.82	0.30	0.05
4	-0.89	-0.08	-0.08
5	0.82	-0.08	-0.26
6	0.06	-0.70	0.32

--

Factor Score Coefficients
-factors are columns, variables are rows-

	1	2	3
1	0.12	0.38	0.86
2	-0.11	-0.53	0.32
3	-0.36	0.25	0.05
4	-0.39	-0.07	-0.09
5	0.36	-0.07	-0.27
6	0.03	-0.59	0.33

End of Analysis

TABLE 5. 2 LEVEL NESTED ANOVA (ANALYSIS OF VARIANCE) JANUARY 1982

AMERICAN SAMOA DUMP TEST^Control/Test^Depth^%T

-- PERCENT TRANSMITTANCE VARIES SIGNIFICANTLY WITH DEPTH. (P=0.000)

ANOVA Table:

level	SS	df	MS	Fs	P
2 (STATIONS)	492.050	2	246.025	1.871	0.196
1 (DEPTHS)	1565.668	12 12.0	130.472 131.503	9.339	0.000
0 (OTHER)	670.600	48	13.971		

--

Variance Components:

level	var. comp.	%
2	5.5075	11.6401
1	27.8366	58.8326
0	13.9708	29.5273

--

Table of Coefficients:

2	4.2	20.8
1	4.2	

TABLE 5, CONTINUED. 2 LEVEL NESTED ANOVA JANUARY 1982

AMERICAN SAMOA DUMP TEST^Control/Test^Depth^Ammonia

-- AMMONIA VARIES SIGNIFICANTLY WITH DEPTH (P=0.000)

ANOVA Table:

level	SS	df	MS	Fs	P
2 (STATIONS)	14.162	2	7.081	1.200	0.345
1 (DEPTHS)	53.379	9 9.0	5.931 5.903	5.162	0.000
0 (OTHER)	45.956	40	1.149		

--

Variance Components:

level	var. comp.	%
2	0.0684	2.9463
1	1.1036	47.5503
0	1.1489	49.5033

--

Table of Coefficients:

2	4.3	17.2
1	4.3	

TABLE 5, CONTINUED 2 LEVEL NESTED ANOVA JANUARY 1982

AMERICAN SAMOA DUMP^Control/Test^Depth^BOD

-- BOD 5 VARIES SIGNIFICANTLY WITH STATION (P=0.023)

ANOVA Table:

level	SS	df	MS	Fs	P
2 (STATIONS)	41.769	2	20.884	5.886	0.023
1 (DEPTH)	31.928	9 9.0	3.548 3.548	1.532	0.172
0 (OTHER)	90.313	39	2.316		

--

Variance Components:

level	var. comp.	%
2	1.0233	28.1969
1	0.2902	7.9951
0	2.3157	63.8079

--

Table of Coefficients:

2	4.2	16.9
1	4.2	

SINGLE CLASSIFICATION ANOVA (FIGURES 13-18)

BY ITSELF THE 2 LEVELS NESTED ANOVA IS INCONCLUSIVE.

DATA WERE ORGANIZED INTO CONTROLS, DUMP STATIONS AND POST-DUMP STATIONS FOR SEPARATE PARAMETERS.

THERE IS SIGNIFICANT VARIATION WITH DEPTH, SO THESE DATA CANNOT BE AVERAGED BUT CAN BE GROUPED IN THE THREE CATEGORIES MENTIONED AND ANALYZED.

III. JULY FIELD RESEARCH

CRUISES

Field research in July 1982 was undertaken from 18 July through 28 July, and samples were analyzed for BOD, DO and NH_3 in Pago Pago using portable laboratory equipment, hotel facilities, and field assistance from the Marine Resources Center. Instead of the expected seasonal Trade Winds, however, a series of violent storms from the south passed through, limiting the field days. (Lack of Trade Winds in 1982 is associated with the large-scale meteorological changes in the Pacific including the "El Nino" current off South America). Fortunately a complete series of measurements and the necessary samples for NH_3 analysis and incubation for the BOD 5 were obtained on 20 July, along with samples to transport to USC for Total Organic Carbon (TOC) analysis. The BOD samples were collected, and held in icepacks on the boat. They were subsequently diluted to begin incubation the same night to reduce potential changes. Results were then read at the same night-time intervals after incubation of five days. Ammonia and dissolved oxygen were read by electronic probe; DO was standardized by Winkler analysis. Cruise logs and field and laboratory data for July are presented in Appendix B.

On 23 July, two principal tasks were carried out; examination of DO in surface transects across the plume to look for immediate oxygen sag, and examination of plume movement with surface, 10m and 20m drogues. Surface drogues alone were deployed on 20 July because sampling completion had top

priority and multiple sightings consume considerable time with sextant and triangulation. The monitoring stations for 20 July are shown in Figure 19; Stations for 23 July are plotted in Figure 20. Efforts were made to circumscribe the plume in each case.

Movement of Droques and Plume

On 20 July, the direction of the plume was to the north (Figure 19), and the shape gradually widened toward the coast, perhaps influenced by meeting the outgoing tidal flow by 1400 hrs. The south wind ranged from 10-16k, with gusts to 25k. Surface drogues tended to blow faster than the plume moved so that station T, nearest the harbor, where surface drogues were last sighted, was well beyond the dissipating slick. The net speed of the slick was about 0.27k (13.9cm/sec), from Station C to N, while that of the drogues was about 0.47k (24.2cm/sec), from station C to T.

On 23 July, the surface platters were deployed along with drogues which consisted of bleach bottles with sand bags attached and plastic vanes suspended at 10m and 20m depths. Plastic tubing masts with foil balloons atop were used to locate the drogues; the balloons glittered in the sun sufficiently to relocate them fairly easily. The slick tended toward the north and northeast on an incoming tide (Figure 20). The winds were low, with 2-6k gusts, and seas calm with a long swell out of the south. The surface balloon drogues

traveled at 0.22k (11.3cm/sec), from Station 3 to 13, while the 10m and 20m drogues stayed close together and traveled at about 0.18k (9.3cm/sec), from stations 3 to 12.

The red platter drogues, released at 0954 at station TP (2), were found well to the north of the slick after 1530hrs. The following day, on a dive on Taema Bank, a red drogue was found. There was of course no visible slick associated with it. Even though the slick is sometimes visible as a milky blue for several hours after the dump, the water quality is not measurably different from ambient according to any of the parameters measured. Thus BOD or NH_3 could not exert a negative effect.

Turbidity

Turbidity increased immediately when dumping began, and light transmittance decreased with depth as dumping continued. This is reversed as soon as dumping ceases. Results demonstrating the return to ambient conditions are shown for percent light transmittance (%T) for 20 July 1982 in Figure 21. The data from the morning controls were quite high. The surface transparency dropped rapidly with the start of dumping, less so at 3m, 6m or 10m. Transparency rose rapidly before cessation of dumping, but Station I may have been out of the plume or on the fringes of it. Thereafter the readings approached those of the afternoon control (CS) levels.

Ammonia and BOD 5

The parallel between BOD and NH_3 is more striking on 20 July Figure 22, than it was in January, (Figure 9) largely because control site BODs were high in January and low in July. There were immediate parallel increases in BOD and NH_3, followed by rapid decline before cessation of dumping (center vertical line). Levels were then within the range of morning and afternoon control values.

Dissolved Oxygen

Dissolved oxygen readings on 20 July were somewhat incosistent with other patterns. Levels dropped below the morning controls with the start of dumping. They rose at the end of disposal, but, as in Figure 21 for Light Transmittance, Station 1 may have been on the edge of the slick and the elevation may be considered an artifact. Recovery did not appear to begin until two hours after the end of dump and had not reached ambient afternoon control levels at the end of monitoring.

It should be emphasized that the dissolved oxygen, while showing slight depression, never dropped to levels which might inhibit marine life. Dissolved oxygen readings showed a quick depression on 23 July, (Figure 26) with rapid recovery to afternoon control levels. Most test and afternoon control levels did not approach the morning control levels.

Water Transparency and Color

The inverse trends seen in January (Figure 11) between

Secchi disc measurement of light penetration and color as judged by the Forel-Ule scale were apparent in July. However, there were unexpected differences between the results for the two days monitored. On 20 July (Figure 27) it was very windy and good dispersal would be expected, but transparency did not return to ambient control levels in 2 hr 25m after dumpimg stopped. However, on 23 July some transparency measurements returned to ambient levels within an hour after dumping stopped (Figure 28), even though the day was much more calm (See field logs, Appendix B) but there was a pronounced swell.

The Forel-Ule (FU) color changes differed as well, ranging from FU 1 (cobalt blue) at morning controls to FU 3 (blue) at afternoon controls on 20 July. The dump caused increases to FU 8 (brownish green), but returned to FU 3 when dumping ended. On 23 July, morning and afternoon control site color was FU 1, and dumping caused an increase to FU 6. After dumping, the color returned to a range of FU1-FU3 at station 10. The dispersion of the slick can be quite irregular and patchy even when the wind is not strong.

Total Organic Carbon

The measurement of total organic carbon (TOC) has been made in southern California and Samoa, but, thus far, none of the data have produced statistically significant correlations. The problem seems to be due principally to suspended fine particulates which may unduly skew the counts in the sealed

ampules. Tests of homogenous wastes, or of fluids with soluble carbons, produce good test results. Transport by air of samples from Samoa, with associated temperature and pressure changes, may be causing some materials to precipitate out. Filtration of samples has been tested, but this may remove relevant carbon. Further examination of the problems associated with using TOC measurements is more appropriate to the southern California monitoring, which does not entail such transport and consequent variation in conditions.

At present, the turbidity and ammonia patterns seem to be the more consistent and reliable tracers for the plume than TOC.

Computer Analysis, July 1982.

The 20 July sampling produced a very complete set of data and, hence, a balanced matrix for computer analysis. There were six sample depths for temperature, salinity, dissolved oxygen, pH and percent light transmittance (%T), and four sample depths for ammonia and BOD 5. Thus multivariate analysis was done as two separate matrices; Table 6 is the physical matrix for all depths, and Table 7 is the abiotic matrix for four depths.

There were many significant correlations prior to rotation (greater then 2.0, P=0.05). Figure 29 illustrates the parameters after rotation which show four significant factors. Factor 1, dominated by depth, salinity and %T with minor compo-

nents from DO and pH, accounts for 37 percent of the variation. Factor 2 was dominated by time, with some temperature and DO; Factor 3 was a combination of pH and temperature, and Factor 4 was primarily temperature. Parallel vectors indicate direct correlations, while vectors in opposing directions indicate inverse relationships. Perpendicularly-directed vectors are assumed not to be related.

In the abiotic matrix, ammonia and BOD 5 were closely correlated (Figure 30). Prior to rotation, parameters were significantly correlated if greater than 0.23 (P=0.05). After rotation, Factor 1, composed of Ammonia and BOD 5 junctioned together, independent of time and depth in this analysis. The two parameters, acting together or independently, appear to distinguish between test sites and control sites.

Percent light transmittance (Figure 32) was treated somewhat differently from January data in the 20 July analysis, since there were 6 depths at 18 stations to consider in July. Data were averaged through depth at each station (center vertical line of bar). The increase in turbidity due to the plume during dumping (TS 1 through TS 6) is quite apparent, as is the return of the transparency in the plume to ambient conditions for the typical of the afternoon conditions, as shown at control south (CS). Transparency levels did not reach those of the morning controls (CN and TP 1). Differences were significant, (P=0.018).

Differences in ammonia on 20 July were highly significant

(P=0.001) and showed increasing concentrations during dumping (Figure 33). Levels returned to the range of control north (CN 1) but means did not quite return to TP 1 and CS 1 mean concentrations. The latter differences would not be significant because of overlap.

The BOD 5 on 20 July 1982 (Figure 34) showed highly significant differences (P=0.001) between the levels during dumping and those during post-dumping. The rapid decrease to control levels is perhaps surprising, but the means (center vertical bars) at control sites exceed those at some of the post-dump sites, limiting the statistical significance.

BOD 5 values in July are considered to be more representative of conditions than are the January values; July samples were processed immediately in American Samoa in the hotel "laboratory", whereas the January samples were fixed in standard procedures and shipped back to southern California. Results in July were more consistent, and the immediate processing may have made the difference between a BOD 5 range up to about 18 mg/l in July and 9 mg/l in January, since the wastes should have been similar.

Dissolved oxygen levels (Figure 35, 36) showed significant differences in both 20 July and 23 July, in contrast to non-significant differences in January (Figure 18). The degree of overlap of 2 standard errors determines the significance, but even in data without statistical significance it is obvious in all cases that dumping causes an immediate depression of DO.

However, DO depression is not serious since it has not decreased below about 5.5 ppm, which is considered by regulatory agencies to be a more than adequate for marine life. Recovery of DO to the levels of morning controls after cessation of dumping was not seen, but recovery did approach afternoon control DO ranges at several stations on each occasion.

The transitory nature of DO depressions, and the relatively minor amounts measured, suggest that the oxygen demand of the dispersing plume would not impact the shoreline if it were to reach there within 1-2 hours after dumping.

Patterns for salinity differed on the two July dates; differences were not significant on 20 July but were statistically significant on 23 July. Strangely, salinity appeared to be highest (34.12-34.25 ppth) at control north on 20 July (Figure 37), but lowest (34.22-34.3 ppth) at control north on 23 July (Figure 38), in comparison with the dumped material. This creates the visual impression that the controls differed according to the two figures, when in fact the salinity of the wastes was higher on 23 July than on 20 July. The salinities measured probably do not vary sufficiently to create any impact or influence on pelagic species.

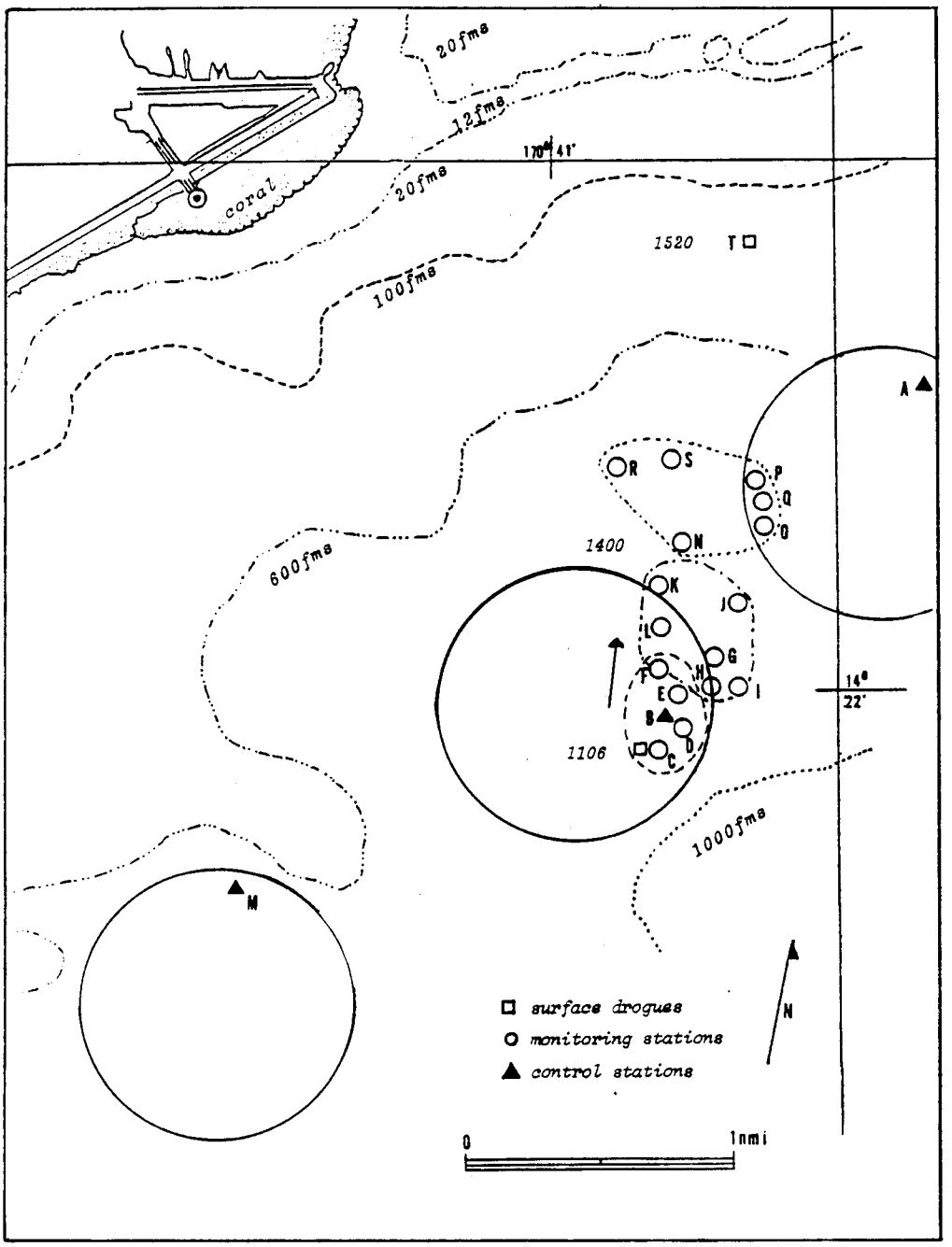


Figure 19. Waste Plume (dotted Circles), Monitoring Stations and Drogue Movements, 20 July 1982. (Southwind, 10-16k, low tide 1255, -0.5ft).

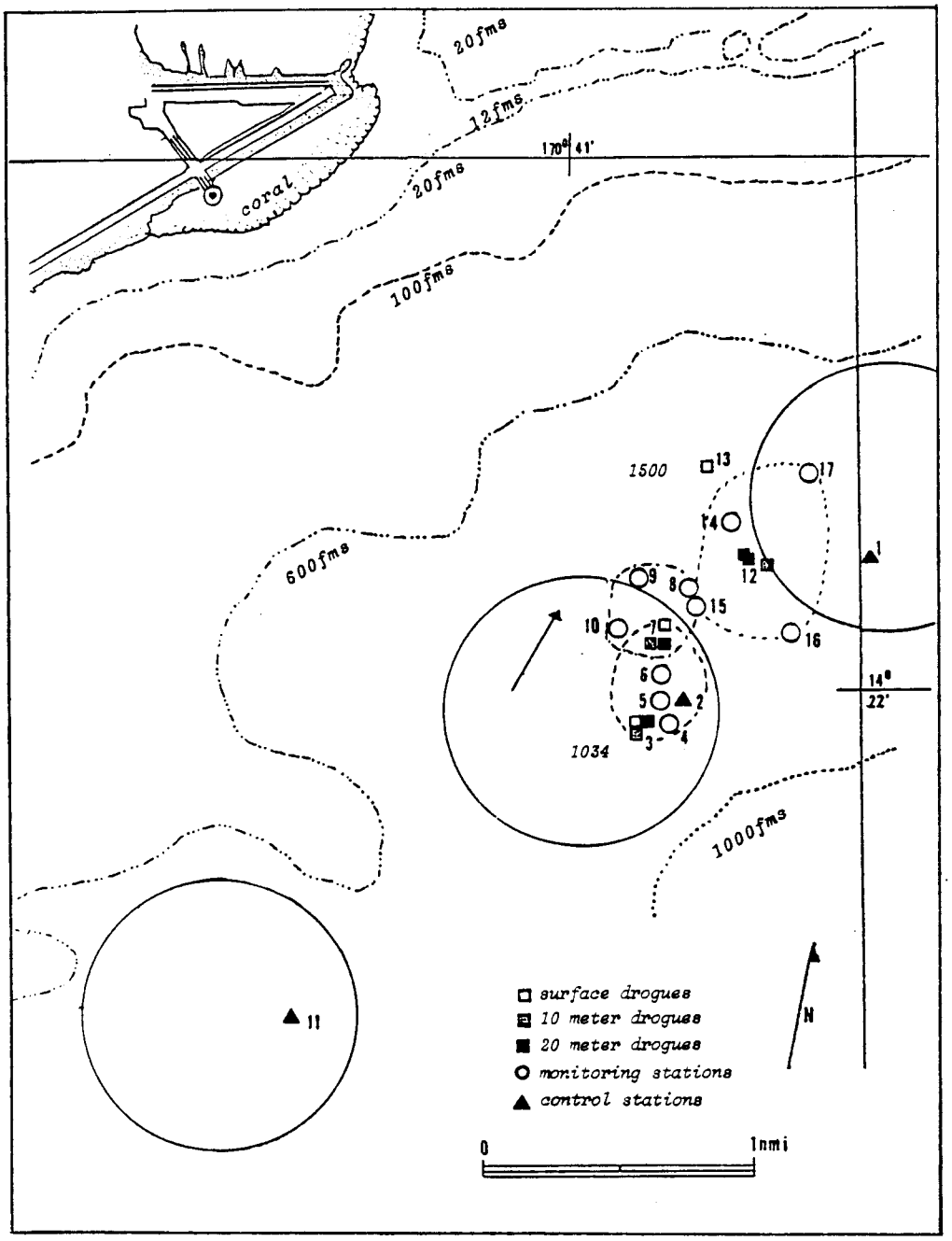


Figure 20. Waste Plume (dotted Circles), Monitoring Stations and Drogue Movements, 23 July 1982. (Southwind, 0-6k; low tide 1530,-0.5ft).

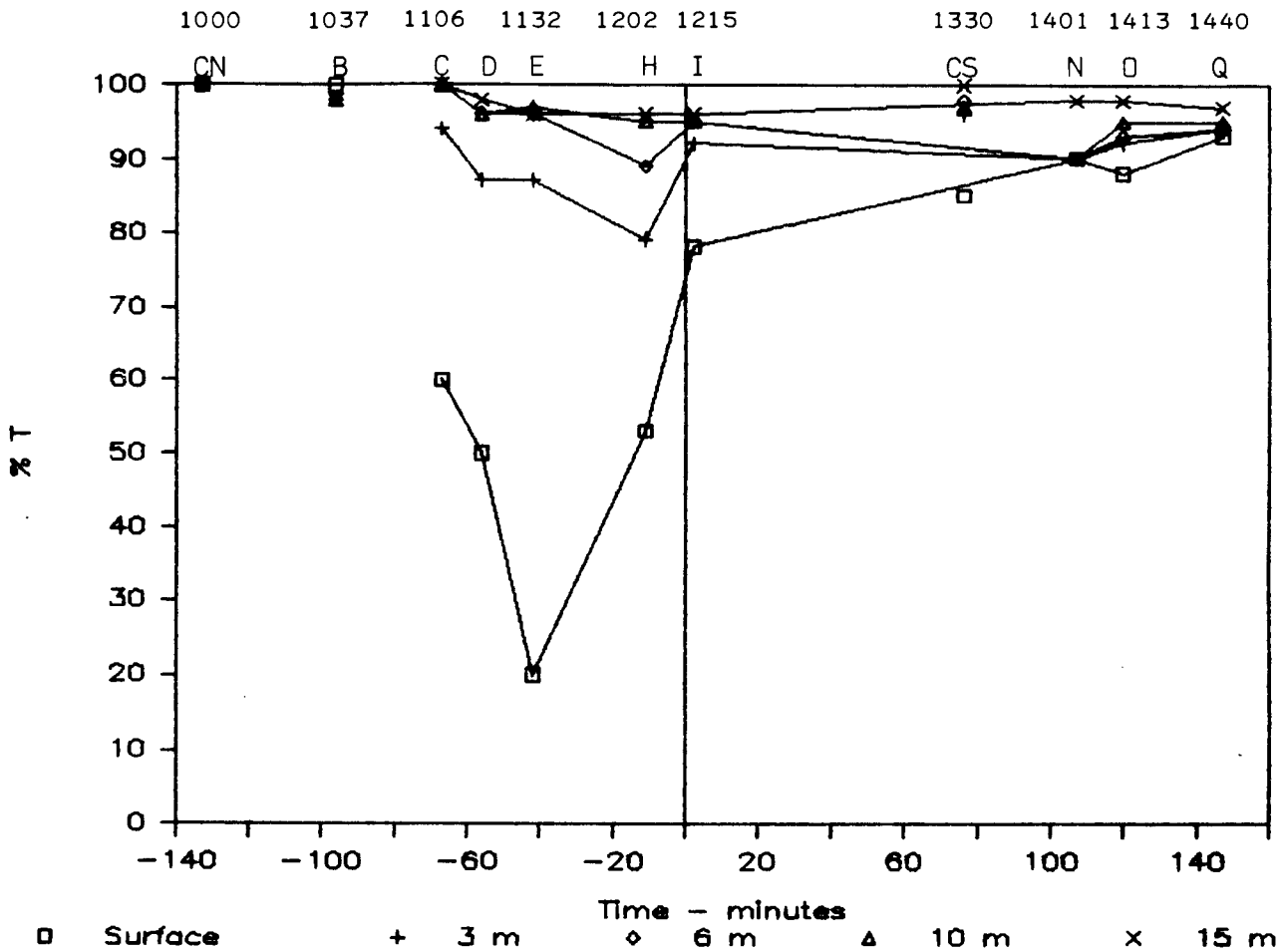


FIGURE 21. PERCENT LIGHT TRANSMITTANCE, (%T). 20 JULY 1983

TRANSPARENCY WAS GREATER AT DEPTHS IN CONTROL STATIONS IN JULY THAN IT WAS IN JANUARY (FIGURES 5, 6 AND 7). THIS MAY HAVE BEEN DUE TO THE STRONG SOUTH WINDS THAT PREVAILED DURING THE SAMPLING PERIOD. THE SURFACE TRANSPARENCY DROPPED MUCH MORE RADICALLY AT THE BEGINNING OF THE JULY 20 DUMP, BUT RECOVERED TO PM CONTROL (CS) VALUES IN LESS THAN 2 HOURS. STATION 1 MAY HAVE BEEN IN LESS TURBID PATCH OF SLICK, INDICATING MORE RAPID RECOVERY THAN EXPECTED.

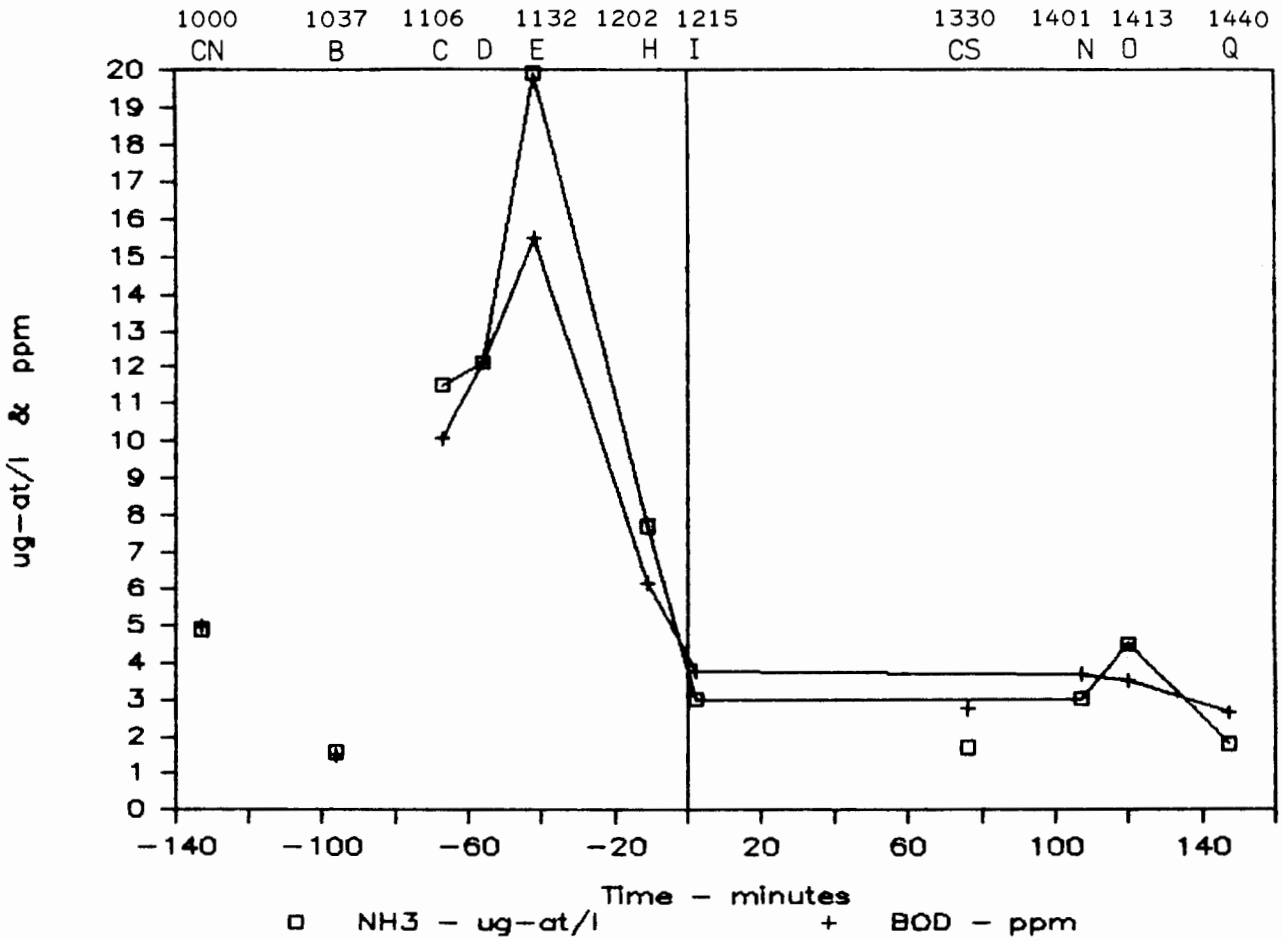


FIGURE 22. COMPARISON OF SURFACE AMMONIA (NH_3) AND BOD 5, 20 JULY 1982.

THE COINCIDENCE OF LEVELS OF AMMONIA AND BOD IN AM CONTROLS AND THE PARALLEL IN INCREASE, DECREASE AND STABILIZATION INDICATE THAT AMMONIA IS AS VALID A PARAMETER AS BOD 5 TO TRACK, AND MUCH LESS EXPENSIVE TO PERFORM. *(1 ug.at NH_3/l = 0.017mg NH_3/l)*

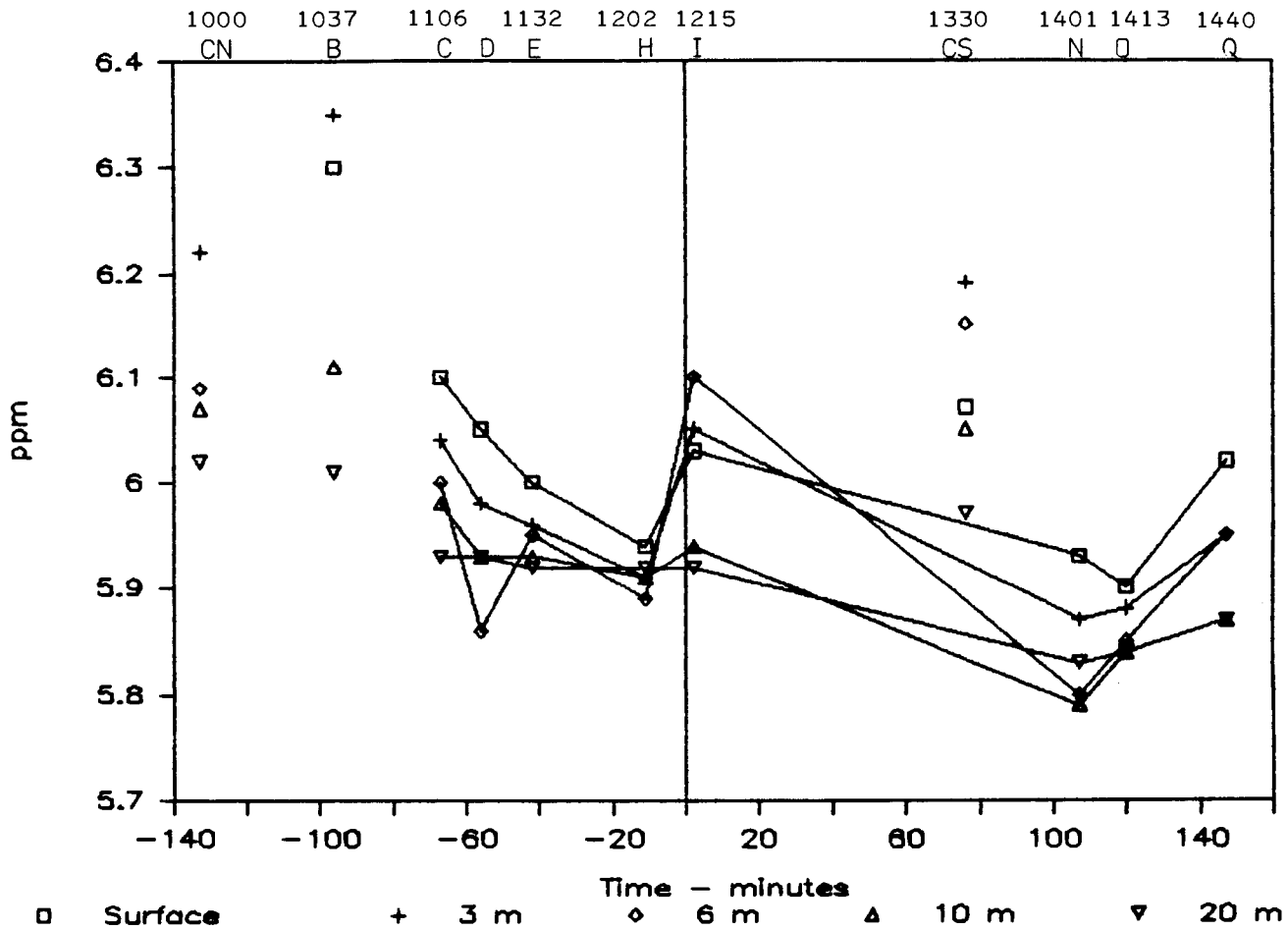


FIGURE 23. DISSOLVED OXYGEN PROFILE, 20 JULY 1982.

DECREASE IN DISSOLVED OXYGEN (DO IN PPM) FOLLOWED DUMPING FROM 1106 (STA. C) THROUGH 1202 (H). EXCEPT FOR STATION I, WHICH MAY HAVE BEEN IN LESS TURBID PATCHY AREA, DOS DID NOT RETURN TO THE AMBIENT LEVELS OF THE PM CONTROLS (CS).

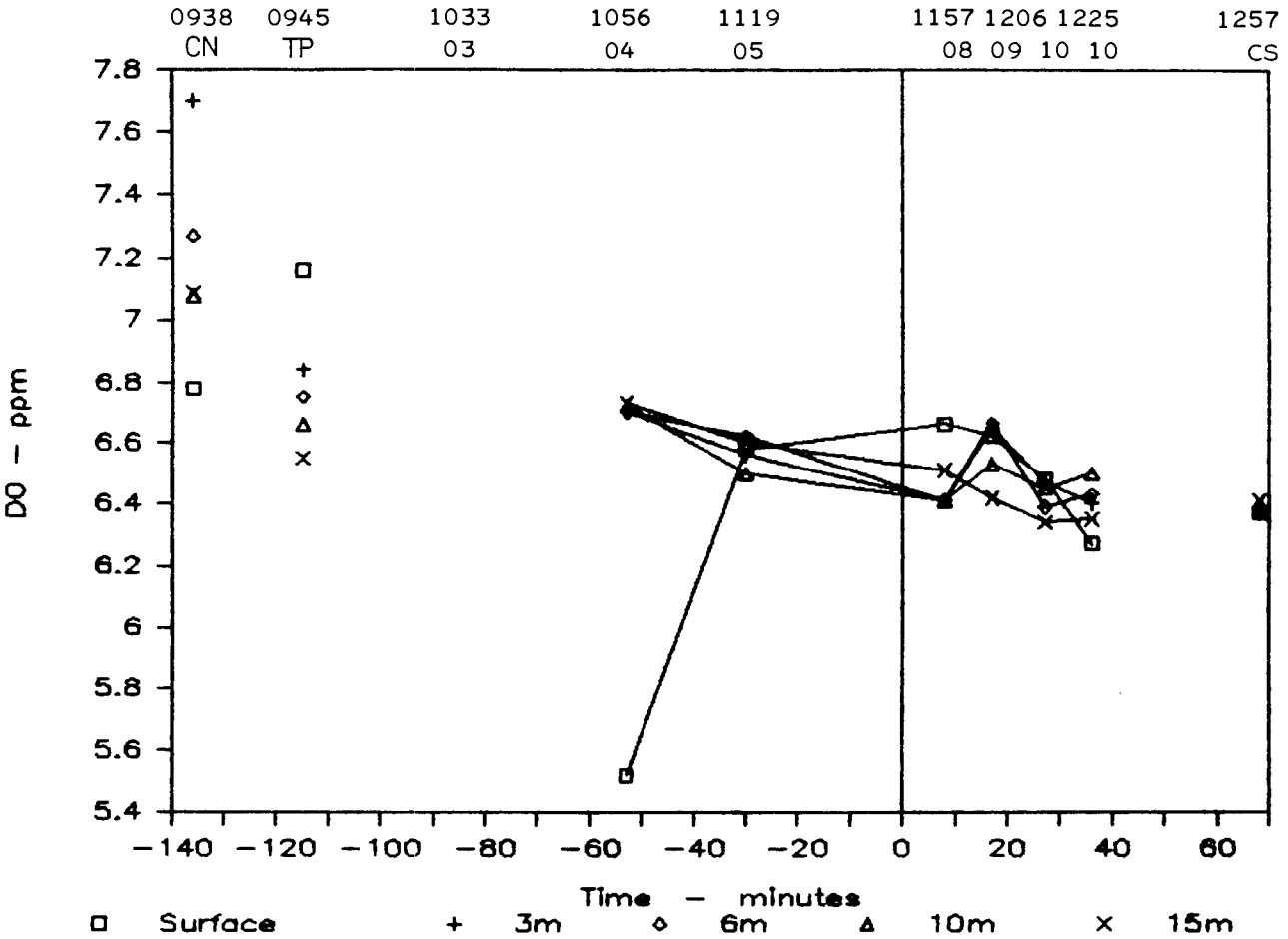


FIGURE 24. DISSOLVED OXYGEN PROFILE, 23 JULY 1983.

DISSOLVED OXYGEN (DO IN PPM), MEASURED WITH MARTEK REMOTE ELECTRONIC PROBE, WAS HIGH AT AM CONTROL STATIONS. DUMPING STARTED AT 1033 SO THAT SURFACE VALUES WERE LOW AT 1056, BUT RECOVERED SUBSTANTIALLY PRIOR TO CESSATION OF DUMPING AT 1149. LEVELS APPROACHED THE PM CONTROLS AFTER 35 MIN.

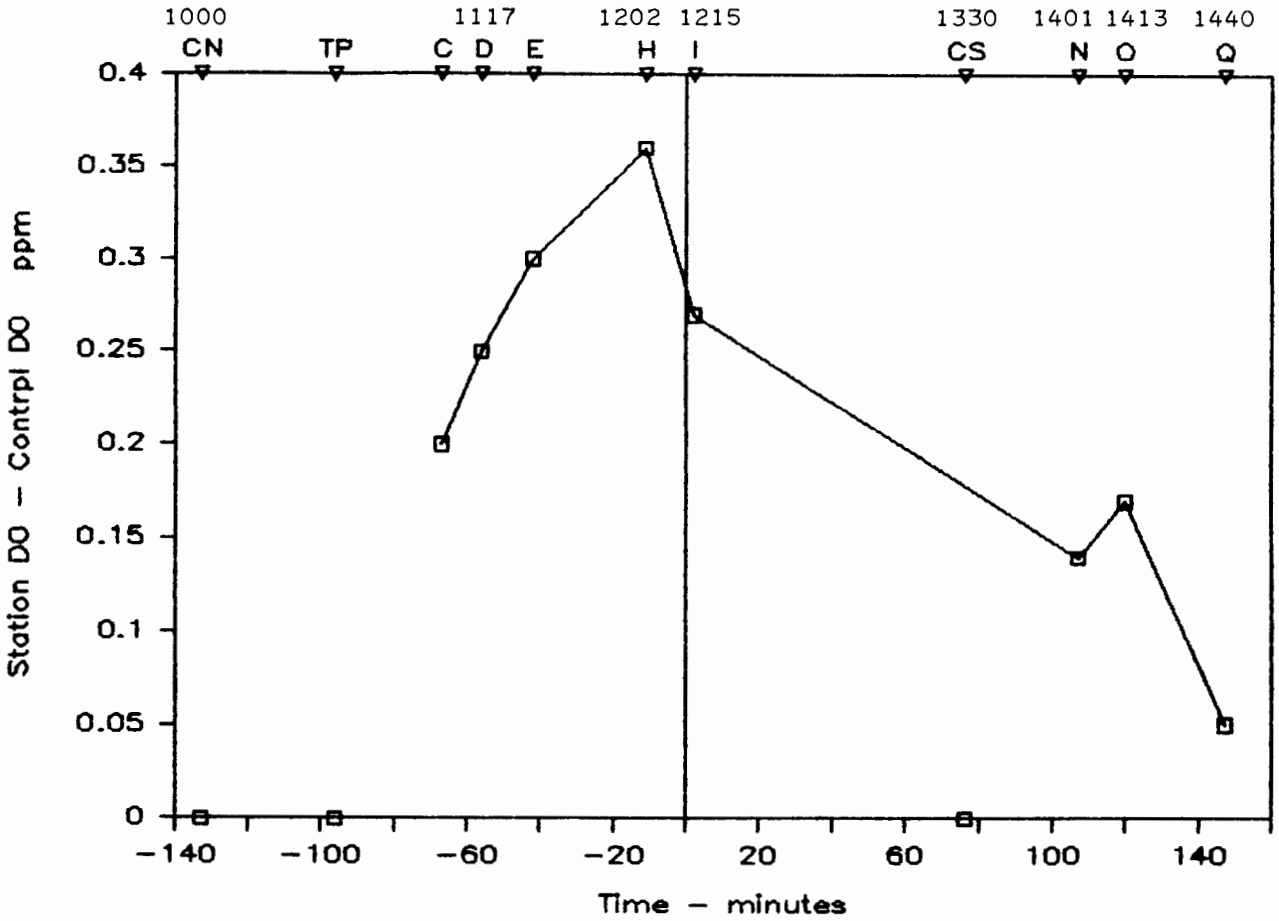


FIGURE 25. OXYGEN SAG, 20 JULY 1982.

RATIO OF DISSOLVED OXYGEN AT SURFACE OF PLUME TO AMBIENT OXYGEN LEVELS AT CONTROL SITES. OXYGEN DROPPED AS DUMPING PROCEEDED BUT RECOVERY STARTED IMMEDIATELY AFTER DUMPING STOPPED AND APPROACHED AMBIENT BY THE END OF THE MONITORING PERIOD.

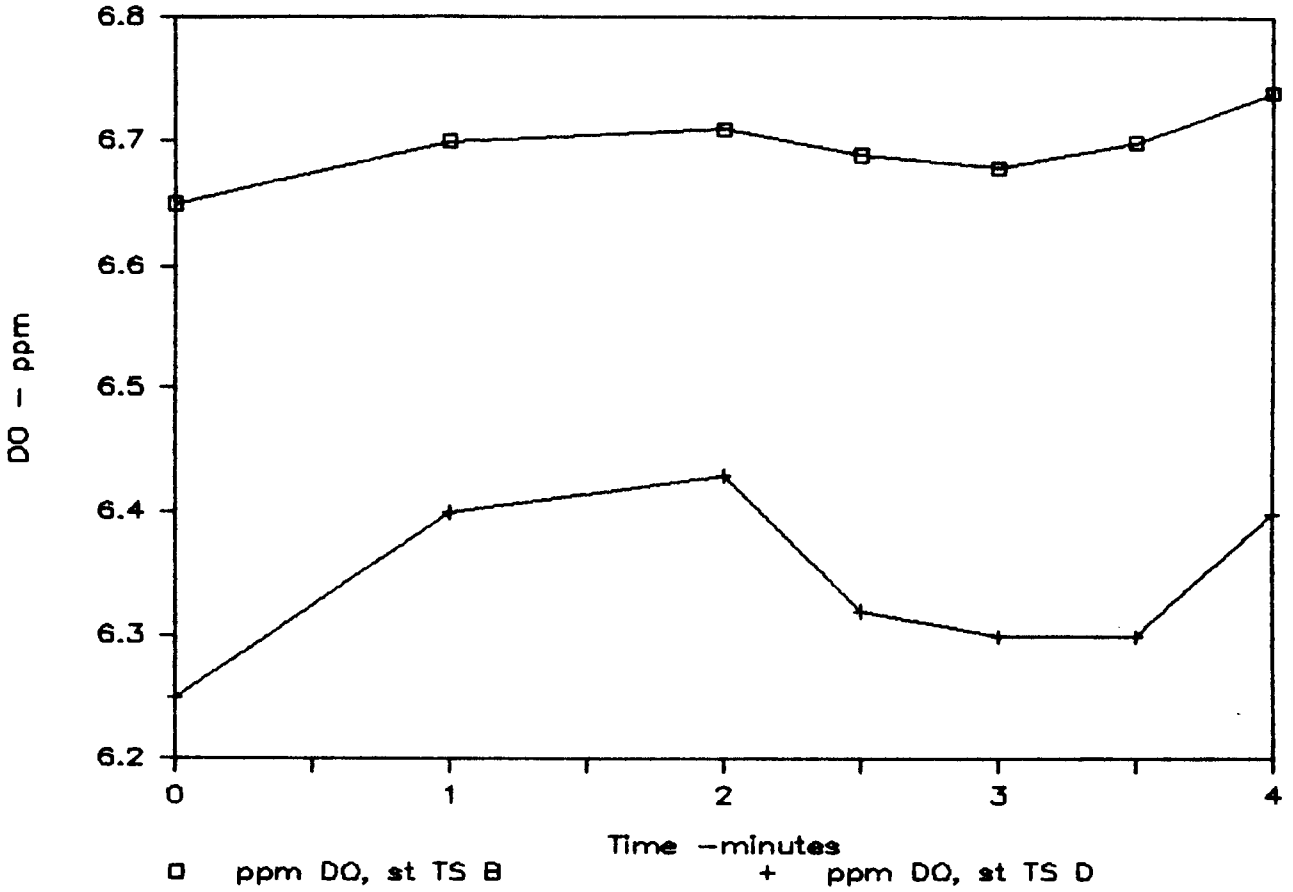


FIGURE 26. SURFACE DISSOLVED OXYGEN, 23 JULY 1982.

COMPARISON OF DISSOLVED OXYGEN LEVELS IN TRANSECTS SURFACE AT TWO STATIONS, TS-B AND TS-D (STATIONS 5 AND 6 RESPECTIVELY ON MAP, FIGURE 20). LEVELS DECREASED IRREGULARLY ACROSS THE PLUME AND RECOVERED BETWEEN 2-4 MINUTES.

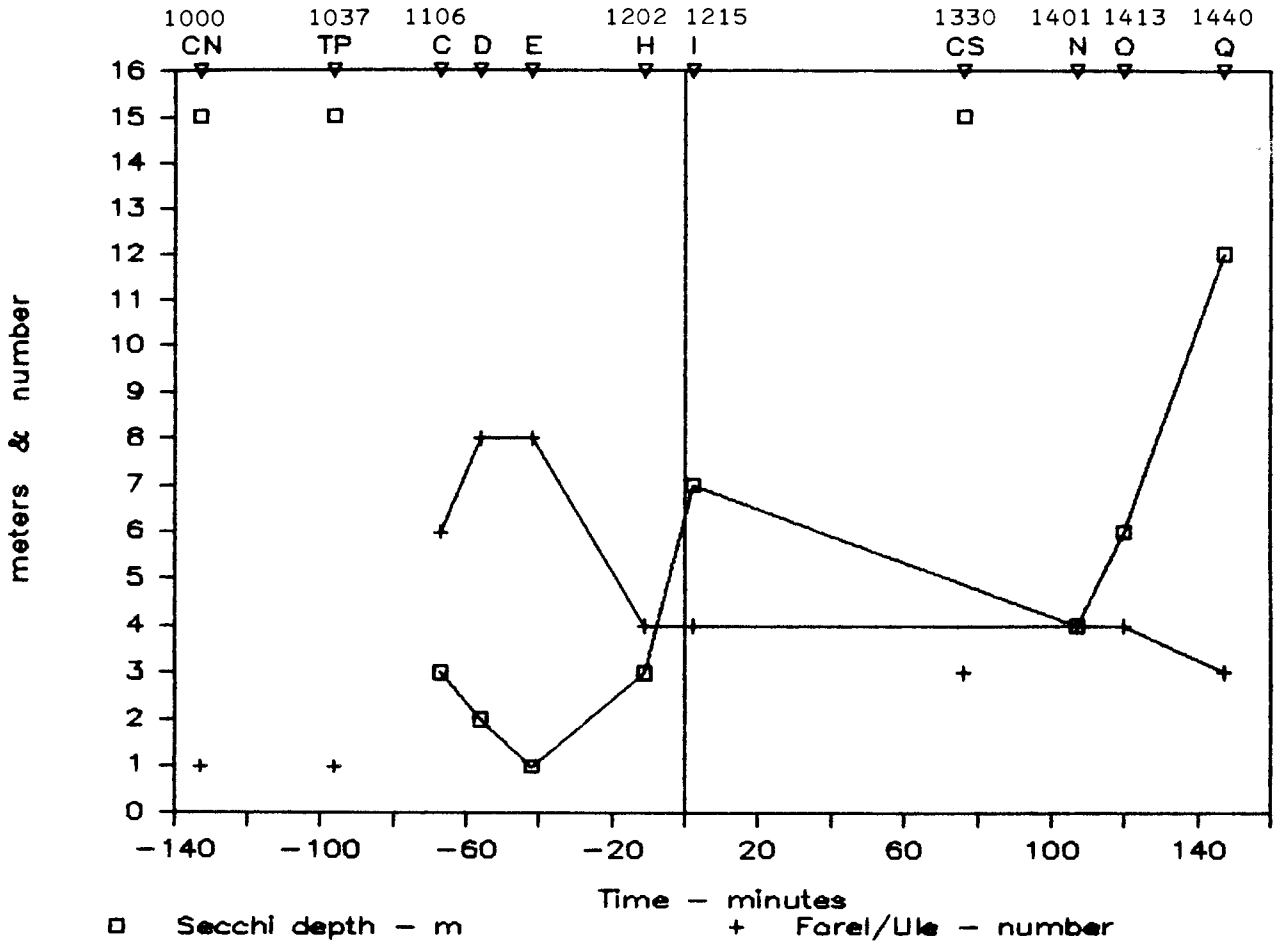


FIGURE 27. WATER TRANSPARENCY MEASURED BY SECCHI DISC AS COMPARED WITH COLOR MEASURED BY FOREL-ULE SCALE, 20 JULY 1982.

BOTH VALUES ARE MEASURED VISUALLY AND ARE THUS SUBJECTIVE. THERE WAS AN INVERSE RELATIONSHIP FROM THE BEGINNING OF DUMPING (C) AND CLOSE TO THAT AFTER CESSATION OF DUMPING (CENTER VERTICAL LINE). SECCHI DISC VALUES DID NOT RETURN TO AM OR PM CONTROL LEVELS, BUT FOREL-ULE NUMBERS DID. THE PATTERN DURING DUMPING DIFFERED FROM THAT OF 20 JANUARY (FIGURE 11), PROBABLY DUE TO DIFFERENCES IN SAMPLING SEQUENCE.

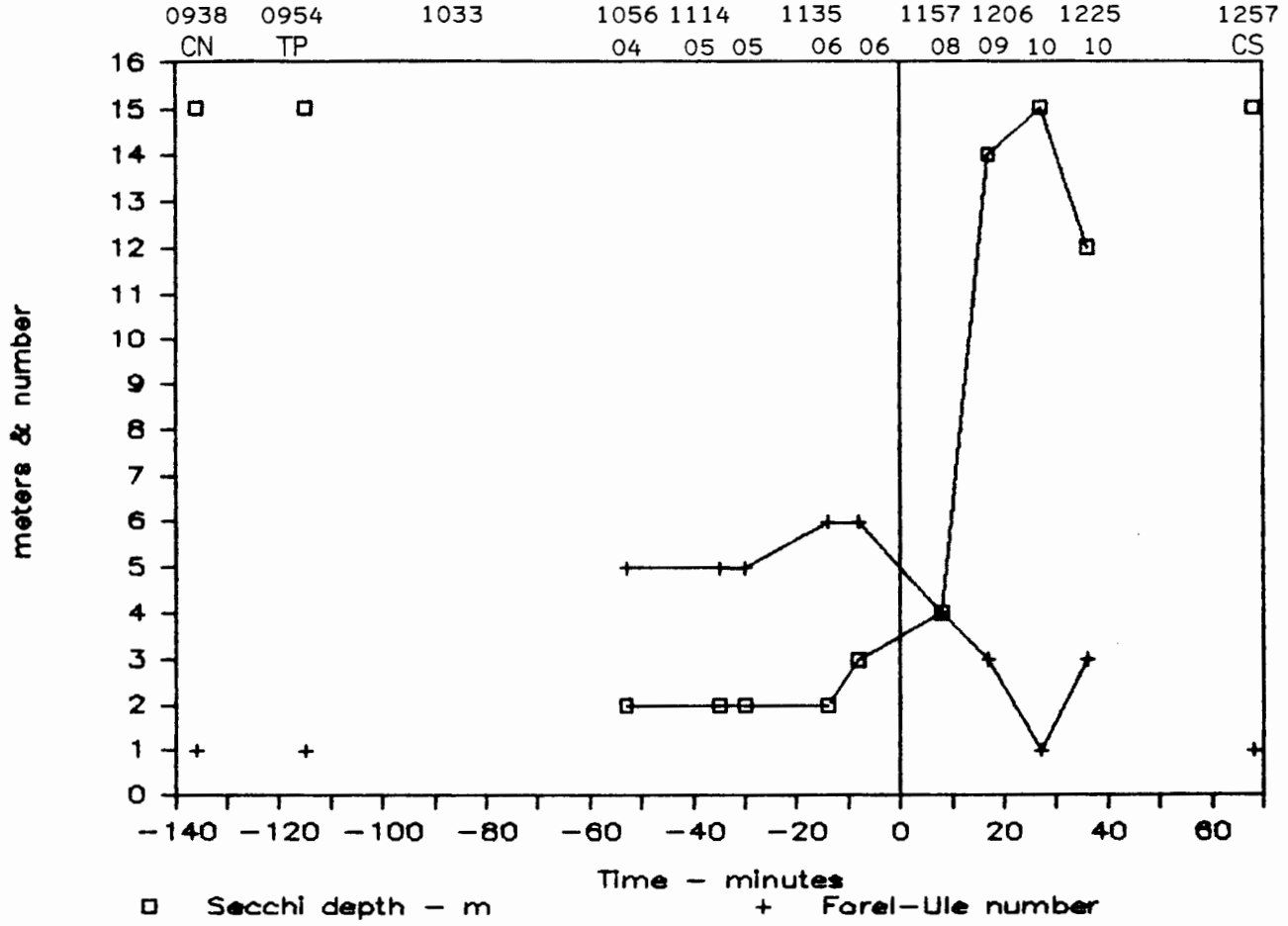
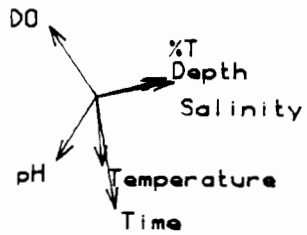


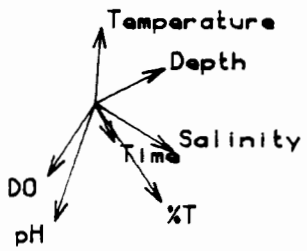
FIGURE 28. WATER TRANSPARENCY MEASURED BY SECCHI DISC AS COMPARED WITH COLOR MEASURED BY FOREL-ULE SCALE, 23 JULY 1982.

THE INVERSE RELANTIONSHIP SEEN PREVIOUSLY (FIGURE 11, 27) DURING AND AFTER DUMPING (STATIONS 04-10), AS COMPARED TO AM AND PM CONTROLS. THE CHANGES BETWEEN THE FIRST AND SECOND MEASUREMENTS AT STATION 10 REPRESENT THE UNEVEN DISPERSAL OF THE SLICK.

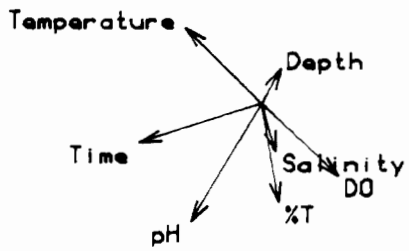
FACTORS 1 AND 2



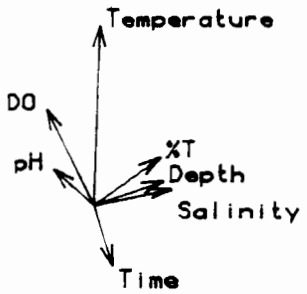
FACTORS 1 AND 3



FACTORS 2 AND 3



FACTORS 1 AND 4



FACTORS 2 AND 4

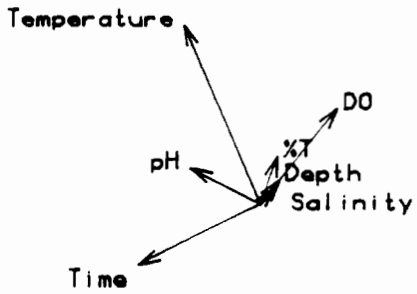
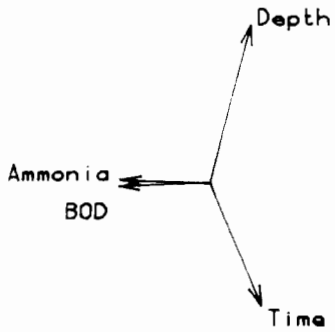


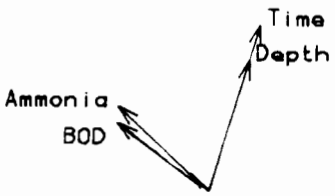
FIGURE 29. PRINCIPAL COMPONENT ANALYSIS (PCA), 20 JULY 1982.

FACTOR 1 INCLUDES DEPTH, SALINITY, %T, DO AND PH. FACTOR 2 INCLUDES TIME, TEMPERATURE AND DO. FACTOR 3 IS PH AND TEMPERATURE, AND FACTOR 4 IS TEMPERATURE. PARALLEL VECTORS ARE CORRELATED; OPPOSITE VECTORS ARE INVERSELY RELATED, AND PERPENDICULAR VECTORS ARE UNRELATED.

FACTORS 1 AND 2



FACTORS 1 AND 3



FACTORS 2 AND 3

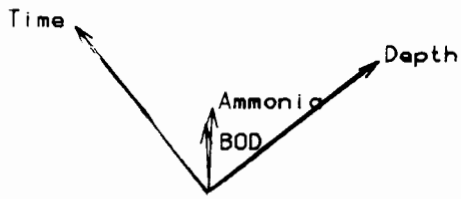
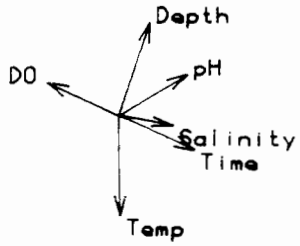


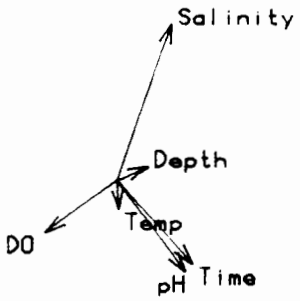
FIGURE 30. PCA, ABIOTIC MARTIX, 20 JULY 1982.

FACTOR 1 IS AMMONIA AND BOD., FACTOR 2 IS AN APPARENT RELATIONSHIP BETWEEN TIME AND DEPTH, AND FACTOR 3 IS A COMBINATION OF OTHER FACTORS. AMMONIA AND BOD HAVE A VERY STRONG RELATIONSHIP, INDEPENDENT OF TIME OR DEPTH, AND EACH HAS A PROBABLE RELATION TO SITE.

FACTORS 1 AND 2



FACTORS 1 AND 3



FACTORS 2 AND 3

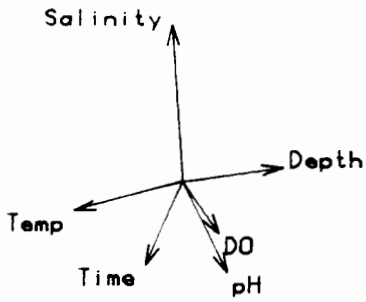
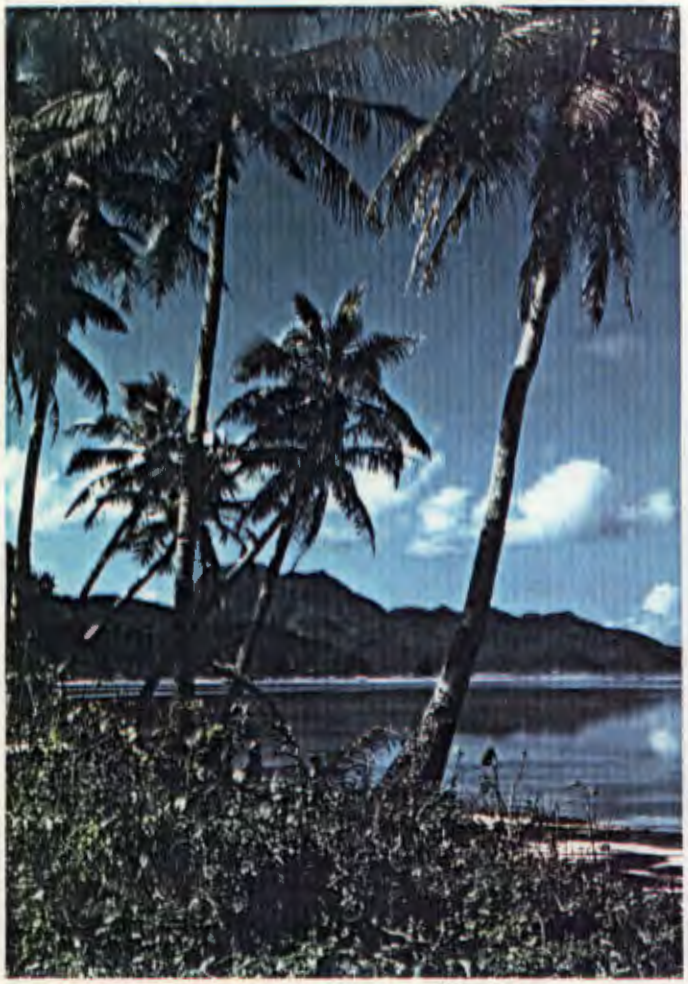


FIGURE 31. PCA, ABIOTIC MARTIX, 23 JULY 1982.

FACTOR 1 IS DOMINATED BY TIME, SALINITY, PH AND DO (AN INVERSE RELATIONSHIP. FACTOR 2 IS A TEMPERATURE-DEPTH RELATIONSHIB, AND FACTOR 3 IS MOSTLY SALINITY. FACTOR 1 PARAMETERS APPEAR UNRELATED TO FACTOR 2 PARAMETERS (VECTORS ARE ORTHOGONALLY DIRECTED).



Left, View of Scenic Shoreline from SW of Pago Pago Harbor, Looking Toward Fatu Rock and Harbor Entrance. Shallows are Exposed at Low Tides to Harvest Shellfish and Must Be Protected from Pollution by Choice of Ocean Disposal Location.

Right, Main Street of Fagatogo with Sports Parade and Local Traffic; Land Disposal Truck for Fish Wastes Used This Route also.

Fish Processing Plants at Base of Alava Mt., Bottom, in Pago Pago Harbor across from Fagatogo, connected by Narrow Roadway. Cargo Dock is in Upper Center, Fuel Dock, Convention Center and Hotel, Upper Left Peninsula.

View of Inner Pago Pago Harbor Toward West, from Cable Car; Canneries Below, Lower Left of Picture (Left).

Below, View from Cable Car Terminal on Alava Mt., Toward Southeast. Fuel Tanker at Dock by Rainmaker Hotel in Center; Utulei Bay and Tulutula Pt., Urban and Recreational Areas.

Left, Outer Pago Pago Harbor from Cable Car Terminus, View Toward Breakers Pt. Dumpsite at Sea, Upper Right.

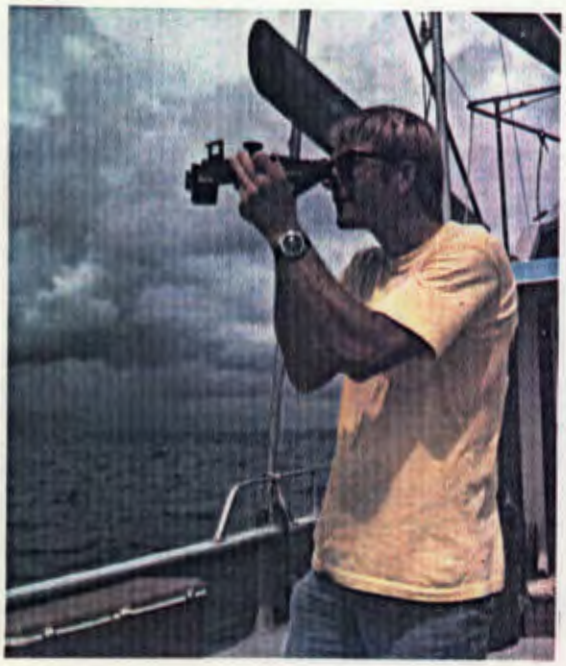
Tuna Superseiner in Pago Pago Harbor; Helicopter is on Deck Amidship. Governor's Residence is on Hill Above Ship (Left).

Below, the Autele, at the Office of Marine Resources, American Samoa. Vessel was used in Ocean Disposal Investigations.

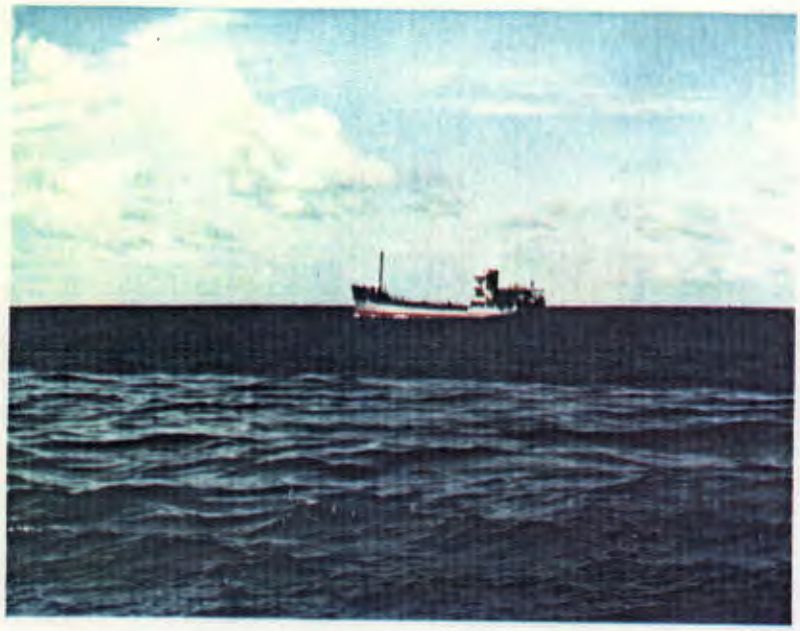
Right, the OMR vessel Sausauimoana, used in Initial Survey for Congressional Committee Demonstration in Rainy Season. Note mud, which washes into bays and harbor.

Dump Vessel Misimoa Begins Disposal of Wastes off Tutuila Island, American Samoa; Note Turbid Wake

Making Water Quality Measurements with Electronic Probes in Wake

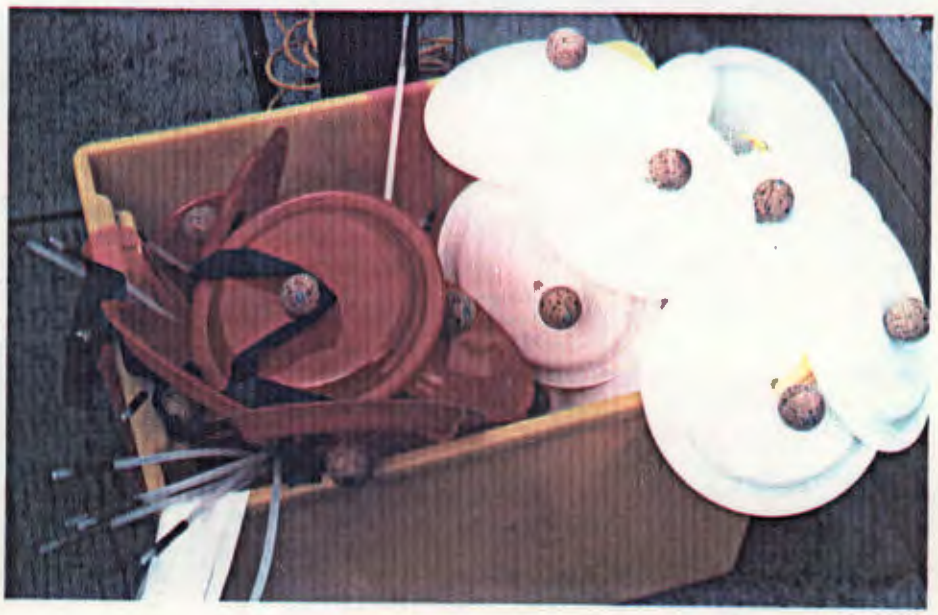


Dr. Richard Wass of the Marine Resources Office, Pago Pago Taking Positions with Sextant (above). Right, Misimoa Circling to Dump.



The Dump Vessel Misimoa after Completing Disposal. Note the Contrast of Light Blue-green Plume with Deep-blue Waters. Depth is Over 1600 Meters at Dumpsite Center, about Three Nautical Miles from Shore. Below, Drogues with Foil Reflectors to Track Surface, 10 and 20 Meter Currents.

Above, and Right, Surface Drogues to Track Movement of Plume During and after Waste Disposal.
Note Patchiness of Light-colored Waste Above.
Persistence of Plume Varies According to Wind and Weather.



Sampling in Fish Waste Disposal Plume (Left), Collecting Water for Later Chemical Analyses in Laboratories in American Samoa and at the University of Southern California. Below, Analyzing Dissolved Oxygen in Hotel "Laboratory".

Above, Analyzing Ammonia Samples in Hotel "Laboratory". Right, Star-Kist Foods Chemical and Quality Control Laboratory.

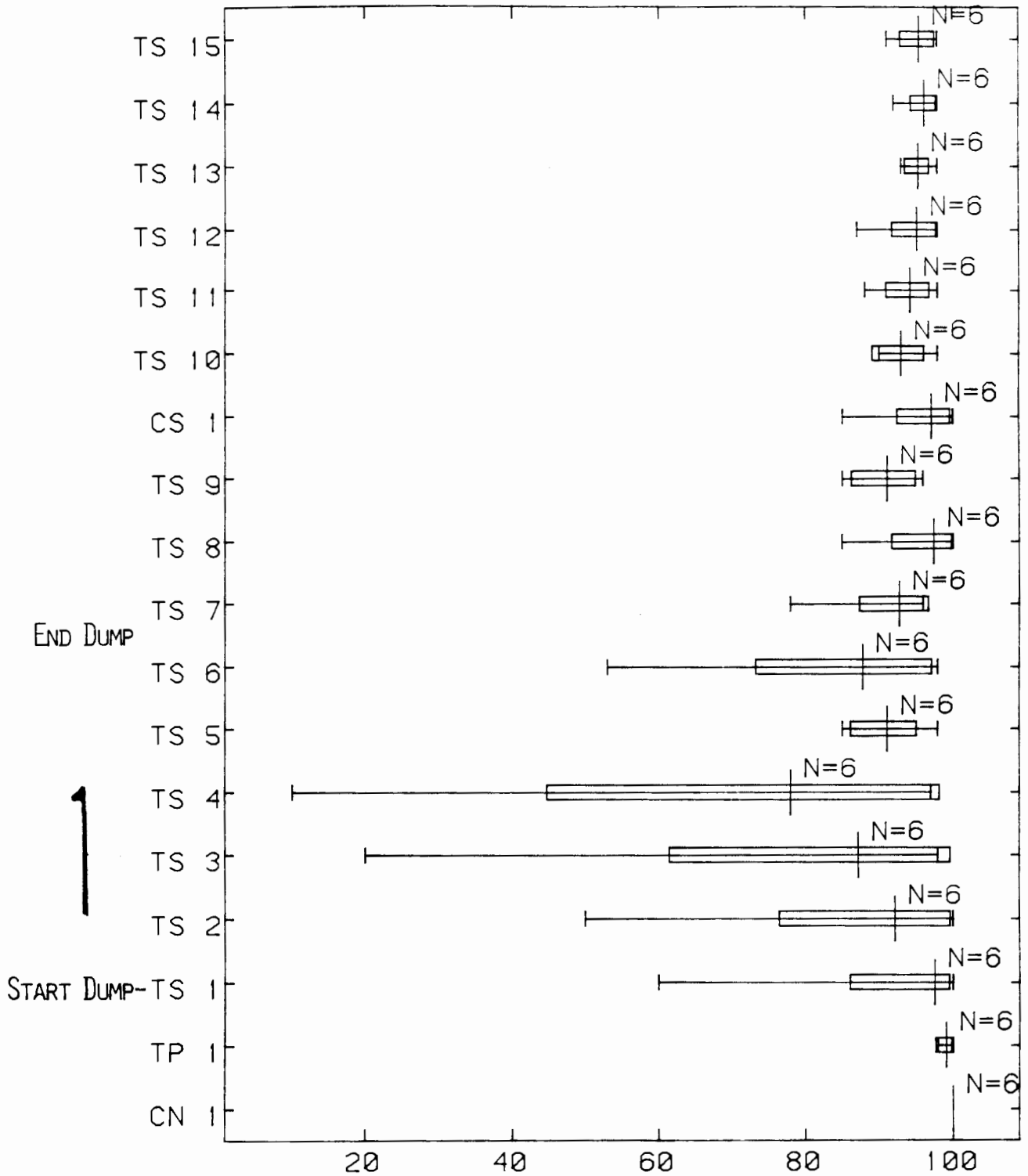


FIGURE 32. PERCENT LIGHT TRANSMITTANCE, 20 JULY 1982. (%T)

* The difference is significant (by anova, P= 0.018).
Range & mean ± 2 S.E. are shown.
Homogeneity of variances requirement realized with arcsine transformation. (C=0.2910).

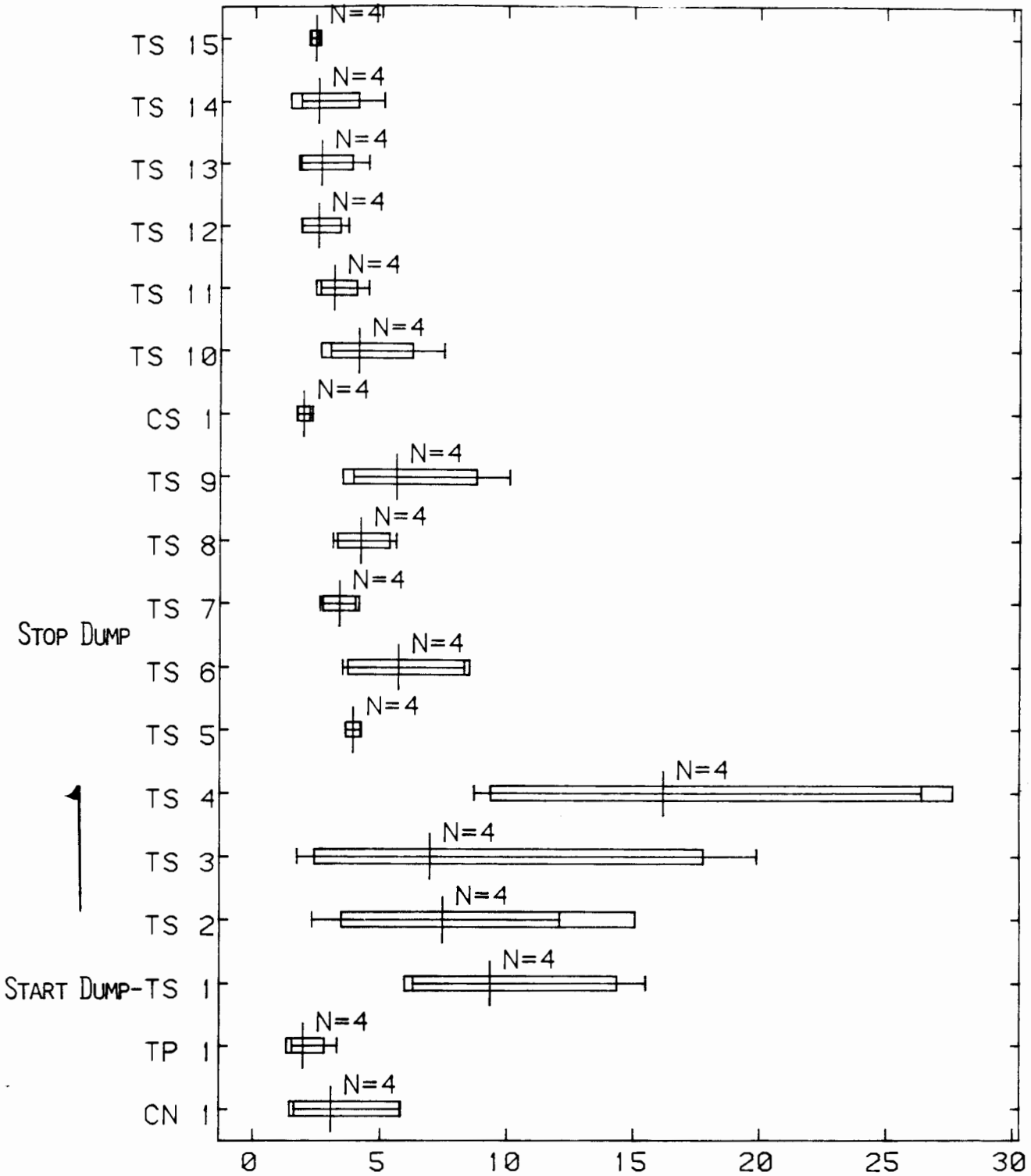


FIGURE 33. AMMONIA, 20 JULY 1982. *(µg-at/l = 0.17mg NH_3/l)*

* The difference is significant (by anova, P< 0.001).
Range & mean ± 2 S.E. are shown.
Homogeneity of variances requirement realized with logarithmic transformation. (C=0.2748).

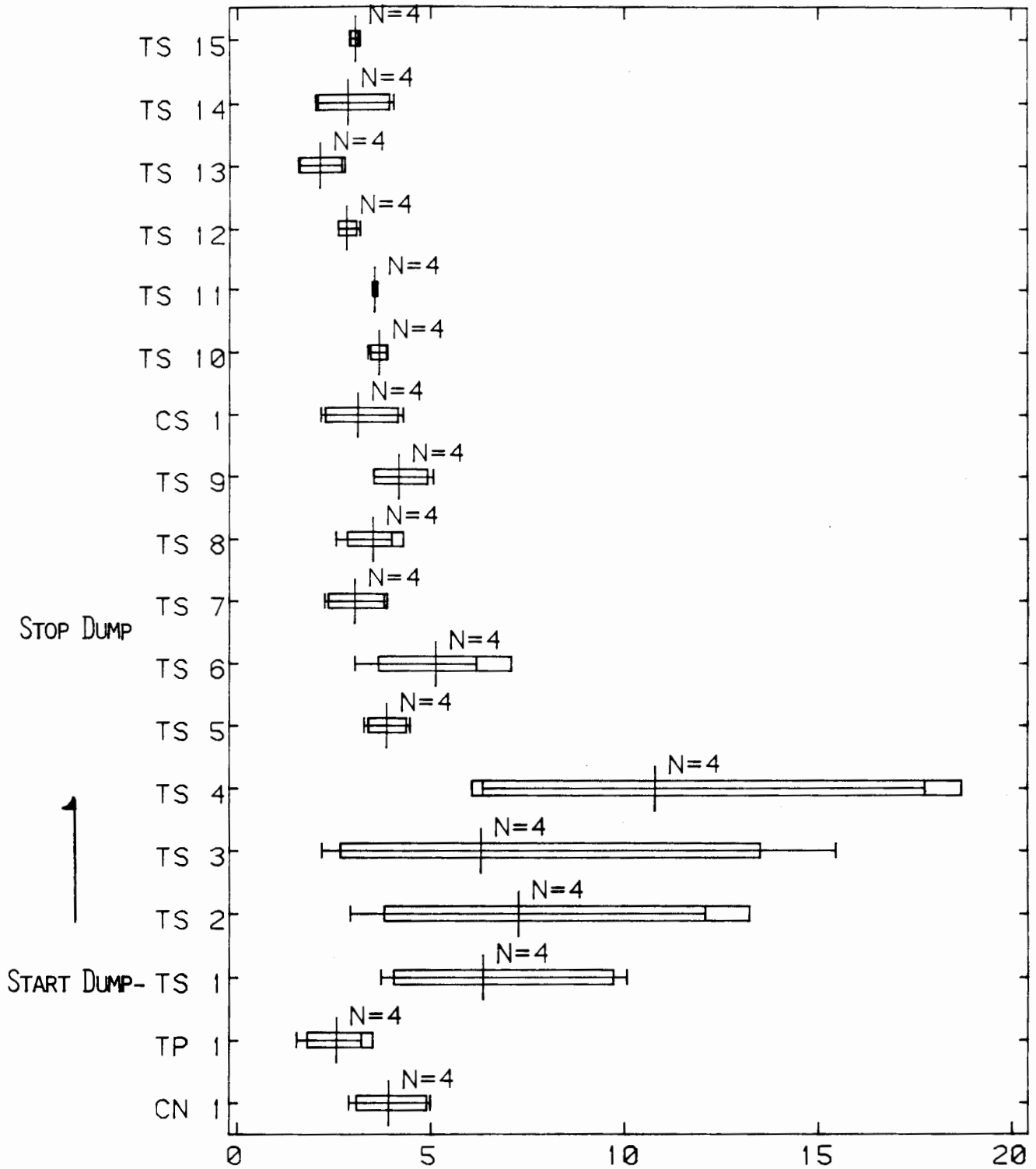


FIGURE 34. BOD *(mg/l)*, 20 JULY 1982.

* The difference is significant (by anova, P< 0.001).
Range & mean ± 2 S.E. are shown.
Homogeneity of variances requirement realized with logarithmic transformation. (C=0.2994).

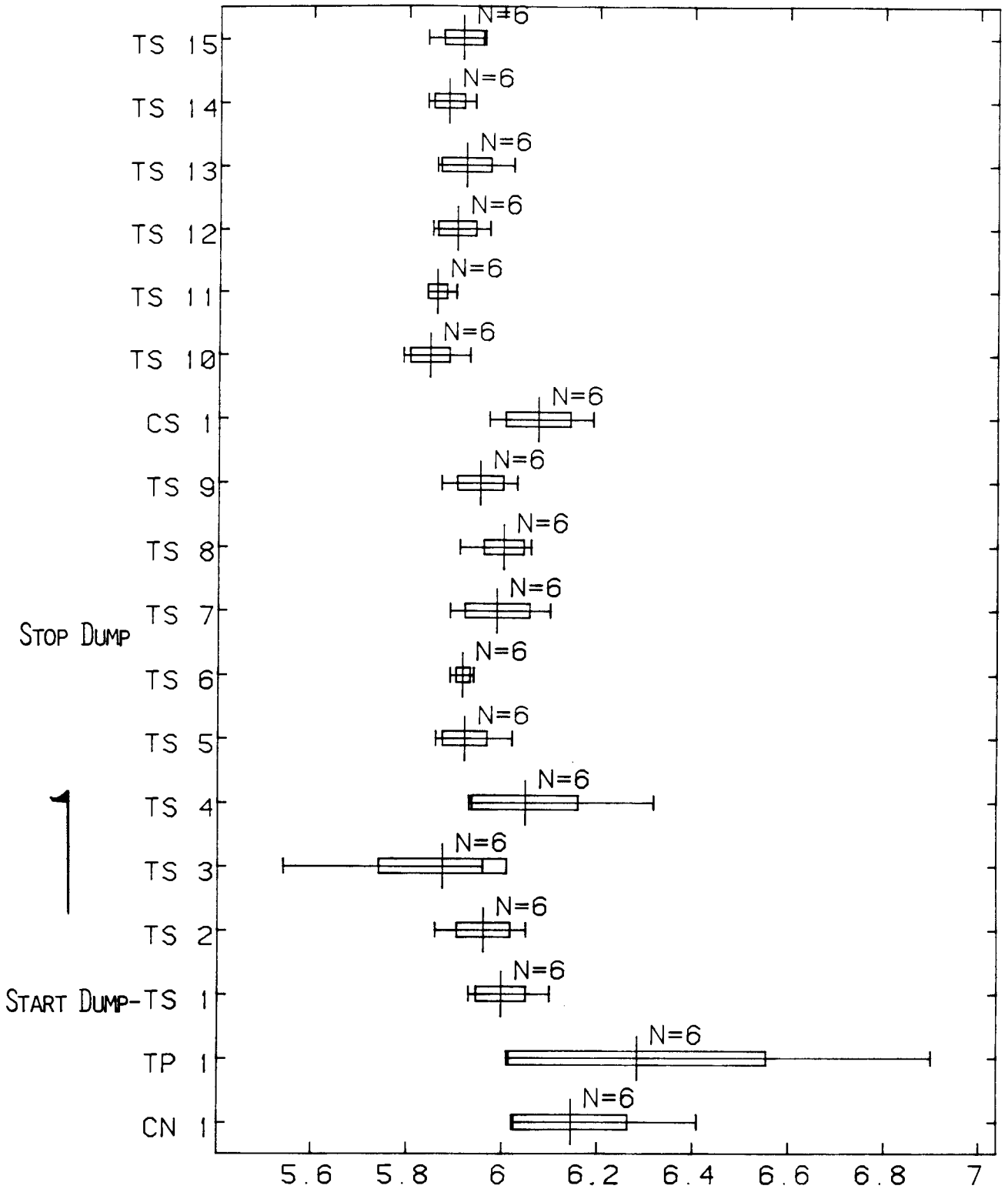


FIGURE 35. DISSOLVED OXYGEN *(mg/l)*, 20 JULY 1982.

* The difference is significant (by anova, P< 0.001).
Range & mean ± 2 S.E. are shown.
Data processed without transformation.

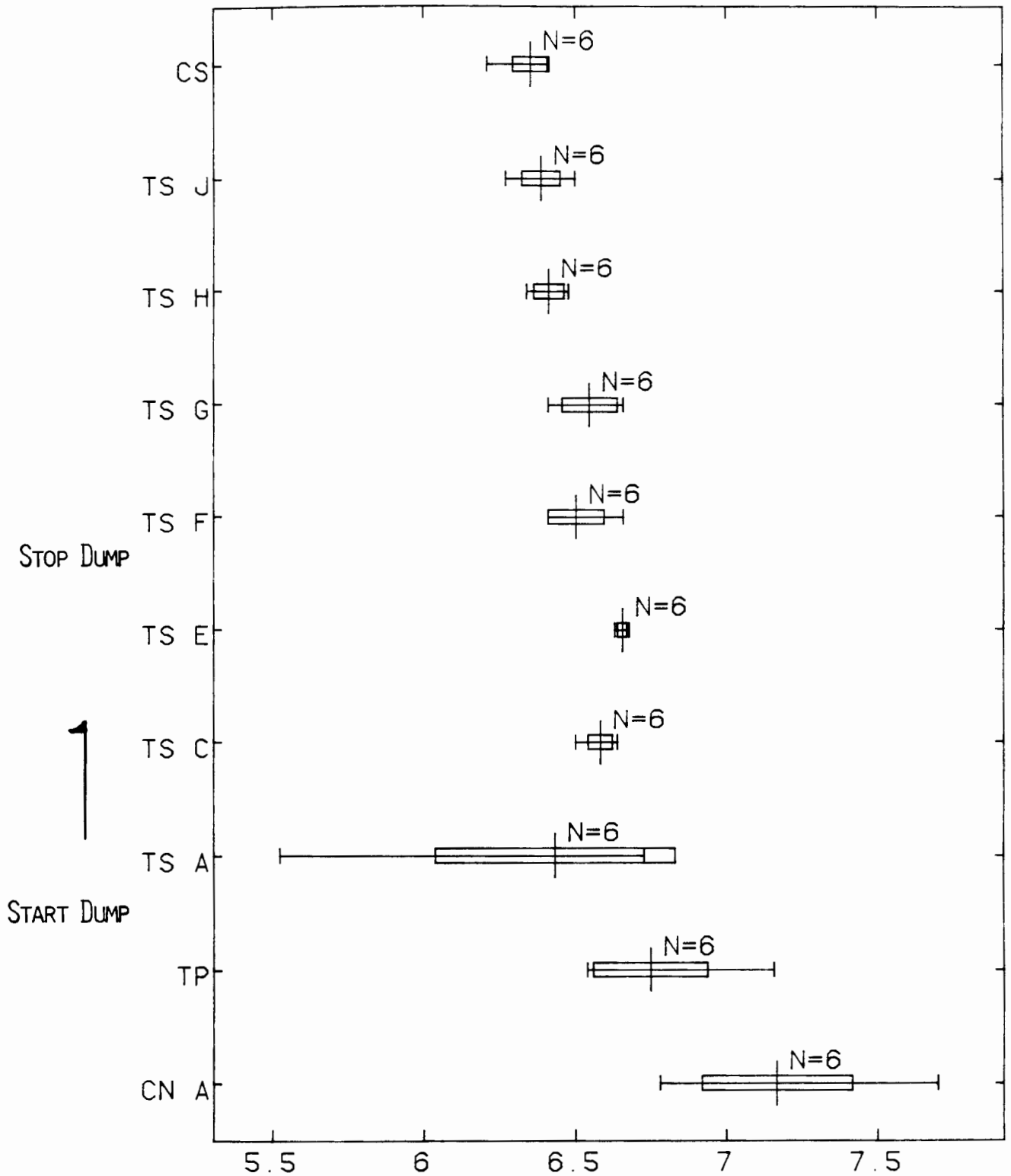


FIGURE 36. DISSOLVED OXYGEN *(mg/l)*, 23 JULY 1982.

* The difference is significant (by anova, P< 0.001).
Range & mean ± 2 S.E. are shown.
Data processed without transformation.

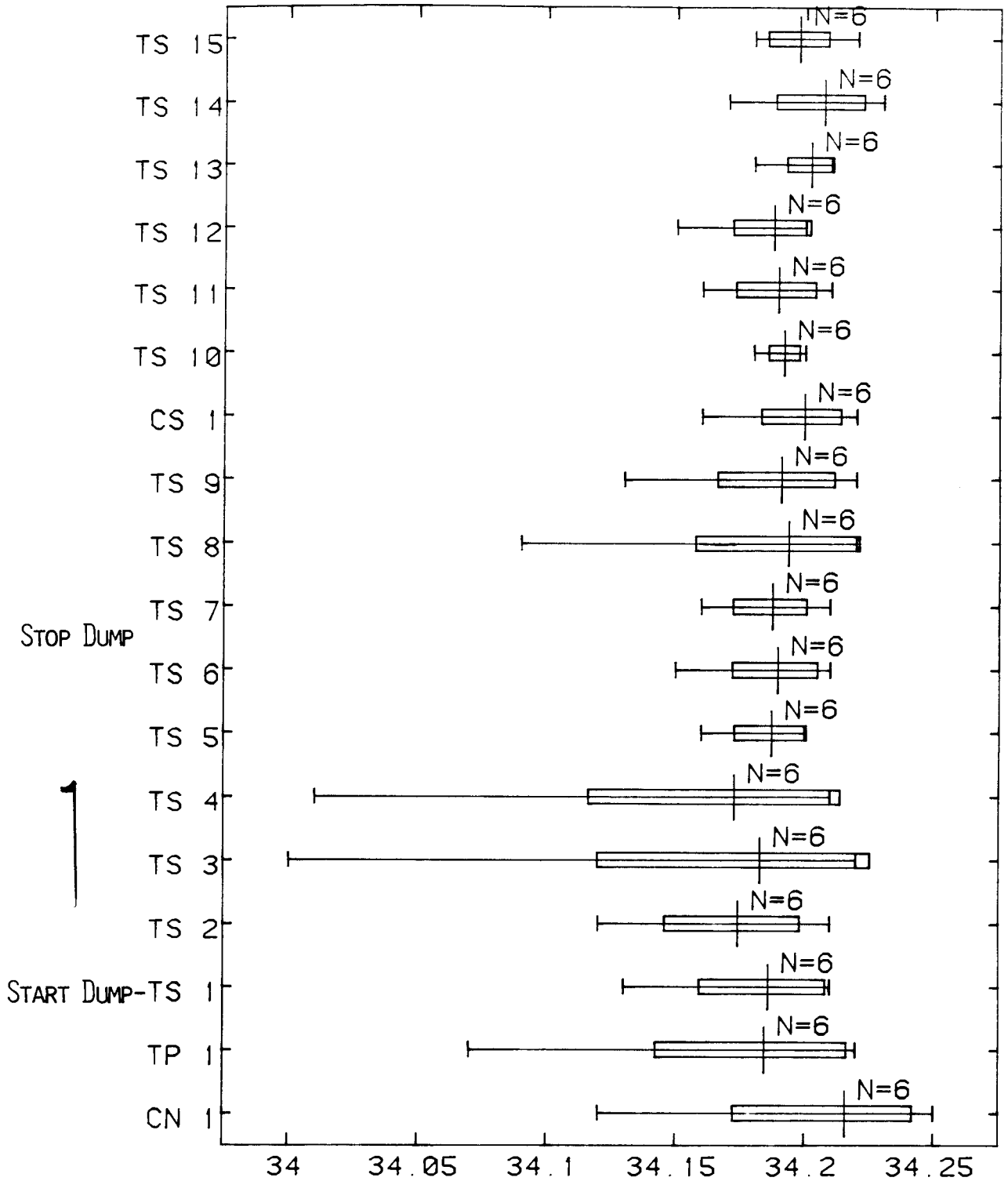


FIGURE 37. SALINITY *(pp th)*, 20 JULY 1982

* The difference is not significant (by anova, P= 0.788).
Range & mean ± 2 S.E. are shown.
Homogeneity of variances requirement realized with arcsine transformation. (C=0.1992).

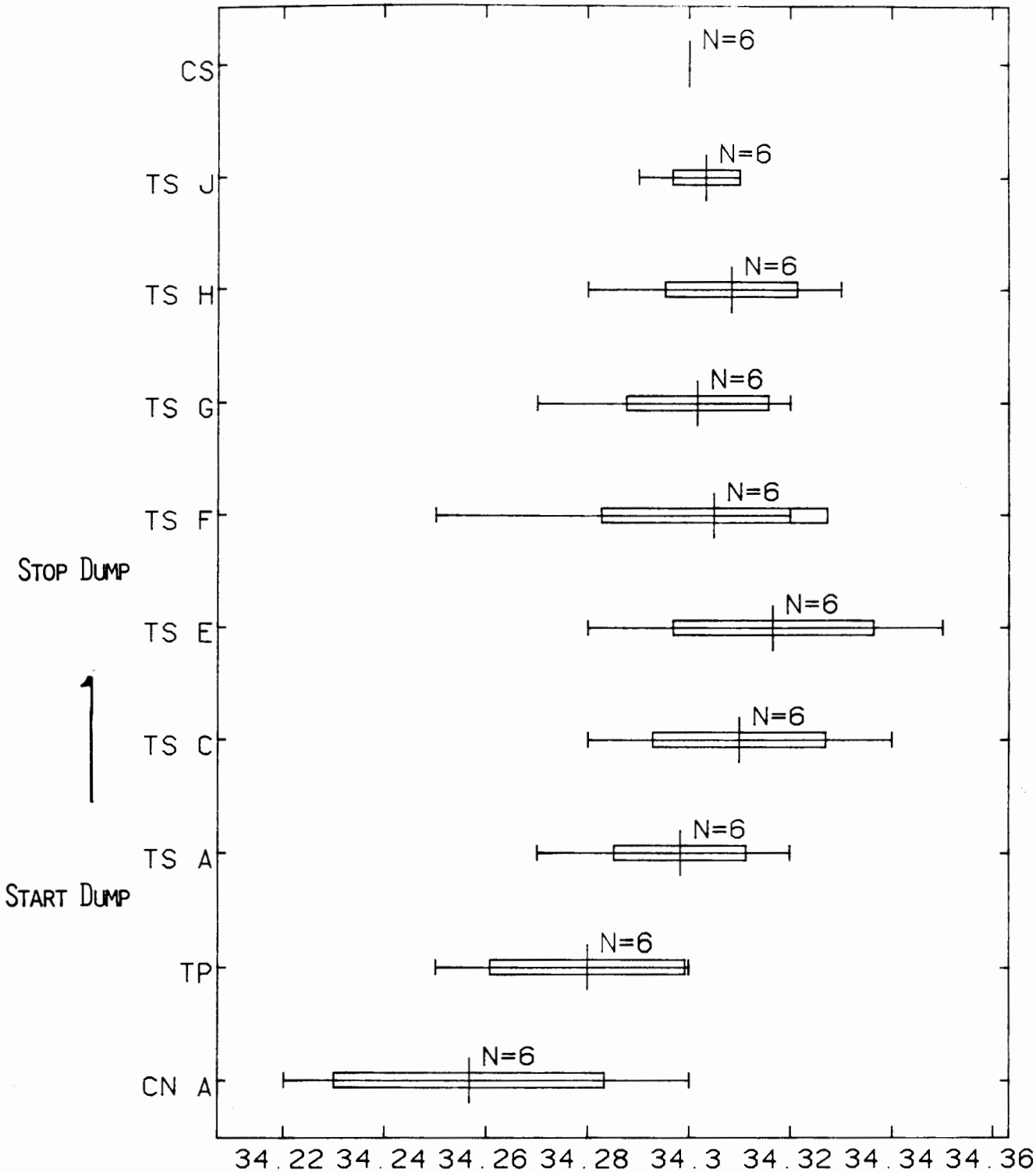


FIGURE 38. SALINITY *(pp th)*, 23 JULY 1982.

* The difference is significant (by anova, P< 0.001).
Range & mean ± 2 S.E. are shown.
Homogeneity of variances requirement realized without transformation. (C=0.2492).

TABLE 6 PRINCIPAL COMPONENT ANALYSIS 20 JULY 1982

PHYSICAL MATRIX

7 variables:
1 - Depth
2 - Time
3 - Temperature
4 - Salinity
5 - DO
6 - pH
7 - %T

108 sets of observations.

--

Variable correlation matrix (R): CORRELATION > 0.20 IS SIGNIFICANT (P=0.05).

	1	2	3	4	5	6	7
1	1.00	0.00	0.07	0.59	-0.36	-0.38	0.46
2	0.00	1.00	0.19	0.15	-0.46	0.28	0.10
3	0.07	0.19	1.00	-0.02	-0.17	0.07	-0.05
4	0.59	0.15	-0.02	1.00	-0.30	-0.33	0.77
5	-0.36	-0.46	-0.17	-0.30	1.00	0.21	-0.12
6	-0.38	0.28	0.07	-0.33	0.21	1.00	-0.11
7	0.46	0.10	-0.05	0.77	-0.12	-0.11	1.00

Determinant of R = 0.1023
For Spericity test, Chi-square = 236.740, df = 21

--

Eigenvectors (axis loadings)
-factors are columns, variables are rows-

	1	2	3	4
1	0.50	0.10	0.17	0.11
2	0.13	-0.68	-0.19	-0.27
3	0.04	-0.42	0.38	0.81
4	0.56	0.08	-0.24	0.07
5	-0.34	0.42	-0.36	0.43
6	-0.29	-0.39	-0.59	0.16
7	0.47	0.09	-0.50	0.21

V'V=

1.00	0.00	0.00	0.00
0.00	1.00	0.00	0.00
0.00	0.00	1.00	0.00
0.00	0.00	0.00	1.00

TABLE 6 CONTINUED page 2 of 2 20 JULY 1982

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Factor	Eigen-value	%	Cum %	df	Chi-square
1	2.560	37	37	21	236.740
2	1.536	22	59	15	145.816
3	1.066	15	74	10	95.549
4	0.854	12	86	6	61.299

--

Factor Pattern (factor-variable correlations) .
-factors are columns, variables are rows-

	1	2	3	4
1	0.80	0.13	0.18	0.10
2	0.22	-0.84	-0.20	-0.25
3	0.07	-0.52	0.39	0.75
4	0.89	0.10	-0.25	0.07
5	-0.54	0.53	-0.38	0.40
6	-0.46	-0.48	-0.61	0.15
7	0.76	0.12	-0.51	0.20

--

Factor Score Coefficients
-factors are columns, variables are rows-

	1	2	3	4
1	0.31	0.08	0.17	0.12
2	0.08	-0.55	-0.19	-0.30
3	0 03	-0.34	0.37	0.87
4	0.35	0.06	-0.23	0.08
5	-0.21	0.34	-0.35	0.46
6	-0.18	-0.31	-0.57	0.18
7	0.30	0.08	-0.48	0.23

End of Analysis

TABLE 7 PRINCIPAL COMPONENT ANALYSIS 20 JULY 1982

ABIOTIC MATRIX

4 variables:
1 - Depth
2 - Time
3 - Ammonia
4 - BOD

72 sets of observations.

--

Variable correlation matrix (R):

	1	2	3	4
1	1.00	0.00	-0.25	-0.30
2	0.00	1.00	-0.34	-0.36
3	-0.25	-0.34	1.00	0.90
4	-0.30	-0.36	0.90	1.00

Determinant of R = 0.1448
For Spericity test, Chi-square = 133.008, df = 6

--

Eigenvectors (axis loadings)
-factors are columns, variables are rows-

	1	2	3
1	0.28	0.78	0.55
2	0.36	-0.62	0.70
3	-0.62	0.02	0.36
4	-0.63	-0.02	0.29

V'V=

1.00	0.00	0.00
0.00	1.00	0.00
0.00	0.00	1.00

TABLE 7 CONTINUED page 2 of 2 20 JULY 1982

Factor	Eigen-value	%	Cum %	df	Chi-square
1	2.223	56	56	6	133.008
2	1.000	25	81	3	79.105
3	0.681	17	98	1	56.707

--

Factor Pattern (factor-variable correlations)
-factors are columns, variables are rows-

	1	2	3
1	0.42	0.78	0.45
2	0.53	-0.62	0.58
3	-0.93	0.02	0.30
4	-0.95	-0.02	0.24

--

Factor Score Coefficients
-factors are columns, variables are rows-

	1	2	3
1	0.19	0.78	0.67
2	0.24	-0.62	0.84
3	-0.42	0.02	0.43
4	-0.43	-0.02	0.35

End of Analysis

TABLE 8 PRINCIPAL COMPONENT ANALYSIS 23 JULY 1982

ABIOTIC MATRIX

6 variables:
1 - Depth
2 - Time
3 - Temp
4 - Salinity
5 - DO
6 - pH

60 sets of observations.

--

Variable correlation matrix (R): (R > 0.25 FOR P=0.05).

	1	2	3	4	5	6
1	1.00	0.00	-0.54	0.12	-0.09	0.45
2	0.00	1.00	0.27	0.25	-0.64	0.64
3	-0.54	0.27	1.00	0.02	-0.17	-0.22
4	0.12	0.25	0.02	1.00	-0.50	0.22
5	-0.09	-0.64	-0.17	-0.50	1.00	-0.28
6	0.45	0.64	-0.22	0.22	-0.28	1.00

Determinant of R = 0.0826
For Sperricity test, Chi-square = 140.068, df = 15

--

Eigenvectors (axis loadings)
-factors are columns, variables are rows-

	1	2	3
1	0.22	0.61	0.07
2	0.54	-0.23	-0.40
3	0.01	-0.67	-0.14
4	0.39	-0.07	0.75
5	-0.51	0.22	-0.25
6	0.49	0.27	-0.44

V'V=

1.00	0.00	0.00
0.00	1.00	0.00
0.00	0.00	1.00

TABLE 8 CONTINUED page 2 of 2 23 JULY 1982

Factor	Eigen-value	%	Cum %	df	Chi-square
1	2.366	39	39	15	140.068
2	1.738	29	68	10	97.674
3	0.915	15	84	6	50.543

--

Factor Pattern (factor-variable correlations)
-factors are columns, variables are rows-

	1	2	3
1	0.35	0.81	0.06
2	0.84	-0.30	-0.38
3	0.02	-0.88	-0.13
4	0.60	-0.09	0.72
5	-0.79	0.29	-0.24
6	0.76	0.36	-0.42

--

Factor Score Coefficients
-factors are columns, variables are rows-

	1	2	3
1	0.15	0.47	0.07
2	0.35	-0.17	-0.42
3	0.01	-0.51	-0.15
4	0.25	-0.05	0.78
5	-0.33	0.17	-0.26
6	0.32	0.21	-0.46

End of Analysis

IV. FATE OF THE WASTES

Physical Characteristics of the Waste

In order to examine the potential behaviour of the wastes in the field, a column 14 feet high with a 2.5 inch inner diameter (4.3 m x 6.5 cm) was constructed at the USC laboratories, Terminal Island, CA. The column was filled with seawater and aliquots of 200 ml of 33 percent sludge and 67 percent filtered seawater were added near the surface with a syringe. Samples were taken at various depths in the column through syringe ports or from a sediment cup at the base of the column in a 30 minute test or a 120 minute test.

The waste column was observed to separate into three distinct zones; a surface zone of floating material, a mixing zone with high turbidity, and a clear zone through which discrete particles could be seen sinking toward the bottom. The clear zone was the largest layer, comprising about 75 percent of the water column. This fits well with the observed turbidity patterns in the field. The surface zone of floating material was about 3.0 cm thick.

Samples of known volumes were withdrawn through the ports at various depths in the column, filtered and the captured solids were oven-dried and weighed. Weights for each layer were calculated based on volume, and the proportion of total material in each zone determined.

At the end of 30 minutes, 92 percent of the recovered material was in the surface layer, and only 0.5 percent was in the bottom sediment cup. In the 120 minute test, 72.3 percent of the recovered material was in the surface zone, and 7.1 percent was in the sediment cup, with the remainder in the mixing and clear zones.

Water samples were taken for ammonia analysis from the ports at various depths. These showed that 97.9 percent of the recovered ammonia was in the surface layer in the 30 minute test, but only 61.1 percent was found in the surface after 120 minutes. In both cases, the clear layer showed less that 1.0 percent of the recovered ammonia and the balance was in the mixing layer. The tests indicated that less than 10 percent of the material sank in 120 minutes. While ammonia diffuses into the water column over time, the highest concentration still remains in or near the surface waters, as it did in the field, or passes into the atmosphere.

A waste field test in southern California using remote-closing Niskin bottles with ammonia samplers attached was carried out on 16 April 1982. Bottles were rigged to sample at 3m, 10 m and 20 meters and the array weighted to drift along the bottom. The net accumulation of particulates was calculated to be 2.9 mg/l at 3m, 0.5 mg/l at 10m, and 0.26 mg/l at 20 m. The 20 m value represented about 8.9 percent of the 3 m value.

Specific Gravity Tests

More recently in January 1983, experiments were carried out on freshly collected sludge from Star-Kist Plants One and Four at Terminal Island to determine the specific gravity and behavior of the flotable component. It was hypothesized that residual bubbles in freshly collected sludge might unduly skew flotation column tests. Sludge aliquots were added to 1000 mls of distilled water in a 2 liter vacuum flask. The mixture was agitated by magnetic stirrer while under vacuum aspiration. Samples were siphoned off sequentially into centrifuge tubes during successive 10 gm additions of "Instant Ocean" salts to precipitate out potential settleable solids. The samples were centrifuged for 20 minutes at 2000 rpm at 18^{0}C, and cooled in a desicator prior to weighing.

Liquid in the centrifuge tubes was also decanted and its specific gravity measured. Settled material was triple-washed with distilled water and recentrifuged and placed in beakers for oven drying.

Nothing precipitated out with "Instant Ocean" over a range of salinities bracketing those of seawater, so that the concentration of dissolved material remained constant. It was thus possible to calculate the percentage (by dry weight) of the total floating material versus the specific gravity of the liquid in which it was found (Figure 39).

It would be expected that, as specific gravity of the

liquid (salinity) increases, the amount of floating material would increase. The small amount of floating material at any of the specific gravities was suprising, based on the earlier tests of sludge which had not been deaerated. It would seem then, that fresh aerated sludge differs from that which has been held in storage tanks. The anaerobic conditions of the holding tanks could cause gas bubbles to be trapped as well, if wastes are held in the tank for several hours, but these would dissipate upon dumping.

As shown in Figure 39, only about 1 percent by dry weight of sludge dumped into seawater (Spg 1.0214-1.0283) floats.

Approximately 7 to 8 percent of the sludge dissolved. The vast majority of the sludge (up to 90 percent) would sink even though it was dispersed by movement of the water column.

The sinking rate would depend on whether air bubbles from the DAF treatment were depleted in the holding tanks prior to dumping, or were depleted naturally after the material was dumped and exposed to air and sunlight. This would account for the varied sinking profiles which were monitored by measuring turbidity (percent light transmittance).

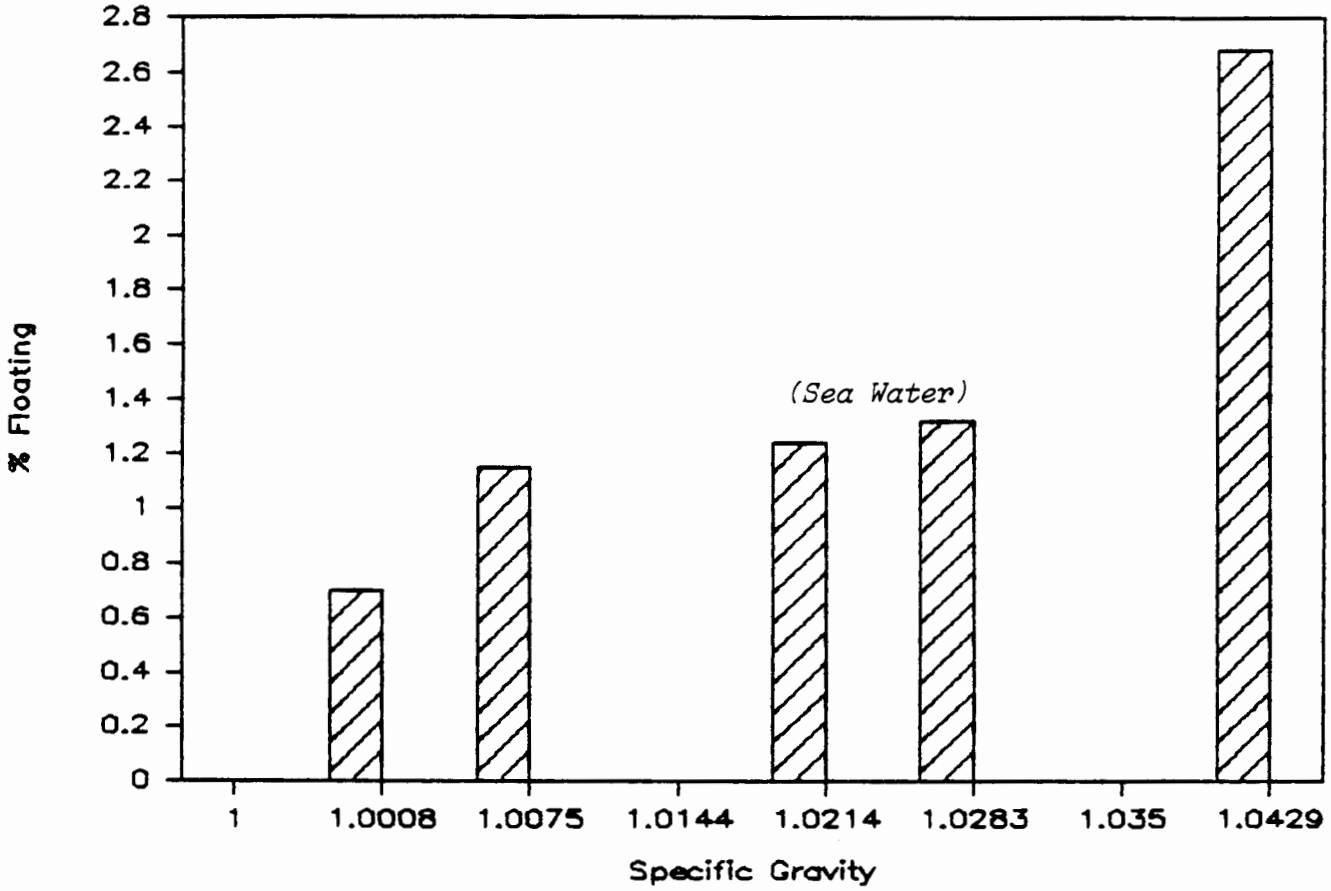

FIGURE 39. THE PERCENTAGE OF WASTES WHICH FLOAT IN LIQUIDS OF VARIOUS SPECIFIC GRAVITIES. SEAWATER FALLS WITHIN THE RANGE OF 1.0214 THROUGH 1.0283.

VI. FEDERAL REGULATORY COMPLIANCE

The Final Revisions of Regulations and Criteria on Ocean Dumping (Federal Register Vol. 42, January 11, 1977) of Marine Protection, Research and Sanctuaries Act (92-532) of 1972, require that specific information be furnished to enable the evaluation of proposed ocean disposal. This section of the report lists the portions of the Regulations relevant to the permit application for ocean disposal of fish processing wastes from facilities of Star-Kist Samoa and Van Camp Seafood, Division of Ralston Purina Co., and summarizes the necessary information, with cross references to the main body of the report as appropriate.

THE NATURE OF THE MATERIAL TO BE DUMPED (part 221)

a. Applicants:

Star-Kist Samoa Inc. 582 Tuna Street Terminal Island, California 90731	Van Camp Seafood, Division of Ralston Purina Co. 11555 Sorrento Valley Rd. San Diego, CA 92121

b. Transporter of materials...:
Anthony Steffany
Inter Island Transport
Pago Pago, American Samoa 96799... or any other person owning or operating a vessel employed for the purpose authorized.

The M.V. Misimoa is 125ft long, with a 24ft 11in. beam and a mean draft of 4ft 6in. It is powered by a 12V71 Detroit deisel and has a Hydromatic 40 MP pump which delivers 500 gpm.

c. Physical and chemical description of materials...:
See Tables 9, 10 and 11, p 86-88.

APPLICATION FOR OCEAN DUMPING PERMIT... (Part 222):
See Appendix C, p C 16 et seq.; Table 2, p 35.

Table 9. Results of Laboratory Monitoring of Waste Materials from Star-Kist Samoa, Disposed of at Sea During Period October 1980 - March 1983 (Quarterly Analyses); Dumping Permit OD 79-01/02.

Results of Laboratory Analyses*

Dumping Period	pH	Bulk Density (gm/ml)	Total Susp. Solids (mg/l)	Total Phosphorus (mg/l)	TKN (mg/l)	BOD_5 (mg/l)	O&G (mg/l)
1980							
Oct-Dec	6.3	0.72	219,000	1785	N.A.(1)	188,000	19,700
1981							
Jan-Mar	6.2	0.75	4,000(2)	780	574	144,000	14,100
Apr-June	6.0	0.87	151,000	880	672	168,000	10,300
July-Sept	6.0	0.86	153,000	813	778	153,000	10,800
Oct-Dec	6.0	0.73	78,000	661	2554	137,000	6,500
1982							
June-Mar	6.0	0.83	100,000	931	907	165,000	6,800
Apr-June	6.1	0.86	148,000	889	1176	150,000	18,100
July-Sept	5.9	0.96	110,000	850	1059	142,000	17,700
Oct-Dec	6.0	0.84	112,000	897	2138	146,000	20,100
1983							
Jan-Mar	6.2	0.90	111.000	967	1540	143,000	19,300
Maximum	6.3	0.96	219,000	1785	2554	188,000	20,100
Minimum	5.9	0.72	4,000	661	574	137,000	6,500
Mean	6.1	0.83	119,000 (131,000)(3)	945	1266	154,000	14,300

Notes:

(1) Equipment not available to complete analysis of TKN

(2) Results for TSS do not appear to be typical although reason not known. Other test results for this sample look representative.

(3) Mean TSS is 13.1 without January - March 1981 sample.

* Supplied by Jeffrey Naumann

Table 10. Results of Laboratory Monitoring of Waste Materials from Van Camp Samoa, Disposed of at Sea During Period January 1981 - March 1983 (Quarterly Analyses); Dumping Permit OD 7 -01/02.

Results of Laboratory Analyses**

Dumping Period	pH	Bulk Density	Total Susp. Solids (mg/l)	Total Phosphorus (mg/kg)	TKN (mg/kg)	BOD_5 (mg/l)	O&G (mg/l)
1981							
Jan-Mar	6.1	.99	7,390	0.52	70	12,622	16,688
Apr-June	6.1	.99	4,000	0.50	336	5,805	10,373
Jul-Sept	6.1	.99	3,106	450	70	13,040	1,123
Oct-Dec	6.1	.99	94,600	340	2,204	23,768	523
1982							
Jan-Mar	6.1	.99	51,200	270	722	17,867	21,023
Apr-June	6.1	.99	111,300	264	4,284	24,500	41,430
Jul-Sept	6.1	.99	96,600	4,284	1,057	62,897	7.5*
Oct-Dec	6.1	.99	133,875	645	1,722	63,313	46,024
1983							
Jan-Mar	6.1	.99	103,200	480	2,744	83,385	56,031

* Appears to be in error

** Supplied by Robert E. Diehl

TABLE 11. COMPARISON OF CHEMICAL ANALYSES OF CANNERY DAF SLUDGES; BASELINE STUDY AND ASSESSMENT STUDY

PARAMETER	BASELINE STUDY - 1979			ASSESSMENT STUDY - 1983		
	OVERALL RANGE	VAN CAMP MEAN	STAR-KIST MEAN	VAN CAMP	STAR-KIST	BOAT COMBINED
pH, pH units	5.8-6.2	6.1	5.9	---	5.9-6.3	---
Bulk Density, gm/ml	0.77-1.02	0.89	0.96	0.99	0.72-0.96	---
Total Solids, %	---	---	---	21.5	44.4	37.1
TVS, %	---	---	---	18.5	39.2	34.4
TSS, Wt. %	9.6-21.4	18.5	14.1	---	---	---
VSS, % of TSS	79.4-96.5	95.4	86.5	---	---	---
TOC, gm/kg dry wt.	456-965	625	567	559	574	604
Total Phosph., mg/kg	739-1031	809	793	26,549	9,451	13,477
TKN, mg/kg	587-769	678	621	19,000	15,000	17,000
BOD_5, mg/l	105,000-258,000	225,000	142,000	92,000	182,000	228,000
MBAS, mg/l	0.5-13.4	2.8	12.0	0.09	0.22	0.59
Aluminum, mg/kg dry wt.	711-10,400	5,770	1,260	17,420	2,158	4,285
Cadmium, mg/kg dry wt.	1.3-6.4	3.5	3.3	1.9	1.3	1.4
Mercury, mg/kg dry wt.	0.011-0.050	0.030	0.015	0.11	0.05	0.06
Oil & Grease, %	---	---	---	3.98	23.9	19.6

NOTE:

(1) Baseline data based upon series of three samples at each cannery collected July 1979.

(2) Assessment data based upon single grab from each cannery and dumping boat May 1983, except for pH and bulk density, which are ranges found during the quarterly monitoring October 1980-March 1983.

JRN: 5/23/83

OCEAN DISPOSAL CONSTRAINTS (Part 227)

Limiting Permissible Concentration (227.27)

Determination of the Limiting Permissible Concentration (LPC) of the waste being discharged was based on results of bioassay tests conducted in the spring of 1980, in accordance with EPA-approved procedures, on samples of the sludge collected from the dissolved air flotation system at the Star-Kist - Samoa cannery. For these assays the frozen sludge was delivered to the USC laboratory and tested, following appropriate dilution, on the California killifish, *Fundulus parvipinnis*, the mysid shrimp, *Acanthomysis sculpta*, and a planktonic copepod, *Acartia* sp. The lethal concentration for 50% (L_{c50}) of the exposed organisms was calculated based on 96 hour toxicity tests, which yielded the following results:

96 Hour Toxicity, Samoa DAF Sludge

Species	LC_{50}
Acartia	0.046%
Acanthomysis	0.040%
Fundulus	0.46%

The LPC is defined in 227.27(a)(2) as "...0.01 of a concentration shown to be acutely toxic ...". Using the worst case found in the bioassays, an LC_{50} of 0.040 percent for the mysid shrimp, this would be 0.01 X 0.04 percent, = 0.0004 percent concentration of the sludge.

Release Zone (227.28)

The release zone is defined as "...the area swept by the locus of points 100 meters from the perimeter of the conveyance engaged in dumping activities ...".

The width of the release zone is the sum of 100 meters on either side of the dumping vessel, the MV *Misimoa*. The beam of the vessel is 7.62 meters (25 feet) making the width of the swept area 207.62 meters.

The length of the release zone was dertermined by multiplying the speed of the vessel during discharge, 9.62 kmph (5 knots), by the time needed to empty the waste-holding tank aboard the vessel. The tank has a maximum capacity of about 155.2 m^3 and is pumped at a rate of 1.893 m^3/min (500 gpm). The length of the release zone is, therefore, calculated as 9.26 kmph X 155.2 m^3/ 1.893 m^3/min = 12,653 m.

The area of the release zone consists of the width (207.62 m), multiplied by the length (12,653m) 2,627,016m^2 or 2.63 km^2.

Initial Mixing (227.29)

The concentration upon initial mixing was estimated by the method outlined in 227.29(b), as described below.

The waste is assumed to be mixed uniformly in a volume of water bounded horizontally by the area of the release zone, an area of 2.63 km^2, to a depth of 20 meters. In field studies conducted for the present report, and in those conducted by Metcalfe & Eddy (1977) no thermocline or halocline was detected

ERRATA

A Report On Ocean Disposal of Fish Processing Wastes Off Pago Pago, American Samoa

Page 88 (Table II). Analyses data for 1983 samples should be as follows:

	Van Camp	Star-Kist	Boat Combined
TKN, mg/Kg	1900	1500	1700

Note: If any further errors are found please contact the Project Sponsors through Jeff Naumann (213) 548-4411, extension 6319.

JRN: 6/6/83

within the depths measured (to 20m). The bottom is over 800 fathoms (1,463 m), as shown in HO chart 83484, making 20 meters the depth of mixing to be used for calculations as stipulated in 227,29(b)(1). The initial mixing volume is 2.63 km^2 multi-lied by 20 m, or 52.6x106m^3.

Conclusions (227.29 (a))

The concentration of waste in the initial mixing volume is estimated to be the volume of waste (155.2 m^3), divided by the initial mixing volume (52.6 km^3). Expressed as a percent, this would equal 0.000295 percent. If the entire 1 n mi - diameter disposal site area of 2.69 km^3, is to be considered, this would result in a concentration of 0.000288 percent. Neither value approaches or exceeds the LPC of 0.0004 percent.

The solid phase of the waste would probably not settle onto the bottom over an area equal to the release zone, as assumed in 227.29(b)(2). The currents and dispersion noted in this report, and the great depth at the disposal site, indicate that dispersal would take place over a much greater area. In view of the biodegradability and possible consumption of the material by the marine biota it is doubtful that any contribution to benthic deposits would be made by this material.

CRITERIA FOR SITE SELECTION (Section 228)

General Criteria (228.5)

228.5 (a)

The disposal site lies about 2.0 nmi (3.70 km) off the nearest coast of Tutuila and about 4.0 nmi (7.41 km) south of the entrance to Pago Pago Harbor in waters about 800 fathoms (1.46 km) deep. There are no fisheries, either pelagic or benthic, in the area. Schools of pelagic fish occasionally transit the area, but generally remain farther offshore where they may be fished by longliner vessels.

Commercial and recreational navigation in the area of the dumpsite is minor, as it is in all the waters off American Samoa.

228.5 (b), (c), & (d)

The dumpsite is a circle one nautical mile in diameter, centered at 14°20' S and 170°41' W. The nearest shore is about 2 nm (3.7km) to the north-west and is a coral reef near the airport. Taema Bank, about 2.5 nm (4.63km) to the north, was once a favorite fishing and diving area for the local populace but the reef was severely impacted by the spiny starfish *Acanthaster* some years ago and can be considered impoverished.

Our studies, as detailed in this report, showed no evidence that the dispersing waste field reached the coast, although the trajectory of drift was at times toward Taema

Bank. The rate of dispersion and dilution of the waste field suggest that the dump material would not be concentrated enough to be measurable by the time it reached the bank. However, if the material were dumped short of the disposal site, it could impact the reef and shoreline.

Specific Criteria (228.6)

228.6 (a) (1)

The dumpsite is a 1 nautical mile (1.85 km) diameter circle centered at 14°20'S, 170°41'E and lying about 4 nm (7.41 km) south of the mouth of Pago Pago Harbor in 800 fathoms (1,463 m) of water. The nearest coast is the reef off the airport, about 2 nm (3.70 km) to the northwest.

228.6 (a) (2)

Schools of pelagic fish occasionally transit the area, although the normal transit routes lie further offshore and to the southwest. No other living resources or activities have been observed in the area.

228.6 (a) (3)

The nearest reef areas, as stated above, lie 2.0 n mi (3.70 km) to the northwest and about 2.5 n mi (4.63 km) to the north. No other amenity areas are in close enough proximity to be potentially affected by the dumpsite.

228.6 (a) (4)

The wastes to be disposed of consist of fish processing

DAF sludge, as well as press water, and cooker water, which are unprocessed materials. More information on the chemical and physical properties and the source of the wastes is presented in Section IV and VI of this report. The material is transported in a 41,000 gallon (155.2 m^3) tank on board the dumping vessel, M.V. Misimoa. Discharge is at a rate of up to 500 gpm (1,893 liters per minute) while the vessel is moving in a circle within the dumpsite at a speed of 5 knots (9.26 kph).

228.6 (a) (5)

Surveillance and monitoring in the area, except at the most rudimentary level, is possible only by bringing in survey personnel and equipment from other areas. Local resources with the skills and equipment to conduct periodic surveys are either over-taxed or non-existent.

228.6 (a) (6)

Data on currents in the area were reported for July 1979 by Metcalfe & Eddy (1979). The surface currents which they measured by drogues were primarily wind driven, with velocities ranging from nearly 0.0 knots to above 0.4 knots(maximum of 22 cm/sec.) in a 15 - 20 k easterly Trade Wind. Under light and variable winds, drift was reported to be in a southwest direction at about half the velocity reported for the stronger wind. Currents at 100 feet (30 m) were consistently eastward and currents at intermediate depths showed directional flow intermediate between the surface and deep currents and lower

velocities than either.

Our field observations, which were made with drogues set at the surface in January and July 1982 and additionally at 10 and 20 meters in July, showed the surface drift to be essentially wind driven, primarily to the north, in July. Both the 10 meter and the 20 meter drogues showed a north to northeast direction but at a lower velocity than at the surface. These conditions were probably unusual in that the Trade Winds were very transitory in 1982. On July 20, surface drogues traveled at 24.2 cm/sec while the slick moved at 13.9 cm/sec. On July 23, surface drogues traveled at 11.3 cm/sec while the 10 and 20 m drogues moved at 9.3 cm sec.

Vertical mixing should extend to at least 300 feet (91.4 m), since no halocline or thermocline has been found to that depth.

228.6 (a) (7)

No discharges or dumping are known at the present site except for the fish processing wastes. A treated sewage effluent line is located about 2.5 nm (4.63 km) to the north-west in Vai Cove. Locally, open ditch and other discharges are present along the shore serving native villages. Cumulative effects of these discharges on the use of the dump-site are not known but are probably insignificant or non-existent.

228.6 (a) (8)

Ocean disposal should not interfere with any of the listed

uses of the ocean. It is not considered likely, in view of the currents and the rate of dispersal of the waste field, that interference would take place. The reef area and Taema Bank could be impacted only if dumping accidentally occurred closer to shore than the disignated site, based on drogue tests.

mitigation measures?

228.6 (a) (9)

The existing water quality and ecology of the area are discussed at length in this report and in Metcalf & Eddy (1979). There is no evidence of cumulative effects that have taken place due to the dumping. There was no evidence of the waste discharged the previous day during our studies in the area.

228.6 (a) (10)

No nuisance species were observed in the area during any of our days in the field. Discussion with Dr. Richard Wass, biologist on the staff of the Marine Resources Center of American Samoa, indicated that the area has never been a rich biotic site for either game or food fish, or for nuisance species such as sharks. Observation and trolling in the area did not result in sighting or catching of nuisance species.

228.6 (a) (11)

No significant natural or cultural features of historical importance are in the area of the disposal site.

V. PUBLIC HEALTH ISSUES

The potential for public health concerns related to ocean disposal of fish wastes can be categorized as follows:

1. Potential for bioaccumulation of trace metals in species harvested for human consumption.
2. Potential attraction of undesirable species or those hazardous to human welfare.
3. Possible presence of Clostridium or other toxins such that they are hazardous to humans.
4. Possible toxicity of wastes to ecosystem organisms.

1) Trace Metals

Sludge samples have been analyzed for aluminum, cadmium and mercury as required by EPA and have in the past been screened for a full array of trace metals. Aluminum appears to the only metal present in relatively large amounts. Is this because of the use of coagulants?

2) Attraction of Undesirable Species

In years prior to federal waste regulations, fish processing wastes contained heads, guts and chunks of flesh as well as course particulates. During those years, sharks might well have been attracted to disposal sites, where wastes would attract smaller fish to feed and provide extensive prey. Sharks are not filter feeders however, and thus would find little to attract them to the present waste plume, unless schools of filter-feeding prey were first attracted.

In American Samoa no sharks have been sighted during

disposal. They are sometimes sighted at the fish-aggregation device (FAD) located southwest of control south (CS), according to Dr. Richard Wass (pers. comm).

Toxicity to Humans

Anaerobic conditions in the DAF sludge tanks and in shipboard waste tanks lead to production of hydrogen sulfide and ammonia. Although H_2S is prominent in the waste, the tanks are vented for safety. We have not attempted to measure sulfide in the waste plume. We have seen little depression of pH in the field, perhaps because of the rapid dilution of the waste.

The Clostridium Question

The question of whether *Clostridium botulinum* spores and/or toxin could constitute a hazard of ocean disposal processes in one which was raised by NOAA consultants. *Clostridium* species are obligate, spore-forming anaerobic bacteria which occur in soil, in marine sediments and animal gut contents; they may also occur in improperly canned foods, or in closed water-line systems, for example. As a group, *Clostridium* species cause a variety of incapacitating diseases with high mortality; *C. tetani* causes the paralytic tetanus, *C. perfringens* causes the so-called gas gangrene of untreated wounds, and *C. botulinum* produces a heat-stable neurotoxin which may be lethal when ingested even in minute quantities in the disease called botulism.

Clostridium spores are virtually ubiquitous in the

terrestrial environment, but botulism is a relatively rare disease. Theoretically anaerobic urban sewage treatment tanks and the dissolved air flotation tanks could provide the anaerobic conditions favorable to Clostridium growth, although air is constantly pumped through the DAF tanks. Other conditions would have to occur, however, such as maintenance of unmixed, undiluted concentrations and ingestion of the resultant toxin. Dr. Milo Appleman, professor emeritus of microbiology at USC, who has been active in Clostridium consulting for many years, is aware of some industrial cases of accidental ingestion and the possibility of such occurrences can be recognized even though they are remote.

We have discussed the situation with Star-Kist personnel, who in turn contacted the National Food Processors Association Laboratories at Berkeley, California, where the canned food botulism cases are examined. Ten samples of DAF sludge were sent to that laboratory for testing. Direct innoculation tests of sludge centrate were performed on mice, as well as tests in which liver broth is innoculated and incubated to enhance the potential concentration of pathogens before injection into test mice. In all cases, results were negative. The possibility versus the probability of infection could also be evaluated by searching for records of similar occurrences. The at-risk group, if any, would appear likely to be the workers handling the sludge at its transfer.

The rapid dilution of the waste from the vessel (3-4 orders within 30m at discharge) would seem to make it unlikely that toxins would reach organisms in lethal concentrations in the waste field. Spores are already known to occur in marine sediments and in fish gut material. In our Los Angeles Harbor microbiology studies in 1973-75, no anaerobic gas-formers were found, which would indicate a lack of Clostridium in surface water samples.

APPENDIX A

January 1982

Cruise Logs

Field and Laboratory Data

Cruise: NOAA-OMPA
American Samoa
StarKist/Van Camp

Date: 18 Jan. 1982

Type: Observation, Transmissometer

VESSELS & PERSONNEL:

R.V. Sausauimoana (55ft)

P. Pedro, OMR Operator
D. Soule, USC P.I.
M. Oguri, USC
J. Soule, USC
R. Bostick, USC
R. Wass, OMR

M.V. Misimoa (55ft)

Dump vessel crew

DUMP MATERIAL:

16,800 gals sludge

STATION LOCATIONS, OBSERVATIONS AND SAMPLING PARAMETERS:

Control North (CN)	14°21.20'x170°39.85'
Test Prime (TP)	14°22.00'x170°41.00'
Control South (CS)	14°23.15'x170°42.40'

(no navigation aids except compass, sextant and 3-arm protractor are available)

Sampling:

Station/Depth	Time	Observations	Parameters
Left dock	1310	Misimoa departed 1250 for Congressional Committee demonstration	
Dump started	1350	Hot, sunny	
NE in TP(A) 15m	1402	Winds to 6mph, 4ft swells	Transmiss-ometer, Martek FU
	1412	Drogues red c blue & white stripe streamers not re-sighted	
NE TS(B) 15m	1432	Yellow drogues c brown & white streamers drifted due south 5-7mph, water rough	Martek shorting Trans, Secchi, FU
SE in CN(C) 10m	1437		Trans, Secchi, FU

18 Jan 1982

Sampling:

Station/Depth	Time	Observations	Parameters
End dump	1440		
NE TP(D) 20m	1452		Trans. Secchi, FU
NW TP(E)	1503		
CS(F)	1530	Wind 20-30mph white caps; rain storm blowing in	"
		High tide 1510, 1.2ft	

Cruise: NOAA-OMPA
American Samoa
StarKist/Van Camp

Date: 20 Jan.1982

Type: BOD/TOC
NH_3, O&G

VESSELS & PERSONNEL:

R.V. Autele (Office of Marine Resources)

R. Wass, OMR Operator
W. Pedro, OMR crew
D. Soule, USC, P.I.
M. Oguri, USC
J. Soule, USC
R. Bostick USC

M.V. Misimoa

Dump vessel crew
J. Naumann (StarKist)

DUMP MATERIAL:

21,000 gals sludge

STATION LOCATIONS, OBSERVATIONS AND SAMPLING PARAMETERS:

Control North (CN)	14°21.20'x170°39.85'
Test Prime (TP)	14°22.00'x170°41.00'
Control South (CS)	14°23.15'x170°42.40'

(no navigation aids except compass, sextant and 3-arm protractor are available)

Sampling:

Station/Depth	Time	Observations	Parameters
CN-G 0,3,6,10m	0900	Small fish schools (skipjack?) many sea birds, wind gust to 4 mph from NE	Water samples for BOD, NH_3, O&G, surface sal., pH., Secchi, transmissometer.
TP-H (pre-dump) 0,3,6,10m	0922	Wind 3mph, ENE	"
CS-J	0955	White drogues c̄ blue streamers, 2ft swells 10ft interval to SW wind 8 mph from N	"
TS-K (start dump) 0,1,3,6,10m	1040	Autele dropped yellow drogues c̄ red streamers; Misimoa set red drogues c̄ brown & white streamers; no floating debris in plume; boat drift to SW	BOD, 0,3,6,10m

20 Jan 1982

Station/Depth	Time	Observations	Parameters
TS-L 0,1,3,6,10m	1050	East edge of plume	Water samples for BOD NH_3, O&G, surface sal., pH, Secchi, transmissometer.
TS-M	1100	Misimoa outside dump circle 14 mph gusts, 6 ft surge to SW clouding over.	"
TS-N	1115	Center dump plume, Misimoa empty, 1125	"
TS-O	1130	Landside of circle, Fish schooling after dumpboat left on S side many birds.	No O&G
TS-P	1145	Back over yellow drogues.	"
TS-Q	1210		
CS-Y	1247	2 gals water for metals background.	"
CS-R	1250	Found CS white drogues; moved 1 mi ± in 3 hrs. brown boobies at fish station (C buoy) offshore looked for sharks; none	"
TS-S	1306	Gurry patch at center of TP, center moved about 0.10 mi in 3 hrs.	"
TS-T	1400	Slight odor of slick remains. West edge of slick found yellow c red drogues 0.9 mi in 3 hrs 20 min, red drogues c stripes (Misimoa) found nearby 1643 ft 1 hr. (0.37k)	"
TS-U	1450	NE edge of slick near start of dump 760 ft to NW in 4 hrs (incoming tide?)	No samples

Cruise: NOAA-OMPA
American Samoa
StarKist/Van Camp

Date: 21 Jan.1982

Type: Martek,backup
BOD, DO

VESSELS & PERSONNEL:

R.V. Autele, OMR (28ft)

R. Wass, OMR Operator
W. Pedro, OMR crew
D. Soule, USC, P.I.
M. Oguri, USC
J. Soule, USC

M.V. Misimoa (55ft)

Dump vessel crew

DUMP MATERIAL:

16,800 gals sludge

STATION LOCATIONS, OBSERVATIONS AND SAMPLING PARAMETERS:

Control North (CN) 14°21.20'x170°39.85'

Test Prime (TP) 14°22.00'x170°41.00'

Control South (CS) 14°23.15'x170°42.40'

(no navigation aids except compass, sextant and 3-arm protractor are available)

Sampling:

Station/Depth	Time	Observations	Parameters
Leaving harbor	0800	Large slick outside harbor, probable bilge pumping, calm; 3 ft swells, light wind NE	
CN 02 0,1,3,6,10m Trans to 20m	0900	Gusts to 12 mph, drogues red c̲ white streamers	Martek, Trans, water for BOD, TOC, Winkler DO 4 depths
TP 03 0,1,3,6,10m Trans to 20m	0927	Gusts to 14mph white drogues c̲ yellow streamers	
CS 04 0,1,3,6,10m Trans to 20m	1000	Gusts to 16 mph near Tafuna outfall 6ft swells, yellow drogues c̲ red stripes	

21 Jan 1982

Station/Depth	Time	Observations	Parameters
TP 05 to 15m	1045	Whitecaps, gusts to 14 mph, dump started at SW edge of circle, Misimoa drogues yellow c̲ blue, Autele red drogues c̲ blue.	
TP 06 0,3,6,10m	1112	East end of plume, gusts to 16 mph, hard to keep station	No BODs
TP 07 to 24.5m	1127	Dump end 1130 on slick drogues, land side of slick gusting 16 mph.	BODs et al
		Looked for sharks on south perimeter for 1 hr. none sighted, saw tuna schools	
TP 08 to 24.5m	1300	Slick drifted SE, wind 16.5 mph	BODs et al
TP 09	1315	Strand of slick most seaward (S) side, drogues blew SW.	No BOD
TS 10 to 24.5m	1335	Trans. battery dropping, storm front crossing, winds 20 mph, slick moved south cross wind (from NE)	
Return to dock		Heavy rain enroute	

CRUISE: NOAA-OMPA American Samoa, Star-Kist Van Camp VESSEL: Sausauimoana DATE: 18 Jan.1982

WEATHER: Early rain; hot sunny; storm later SEA STATE: 4' swell, choppy TIDE: low 0846, 0.4ft

Station	Depth m	Time	Temp °C	Sal o/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TP A	0	1402	29.7		6.7	8.8	65					
	1		29.7		6.3	8.7	85					
	3		29.7		5.7	8.7	98					
	6		29.6		5.7	8.7	99					
	10		29.5		5.5	8.7	97					
	15		29.5		5.5	8.7	100					
TS B	0	1425	29.7		5.5	8.5	80	3	4			
	1		29.7		5.5	8.7	82					
	3		29.6		5.7	8.6	95					
	6		29.5		5.3	8.6	100					
	10		29.5		5.4	8.6	100					
	15		29.5		5.4	8.6	100					
CN C	0	1437	29.6		5.7	8.6	96	29	1			
	1		29.4				97					
	3						97					
	6						98					
	10						99					

CRUISE: NOAA-OMPA American Samoa, Star-Kist Van Camp

VESSEL: Sausauimoana

DATE: 18 Jan 1982

WEATHER: Early rain; hot, sunny

SEA STATE: 4' swells, choppy

TIDE: low; 0846, 0.4ft.

Station	Depth m	Time	Temp °C	Sal ‰	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TP D	0	1452	29.5				92					
	1						93					
	3						96					
	6						96					
	10						96					
	15						97					
	20						99					
TP E	0	1503	29.0				92					
	1						95					
	3						95					
	6						96					
	10						97					
	15						98					
CS F	0	1530	28.0				80		2			
	1						87					
	3						88					
	6						87					
	10						87					
	15						87					

CRUISE: Star-Kist - Van Camp NOAA-OMPA-AMERICAN SAMOA

VESSEL: Autele

DATE: 20 Jan. 1982

WEATHER: AM: Sunny, winds gusty, NE to 4 mph PM: Winds N to E, 14 mph

SEA STATE: AM: 2 ft swell to SW PM: Choppy

TIDE: low 1005, 0.3 ft

Station	Depth m	Time	Temp °C	Sal o/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l	OIL & GREASE
CN G	0	0900		35.5		8.20	92	21.5	1	1.6	7		6.0
	3						97			1.1	7		
	6						98			1.7	8		
	10						100			1.3	7.5		
TP H	0	0922		36.0		8.20	97	24	1	2.1	6		13.5
	3						100			1.1	4		
	6						100			1.2	6		
	10						100			1.2	6.5		
CS J	0	0955		36.4		8.20	89	27	3	2.2	8		24.0
	1						91						
	3						93			1.3	9		
	6						95			<1	8.5		
	10						98			1.3	4		
TP K	0	1040		36.4		8.18	76	22	4	5.6	6.5	3	14.5
	1						88						
	3						94			1.8	6		
	6						98			1.5	3.5		
	10						100			1.0	2		
sludge											87,000	10,400	
raw seawater											6.5	5	

CRUISE: Star-Kist - Van Camp NOAA-OMPA-AMERICAN SAMOA

VESSEL: Autele

DATE: 20 Jan 1982

WEATHER: AM: Sunny, winds gusty, NE to 4 mph
PM: Winds N to E, 24 mph

SEA STATE: AM: 2 ft swells to SW
PM: Choppy

TIDE: low 1005, 0.3 ft

Station	Depth m	Time	Temp °C	Sal ‰	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l	OIL & GREASE
TS L	0	1050		36.3		8.20	75	3.5	4	5.2	5.5	4	6.0
	1						84						
	3						80			5.7	4.5		
	6						90			<1	2		
	10						98			2.6	4	4	
	15						99						
TS M	0	1100		37.0		8.16	84	4	4	4.7	5	4	17.5
	1			37.0		8.16	84						
	3						82			2.9	6.5	4	
	6						96			1.6	4.5		
	10						98			<1	5	4	
	15						99						
TS N	0	1115		37.0		8.19	68	5.5	4	1.8	3	3	14.0
	1						90						
	3						90			3.8	6.5	5	
	6						94			1.4	4		
	10						94			2.6	5	4	
	15						98						

Star-Kist - Van Camp

CRUISE: NOAA-OMPA-AMERICAN SAMOA

VESSEL: Autele

DATE: 20 Jan 1982

WEATHER: AM: Sunny, winds gusty, NE to 4 mph
PM: Winds N to E, 14 mph

SEA STATE: AM: 2 ft swells to SW
PM: Choppy

TIDE: low 1005, 0.3 ft

Station	Depth m	Time	Temp °C	Sal o/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l	OIL & GREASE
TS O	0	1130		36.7		8.20	86	7	3	7.0	7.5		5.0
	1						84						
	3						89			<1	6	4	
	6						92			1.1	8.5	4	
	10						97			1.2	8.5		
	15						98						
	20						99						
TP P	0	1145		36.2		8.20	82	5	4	3.6	5		
	1						82						
	3						83			2.3	6		
	6						88			1.9	4.5		
	10						97			1.3	6.5		
	15						98						
	20						98						
TP Q	0	1210		36.7		8.20	83	6	4	4.0	8		
	1						83						
	3						87			2.6	8.5		
	6						88			2.3	5		
	10						93			<1	7		
	15						96						
	20						97						
	25						98						
	30						99						

Star-Kist - Van Camp

CRUISE: NOAA-OMPA-AMERICAN SAMOA

WEATHER: AM: Sunny, winds gusty, NE to 4 mph
PM: Winds N to E, 14 mph

VESSEL: Autele

SEA STATE: AM: 2 ft swells to SW
PM: Choppy

DATE: 20 Jan 1982

TIDE: low 1005, 0.3ft

Station	Depth m	Time	Temp °C	Sal ‰	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l	OIL & GREASE
CS R	0	1251		36.4		8.20	91	25	1	3.3	6.5		
	1						91						
	3						91			1.0	7.5		
	6						91			1.1	3.5		
	10						91			1.0	5		
	15						93						
TP S	0	1306		36.0		8.20	86	10	3	3.4	4.5		7.0
	1						88						
	3						89			2.9	9		
	6						93			1.7	5.5		
	10						96			1.6	8		
	15						97						
	20						98						
	25						98						
TP T	0	1400		35.9		8.20	88	19	1	2.2	5		12.0
	1						90						
	3						90			<1	8		
	6						91			<1	4		
	10						92			1.6			
	15						93						
	20						94						
	25						95						
	30						95						

CRUISE: Star-Kist - Van Camp NOAA-OMPA-AMERICAN SAMOA

VESSEL: AUTELE

DATE: 21 Jan. 1982

WEATHER: See Cruise Report

SEA STATE: See Cruise Report

TIDE: High; 1710, 2.6ft.

Station	Depth m	Time	Temp °C	Sal ‰	DO mg/l	pH	%T	Secchi m	FU	NH3 µg-at/l	BOD mg/l	TOC mg/l	DO Winkler
CN02	0	0905	29.1	36.5	6.1	8.4	98	25	2		4	3	5.8
	3		29.2	36.1	6.1	8.4	100				3		5.6
	6		29.2	36.3	6.1	8.4	100				4.5		5.6
	10		29.3	36.8	6.1	8.4	100				3	3	5.6
	15		29.3		6.0	8.4	100						
	20		29.3		6.0	8.5	100						
TP03	0	0927	29.4	36.1	6.3	8.4	95	24	1		1.5		5.6
	3		29.3	36.4	5.8	8.4	100				3.5		5.6
	6		29.3	37.2	5.9	8.4	100				4		5.6
	10		29.3	36.5	5.9	8.5	100				4		5.8
	5		29.4		5.8	8.5	100						
	20		29.4		5.9	8.5							
CS04	0	1000	29.5	36.5	6.8	8.5	98	23	1		3		5.7
	3		29.5	36.9	5.9	8.5	97				3.5		
	6		29.4	37.0	5.8	8.5	97				3.5		
	10		29.4	37.0	5.8	8.5	98				5		
	15		29.4		5.8	8.5	99						
	20		29.4		5.8	8.5	100						

CRUISE: Star-Kist - Van Camp NOAA-OMPA-AMERICAN SAMOA **VESSEL:** AUTELE **DATE:** 21 Jan. 1982

WEATHER: See Cruise Report **SEA STATE:** See Cruise Report **TIDE:** High; 1710, 2.6ft.

Station	Depth m	Time	Temp °C	Sal ‰	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l	DO Winkler
TP05	0	1045	29.8	36.3	5.9	8.4	55	3	6		4.5		5.4
	3		29.9	36.8	6.1	8.4	85				3.5		5.4
	6		29.5	37.0	6.1	8.4	90						5.6
	10		29.4	37.0	6.1	8.4	96				3		5.5
	15		29.4		6.0	8.5	98						
TS06	0	1115	29.5	36.1	5.7	8.4	87	4	4				5.4
	3		29.5	36.5	5.5	8.4	86						5.7
	6		29.4	36.5	5.8	8.4	91						5.8
	10		29.4	36.8	6.0	8.5	95						5.6
	15		29.4		5.8	8.5	96						
TS07	0	1135	29.4	36.6	5.7	8.4	90	7	3		7.5		5.6
	3		29.5	36.6	6.0	8.4	88				5		5.4
	6		29.5	36.7	5.7	8.4	91				6		5.6
	10		29.5	36.9	5.8	8.4	92				5.5		5.7
	15		29.5		5.8	8.5	94						
	20		29.4		5.8	8.5	93						
	24.5		29.4		5.8	8.5	93						

CRUISE: Star-Kist - Van Camp NOAA-OMPA-AMERICAN SAMOA

VESSEL: AUTELE

DATE: 21 Jan. 1982

WEATHER: See Cruise Report

SEA STATE: See Cruise Report

TIDE: Low; 1042, 2.1ft.

Station	Depth m	Time	Temp °C	Sal ‰	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS08	0	1300	29.4		5.8	8.5	91		3		3.5	
	3		29.4		6.1	8.4	89				3.5	
	6		29.8		5.8	8.4	88				2.5	
	10		29.7		5.8	8.4	90				2.5	
	15		29.6		5.8	8.5	91					
	20		29.6		5.8	8.5	92					
	24.5		29.5		5.8	8.5	92					
TS09	0	1315	29.6		6.0	8.5	85					
	3		29.7		5.9	8.4	86					
	6		29.7		5.8	8.4	88					
	10		29.7		5.8	8.4	88					
	15		29.7		5.8	8.5	90					
	20		29.7		5.8	8.5	91					
	24.5		29.7		5.9	8.5	90					
TS10	0	1335	29.7		5.9	8.4	87		3		6.5	
	3		29.7		6.0	8.4	86				4	
	6		29.6		6.0	8.4	87				5.5	
	10		29.7		6.0	8.4	88				2.5	
	15		29.7		6.2	8.5	90					
	20		29.7		6.1	8.5	91					
	24.5		29.7		6.0	8.5	91					

APPENDIX B

July, 1982

Cruise Logs

Field and Laboratory Data

Cruise: NOAA-OMPA
American Samoa
Star-Kist/Van Camp

Date: 20 July 1982

Type: BOD, TOC
NH_3, Martek

VESSELS AND PERSONNEL:

R.V. Autele (28 ft)
Office of Marine Resources

R. Wass, OMR, Operator
D. Soule, USC, P.I.
J. Soule, USC
M. Oguri, USC
R. Bostick, USC
D. Eto, USC

M.V. Misimoa (55 ft)

Dump vessel crew

DUMP MATERIAL:

27,650 gals sludge

STATION LOCATIONS, OBSERVATIONS AND SAMPLING PARAMETERS:

Control North (CN)	14°21.20'x170°39.85'	Tide: Extreme spring tides, low at 1255, -0.9 ft.
Test Prime (TP)	14°22.00'x170°41.00'	
Control South (SC)	14°23.15'x170°42.40'	Wind: 10k, south and increasing to 16k

(no navigation aids except compass, sextant and 3-arm protractor are available)

Sampling:

Station/Map Site		Time	Observations	Parameters
Left dock		0858		
CN-1	A	1000		Water samples for BOD TOC, NH_3, Martek, (temp, sal.), DO, pH, Transmissometer, Secchi disk, Forel-Uhle, color scale, wind guage, surface drogues.
TP-1	B	1037	Pre-dump control.	"
TS-1	C	1106	Misimoa started dump on south side of circle. Plume brown-to-tan.	Red drogues deployed.
		1111	Misimoa started second circle	

20 July 1982

Station/Map Site		Time	Observations	Parameters
TS-2	D	1117	Water with 10ft+ waves long swells, wind chop.	Water samples for BOD TOC, NH_3, Martek, (temp, Sal., DO, pH), Transmissometer, Secchi disk, Forel-Uhle, color scale, wind guage, surface drogues.
TS-3	E	1131	Autele moved in behind Misimoa started third circle.	
TS-4	F	1142	Autele moved in plume as Misimoa started fourth circle. Strong wind blows boat N faster than plume (out of plume at 10-20m).	"
TS-5	G	1151	Misimoa in at 4.5 rounds (N side).	"
TS-6	H	1202		
		1213	Misimoa empty.	"
TS-7	I	1215	South side of slick.	"
J		1227	Map position east side of slick, no sample	
TS-8	K	1232	NW landward edge of plume.	"
TS-9	L	1244	West edge of plume.	"
CS-1	M	1329	Control station, no fish, no birds.	"
TS-10	N	1400	SW edge of plume	"
TS-11	O	1413	SE edge of plume.	"
TS-12	P	1427	East edge of plume still visible in circle, center not filled in.	"
TS-13	Q	1440	South edge.	"
TS-14	R	1452	North edge, water light milky blue.	"
TS-15	S	1502	North E edge, water light milky blue.	"
	T	1520	Red drogues from TS-1 sighted north of slick toward harbor. No slick nearby.	

Cruise: NOAA/OMPA American Samoa Star-Kist/Van Camp | Date: 23 July 1982 | Type: Drogue Study, Oxygen Sag

VESSELS & PERSONNEL:

R.V. Autele
Office of Marine Resources

M.V. Misimoa
Dump Vessel

R. Wass, Operator (OMR)
D. Soule, USC P.I.
J. Soule, USC
M. Oguri, USC
R. Bostick, USC

DUMP MATERIAL: 30,200 Gallons Sludge.

STATION LOCATIONS, OBSERVATIONS AND SAMPLING PARAMETERS:

Control North (CN)	14°21.20'x170°39.85'
Test Prime (TP)	14°22.00'x170°41.00'
Control South (CS)	14°23.15'x170°42.40'

Weather: South 2-6k gusts, 8-19ft long swells, no white caps.

Sampling:

Station/Map Site		Time	Observations	Parameters
CN	1	0933	Flat yellow drogues released.	Drogues, Martek (temp., sal., DO, pH.)
CN-A		0938	Control Martek	
TP	2	0954	Flat red drogues released.	"
TS	3	1033	Misimoa starts dump; surface balloon drogues released (2)	(no measurements)
TS		1035	10m balloon drogues released (2)	Parameters
TS		1036	20m balloon drogues released (2)	"
TS		1053	One 20m balloon reset, one sank.	"
TS-A	4	1056	Seas calm	"
TS-B	5	1114	Seven surface readings across waste plume to look for oxygen sag.	"
TS-C	5	1119	Vertical readings for oxygen sag.	"

23 July 1982

Station/Map Site		Time	Observations	Parameters
TS-D	6	1135/ 1139	Eight surface readings	Drogues, Martek (temp., sal., DO pH.).
TS-E	6	1141	Vertical readings	"
	7	1149	Misimoa empty. Surface drogues, north of 10 and 20m drogues, 130 yes ± apart	(no measurements)
TS-F	8	1157	East side of dump circle	Parameters
TS-G	9	1206	North side of dump circle; plume not very visible, lighter blue; particulates floating in water column.	"
TS-H	10	1216	West side of slick.	"
TS-J	10	1225	West side in slick.	"
CS	11	1257	Hot, calm with long swells, 6-10ft.	Martek
		1310/ 1430	Survey for sharks; none found. Two skipjack caught on handline; several large schools between CS and TP, outside plume; many birds diving.	
	12	1450	Balloon drogue, 10m A, picked up.	Drogues
		1453	Balloon drogue, 10m B, picked up 100ft south of A.	"
		1454	Balloon drogue, 20m A, picked up 50ft west. Slick a light blue, visible due to lack of wind ripple.	"
	13	1500	Surface drogues picked up, A was SW of B, separated by 110yds ±; position recorded between them north of northern edge of slick. Final positions of slick recorded. Yellow flat drogues not re-sighted from CN; red drogues on north side of slick.	"

23 July 1982

Station/Map Site	Time	Observations	Parameters
14	1512	North edge of slick	(position only)
15	1520	West edge of slick	"
16	1525	South edge of slick	"
17	1533	North East edge of slick	"

CRUISE: NOAA-OMPA-Van Camp/Star-Kist American Samoa VESSEL: Autele DATE: 20 July 1982

WEATHER: Clear, Sunny, South wind SEA STATE: Long swells, 10 ft. TIDE: Low 1255, -0.9ft.

Station (Map/Site)	Depth m	Time	Temp °/C	Sal °/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
CN 1 (A)	0	1000	28.35	34.12	6.41	8.24	100	< 15	1	4.9	4.98	6.0
	3		18.40	34.20	6.22	8.16	100			5.8	4.27	4.5
	6		28.40	34.22	6.09	8.14	100			1.6	3.70	1.0
	10		28.40	34.22	6.07	8.14	100			1.6	2.87	3.0
	15		28.40	34.25	6.06	8.13	100					
	20		28.39	34.22	6.02	8.14	100					
TP 1 (B)	0	1037	28.38	34.07	6.30	8.41	100	< 15	1	1.6	1.51	56.5
	3		28.39	34.18	6.35	8.19	98			1.7	2.73	48.0
	6		28.40	34.19	6.90	8.16	98			3.3	3.03	48.5
	10		28.40	34.20	6.11	8.16	98			1.5	3.20	1.5
	15		28.38	34.21	6.04	8.14	98					
	20		28.38	34.22	6.01	8.14	100					
TS 1 (C)	0	1106	28.36	34.13	6.10	8.26	60	3	6	11.5	10.07	3.5
	3		28.39	34.16	6.04	8.17	94			6.3	5.30	51.5
	6		28.38	34.19	6.00	8.16	100			6.6	7.91	1.0
	10		28.38	34.20	5.98	8.16	100			15.5	3.70	45.0
	15		28.38	34.21	5.94	8.15	100					
	20		28.38	34.21	5.93	8.15	100					

CRUISE: NOAA-OMPA-Van Camp/Star-Kist American Samoa
WEATHER: Clear, Sunny, south wind

VESSEL: Autele
SEA STATE: long swells, 10ft.

DATE: 20 July 1982
TIDE: Low 1255,-0.9ft.

Station (Map/Site)	Depth m	Time	Temp °C	Sal o/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS 2 (D)	0	1117	28.37	34.12	6.05	8.17	50	2	8	12.1	12.10	2.5
	3		28.39	34.16	5.98	8.16	87			11.2	10.57	1.5
	6		28.38	34.16	5.86	8.15	96			8.8	6.87	1.5
	10		28.36	34.18	5.93	8.14	96			2.3	2.90	110.0
	15		28.37	34.20	6.02	8.18	98					
	20		28.36	34.21	5.93	8.15	100					
TS 3 (E)	0	1132	28.35	34.00	5.95	8.16	20	1	8	19.9	15.47	2.0
	3		28.40	34.17	5.96	8.16	87			9.6	7.79	1.0
	6		28.41	34.20	5.95	8.15	96			5.7	5.16	40.0
	10		28.38	34.22	5.93	8.15	97			1.7	2.16	17.0
	15		28.37	34.21	5.54	8.14	96					
	20		28.38	34.22	5.92	8.16	98					
TS 4 (F)	0	1142	28.29	34.01	6.32	8.23	10	1.5	7	24.4	17.77	7.5
	3		28.40	34.17	6.03	8.16	54			26.4	16.97	67.0
	6		28.40	34.19	6.01	8.15	88			12.0	9.33	7.0
	10		28.41	34.20	6.01	8.15	96			8.7	6.80	1.5
	15		28.38	34.21	5.99	8.16	96					
	20		28.38	34.20	5.93	8.15	97					

CRUISE: NOAA-OMPA-Van Camp/Star-Kist American Samoa
WEATHER: Clear, Sunny, south wind

VESSEL: Autele
SEA STATE: Long swells, 10ft.

DATE: 20 July 1982
TIDE: Low 1255, -0.9ft.

Station (Map/Site)	Depth m	Time	Temp °C	Sal °/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS 5 (G)	0	1151	28.42	34.16	5.95	8.14	89	4	6	3.6	3.26	56.0
	3		28.44	34.17	6.02	8.13	85			3.7	3.95	110.0
	6		28.41	34.19	5.86	8.13	88			4.2	4.44	110.0
	10		28.41	34.20	5.89	8.14	88			4.2	3.80	0.0
	15		28.39	34.20	5.89	8.14	98					
	20		28.38	34.20	5.91	8.15	95					
TS 6 (H)	0	1202	28.39	34.15	5.94	8.21	53	3	4	7.7	6.16	90.0
	3		28.42	34.18	5.91	8.16	79			8.3	6.07	3.0
	6		28.41	34.19	5.89	8.15	89			4.5	5.82	4.0
	10		28.39	34.20	5.91	8.15	95			3.5	3.03	8.5
	15		28.38	34.20	5.93	8.16	96					
	20		28.38	34.21	5.92	8.16	98					
TS 7 (I)	0	1215	28.42	34.16	6.03	8.31	78	7	4	3.0	3.79	9.5
	3		28.41	34.18	6.05	8.21	92			4.0	3.63	2.5
	6		28.41	34.18	6.10	8.19	95			4.0	2.66	33.0
	10		28.38	34.19	5.94	8.17	95			2.6	2.24	100.0
	15		28.37	34.20	5.89	8.16	96					
	20		28.36	34.21	5.92	8.16	96					

CRUISE: NOAA-OMPA-Van Camp/Star-Kist American Samoa VESSEL: Autele DATE: 20 July 1982

WEATHER: Clear, Sunny, south wind SEA STATE: Long swells, 10 ft. TIDE: Low 1255,-0.9ft.

Station (Map/Site)	Depth m	Time	Temp °C	Sal °/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS 8 (K)	0	1232	28.37	34.09	6.02	8.26	85	7	4	4.0	3.93	31.5
	3		28.45	34.20	6.06	8.20	92			5.6	3.69	1.5
	6		28.45	34.22	6.03	8.19	98			4.4	3.97	2.5
	10		28.40	34.20	6.01	8.18	100			3.1	2.54	0.0
	15		28.40	34.21	5.98	8.18	100					
	20		28.39	34.21	5.91	8.18	98					
TS 9 (L)	0	1244	28.43	34.13	5.99	8.37	85	4	4	10.1	4.47	0.5
	3		28.48	34.19	6.03	8.22	85			6.2	5.05	2.5
	6		28.45	34.19	5.95	8.19	87			3.9	3.52	2.0
	10		28.41	34.20	5.97	8.18	95			3.9	3.72	53.0
	15		28.39	34.20	5.90	8.18	95					
	20		28.38	34.22	5.87	8.17	96					
CS 1 (M)	0	1330	28.49	34.16	6.07	8.47	85	< 15	3	1.7	2.74	0.5
	3		28.49	34.20	6.19	8.31	96			2.3	3.57	54.5
	6		28.49	34.22	6.15	8.28	98			1.9	4.27	33.5
	10		28.45	34.20	6.05	8.26	97			1.8	2.14	51.5
	15		28.44	34.20	6.01	8.24	100					
	20		28.44	34.21	5.97	8.24	99					

CRUISE: NOAA-OMPA-Van Camp/Star-Kist, Samoa VESSEL: Autele DATE: 20 July 1982

WEATHER: Clear, Sunny, south wind SEA STATE: Long swells, 10 ft. TIDE: Low 1255,-0.9ft.

Station (Map/Site)	Depth m	Time	Temp °C	Sal °/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS 10 (N)	0	1401	28.48	34.19	5.93	8.34	90	4	4	3.0	3.67	29.5
	3		28.48	34.19	5.87	8.27	90			3.8	3.84	0.0
	6		28.47	34.20	5.80	8.24	90			7.5	3.75	0.5
	10		28.43	34.20	5.79	8.22	90			3.2	3.35	0.0
	15		28.39	34.18	5.85	8.22	98					
	20		28.39	34.19	5.83	8.22	97					
TS 11 (O)	0	1413	28.41	34.16	5.90	8.19	88	6	4	4.5	3.49	0.0
	3		28.41	34.17	5.88	8.18	92			3.0	3.60	0.0
	6		28.47	34.19	5.85	8.19	93			2.7	3.49	0.0
	10		28.43	34.20	5.84	8.19	95			2.6	3.52	0.0
	15		28.39	34.20	5.85	8.18	98					
	20		28.38	34.21	5.84	8.19	97					
TS 12 (P)	0	1427	28.45	34.15	5.92	8.17	87	10	4	3.7	2.86	0.0
	3		28.48	34.18	5.94	8.18	93			2.5	2.68	0.0
	6		28.48	34.19	5.97	8.18	96			2.3	3.15	0.5
	10		28.45	34.20	5.87	8.18	96			1.8	2.60	0.0
	15		28.41	34.20	5.85	8.18	98					
	20		28.40	34.20	5.86	8.18	98					

CRUISE: NOAA-OMPA-Van Camp/Star-Kist, Samoa VESSEL: Autele DATE: 20 July 1982

WEATHER: Clear, Sunny, south wind SEA STATE: Long swells, 10 ft. TIDE: Low 1255, -0.9 ft.

Station (Map/Site)	Depth m	Time	Temp °C	Sal o/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS 13 (Q)	0	1440	28.41	34.18	6.02	8.37	93	12	3	1.8	2.62	0.0
	3		28.46	34.20	5.95	8.23	94			4.5	1.81	1.5
	6		28.44	34.20	5.95	8.20	94			2.3	2.70	54.5
	10		28.42	34.21	5.87	8.20	95			2.4	1.56	0.5
	15		28.39	34.21	5.86	8.20	97					
	20		28.39	34.21	5.87	8.20	98					
TS 14 (R)	0	1452	28.43	34.17	5.94	8.19	92	14	3	1.8	2.19	17.5
	3		28.49	34.19	5.92	8.18	95			1.8	3.47	8.0
	6		28.46	34.22	5.88	8.18	96			5.1	2.07	9.5
	10		28.43	34.21	5.84	8.19	98			2.1	4.03	30.0
	15		28.41	34.23	5.87	8.19	98					
	20		28.40	34.21	5.85	8.19	97					
TS 15 (S)	0	1502	28.47	34.18	5.96	8.18	91	10	3	2.5	3.12	24.0
	3		28.50	34.19	5.93	8.18	94			2.5	2.88	21.5
	6		28.50	34.20	5.95	8.17	93			2.1	3.02	11.0
	10		28.44	34.20	5.94	8.18	98			2.4	3.13	29.0
	15		28.42	34.22	5.86	8.18	98					
	20		28.40	34.19	5.84	8.18	97					
Raw Waste										51,000	339,000	67,000

CRUISE: NOAA-OMPA-Star-Kist Samoa VESSEL: Autele DATE: 23 July 1982

WEATHER: Hot, calm with gusts, 2-6k. SEA STATE: Long swells, 8-10ft TIDE: Low 1530, -0.5ft

Station (Map/Site)	Depth m	Time	Temp °C	Sal ‰	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
CN A (1)	0	0933	28.28	34.22	6.78	8.22	98	15	1			
	3		28.27	34.25	7.70	8.24						
	6		28.26	34.22	7.27	8.24	98					
	10		28.26	34.27	7.08	8.26	99					
	15		28.26	34.28	7.09	8.25	98					
	20		28.26	34.30	7.09	8.25	99					
TP (2)	0	0954	28.24	34.25	7.16	8.27		15	1			
	3		28.23	34.25	6.84	8.26						
	6		28.24	34.29	6.75	8.25						
	10		28.24	34.29	6.66	8.25						
	15		28.24	34.30	6.55	8.26						
	20		28.24	34.30	6.54	8.26						
* TS A (4)	0	1056	28.36	34.27	5.52	8.23		2	5			
	3		28.31	34.30	6.70	8.24						
	6		28.26	34.30	6.70	8.25						
	10		28.24	34.30	6.72	8.26						
	15		28.24	34.30	6.73	8.26						
	20		28.23	34.32	6.23	8.26						

*(3) 1033 Drogues only, no measurements

CRUISE: NOAA-OMPA-Star-Kist Samoa VESSEL: Autele DATE: 23 July 1982

WEATHER: Hot, calm with gusts, 2-6k. SEA STATE: Long swells, 8/10ft TIDE: Low 1530, -0.5ft

Station (Map/Site)	Depth m	Time	Temp °C	Sal °/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS B (5)	0	1114	28.36		6.65	8.22		2	5			
	0	1115			6.70							
	0	1116			6.71							
	0	1116.5			6.69							
	0	1117			6.68							
	0	1117.5			6.70							
	0	1118			6.74							
TS C (5)	0	1119	28.29	34.28	6.58	8.25		2	5			
	3		28.28	34.30	6.56	8.25						
	6		28.26	34.30	6.62	8.25						
	10		28.25	34.32	6.50	8.26						
	15		28.24	34.32	6.60	8.26						
	20		28.24	34.34	6.64	8.26						
TS D (6)	0	1135	28.35	34.28	6.25	8.25		2	6			
	0	1136			6.40							
	0	1137			6.43							
	0	1137.5			6.32							
	0	1137.8			6.30							
	0	1138			6.30							
	0	1138.5			6.40							
	0	1139			6.45							

CRUISE: NOAA-OMPA-Star-Kist Samoa VESSEL: Autele DATE: 23 July 1982

WEATHER: Hot, calm with gusts, 2-6k SEA STATE: Long swells, 8-10ft TIDE: Low 1530, -0.5ft

Station (Map/Site)	Depth m	Time	Temp °C	Sal ‰	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS E (6)	0	1141	28.37	34.28	6.68	8.27		3	6			
	3		28.33	34.30	6.64	8.26						
	6		28.25	34.32	6.68	8.26						
	10		28.24	34.32	6.65	8.26						
	15		28.24	34.33	6.66	8.27						
	20		28.23	34.35	6.63	8.27						
* (7)												
TS F (8)	0	1157	28.59	34.25	6.62	8.25		4	4			
	3		28.29	34.31	6.66	8.26						
	6		28.26	34.31	6.41	8.26						
	10		28.25	34.32	6.41	8.27						
	15		28.25	34.32	6.51	8.27						
	20		28.25	34.32	6.41	8.27						
TS G (9)	0	1206	28.44	34.27	6.62	8.25		14	3			
	3		28.31	34.30	6.65	8.26						
	6		28.26	34.30	6.66	8.27						
	10		28.24	34.31	6.53	8.27						
	15		28.24	24.32	6.42	8.27						
	20		28.24	34.31	6.41	8.27						

*7 1151 drogues only

CRUISE: NOAA-OMPA-Star-Kist Samoa VESSEL: Autele DATE: 23 July 1982

WEATHER: Hot, calm with gusts, 1-6k SEA STATE: Long swells, 8/10ft TIDE: Low 1530, -0.5ft

Station (Map/Site)	Depth m	Time	Temp °C	Sal o/oo	DO mg/l	pH	%T	Secchi m	FU	NH_3 µg-at/l	BOD mg/l	TOC mg/l
TS H (10)	0	1216	28.54	34.28	6.48	8.25		15	1			
	3		28.36	34.33	6.47	8.27						
	6		28.30	34.31	6.39	8.27						
	10		28.28	34.31	6.45	8.28						
	15		28.26	34.31	6.34	8.27						
	20		28.25	34.31	6.35	8.28						
TS J (10)	0	1225	28.52	34.29	6.27	8.24		12	3			
	3		28.34	34.31	6.40	8.26						
	6		28.29	34.31	6.43	8.27						
	10		28.25	34.31	6.50	8.27						
	15		28.25	34.30	6.35	8.27						
	20		28.24	34.30	6.38	8.28						
CS (11)	0	1257	28.78	34.30	6.37	8.27		15	1			
	3		28.25	34.30	6.37	8.28						
	6		28.27	34.30	6.38	8.27						
	10		28.25	34.30	6.39	8.29						
	15		28.23	34.30	6.41	8.29						
	20		28.23	34.30	6.21	8.29						

12,13 drogue positions
14,17 slick positions

APPENDIX C

CORRESPONDENCE

C2

Star-Kist Foods, Inc.

TERMINAL ISLAND, CALIFORNIA 90731

Cable Address "FRENCHSACO"

Telex: 68-6265

Answerback: Star-Kist Term.

November 2, 1981

Mr. Eric Yunker, Permits Branch
Environmental Protection Agency E-4
Region IX
215 Fremont Street
San Francisco, CA 94105

RE: OCEAN DUMPING PERMIT No. OD 79-01/02 (PEA 4-5)

Dear Mr. Yunker:

This is to confirm our telephone conversation on October 30, 1981 in which we discussed a revised scope of work on the impact assessment required to fulfill Special Condition 9d.

Our original proposal consisted of making two site visits, one during the "wet" season (November-March) and one during the "dry" season (June-September). Two locations would have been monitored: a baseline or reference station approximately one mile from the interim site and the dump site itself. We proposed to measure the following parameters in the water column: dissolved oxygen, temperature, pH, salinity, Ammonia, BOD or COD, color and make visual observations. Your response indicated that two additional sample locations and additional parameters would be necessary.

As we discussed subsequently, it is our belief that one or two fairly conservative parameters should be sufficient to demonstrate the fate of the dumped material in terms of dilution versus spatial reference. Although TOC/COD and Ammonia are not normally considered conservative parameters they would not be expected to change significantly during the 2-4 hours over which sampling would occur. We now propose to analyze samples of the dumped material (dissolved air flotation sludge) and background water for the full list of parameters contained within special conditions paragraph 9a of the original permit. These include: pH, bulk density (sludge), suspended solids, volatile suspended solids, TOC, aluminum, mercury, total phosphorus, total Kjeldahl nitrogen, BOD_5, oil and grease, MBAS and cadmium. Additionally, the parameters contained in our original proposal will be measured at four locations: the center of the dumpsite, at the edge of the interim site nearest land, approximately one nautical mile up-current from the disposal site and approximately one nautical mile down-current from the site. Samples would be taken in duplicate at a minimum of four depths. Two site visits shall be made, as originally proposed. It is our intention to obtain several comparison analyses for TOC, BOD and COD so that the ratio of TOC to BOD and/or COD can be determined with a good degree of reliability. The remoteness of the location makes shipment of large volumes of samples impractical

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and we do not feel that freezing samples for BOD analyses is appropriate.

We intend to proceed with field work preparation as soon as possible so that your prompt verification of the sufficiency of this revised proposal would be appreciated.

If this letter does not accurately reflect the substance of our conversation on October 30, please telephone me at (213) 548-4411, extension 2657 as soon as possible. If I do not hear from you by November 10th I will assume that the EPA is in agreement with this scope.

Sincerely yours,

STAR-KIST FOODS, INC.

Jeffrey R. Naumann, Manager
Environmental Engineering

JRN:rg.

cc: Bob Diehl,
Van Camp Seafoods
11555 Sorrento Valley Rd.
San Diego, CA 92121

D. Ballands

BCC: Dr. Dorothy Soule, USC

C4

RECEIVED

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
215 Fremont Street
San Francisco, Ca. 94105

ENGINEERING DEPT.

OCT 9 1981

IN REPLY REFER TO: E-4-2
PEA 4-5

Mr. Jeffrey R. Naumann, Manager
Environmental Engineering
Star-Kist Foods, Inc.
582 Tuna Street
Terminal Island, CA 90331

Re: Ocean Dumping Permit No. OD 79-01/02
Paragraph 9d of the Special Conditions

Dear Mr. Naumann:

The Environmental Protection Agency has reviewed your proposed Scope of Work for the completion of the environmental trend assessment to be used for the final site designation for ocean dumping in American Samoa. This review has been made in respect to 40 CFR 228.13 which provides the guidelines for developing this assessment.

The comments below reference each aspect of the guidelines, noting the adequacy or inadequacy of your specific proposal. EPA approves of this Scope of Work for both Star-Kist and Van Camp Seafood provided that the following recommendations are included as part of the proposal.

a) Timing. Adequate

b) Duration. Adequate

c) Numbers and Locations of Sampling Stations. Inadequate
Two more sampling stations are necessary, in addition to the two which you have proposed, to adequately characterize the disposal site and control area environments. One additional station is needed at the edge of the boundary of the disposal site where the plume is expected to be carried by any persistent currents. Another additional reference station, outside of the disposal site, is needed. One of the reference stations should then be located downcurrent of the dumpsite and the other upcurrent.

d) Measurement in the Water Column at and near the Dumpsite. Inadequate

The extent of the disposal plume should be accurately categorized in terms of both surface area and depth. In this regard, the increments of the proposed depth measurements need further definition (i.e., How many and at what intervals?).

The parameters proposed to be measured should include all of those required in Special Condition 9(a) of the permit. In addition, the BOD tests should be performed regardless of the availability of sufficient laboratory capacity in American Samoa. The samples may be frozen for transport to other available laboratories.

water and sludge or sludge only

e) Measurements of the Benthic Region. Adequate

f) Other Measurements. Adequate

g) Survey Procedures and Techniques. Adequate

The methodology proposed for the analyses of the parameters contained in Special Condition 9(a) of the permit, but not listed in your proposal, should be included.

In addition, the Scope of Work should include the following information:

1) A report based on observations made during monitoring stating whether or not the fishwastes attract nuisance species (e.g., sharks).

2) A description of the extent of any adverse impacts to the marine environment determined to be attributable to the chemical additives contained in the fishwastes.

Should you have any further questions regarding this matter, please contact Mr. Eric Yunker of my staff at (415)556-3454.

Sincerely yours,

William H. Pierce
Chief, Permits Branch
Enforcement Division

cc: Marine Protection Branch (WH-585)
Bob Diehl, Van Kamp Seafood

C6

TERMINAL ISLAND, CALIFORNIA 90731

June 24, 1981

Mr. Eric Yunker, Permits Branch
Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, CA 94105

OCEAN DUMPING PERMIT NO. OD 79-01/02 SPECIAL
PROPOSED SCOPE OF WORK ON IMPACT ASSESSMENT

Dear Mr. Yunker:

As you know, Paragraph 9d of the Special Conditions of the subject permit requires the permittee (Star-Kist Samoa, Inc. and Van Camp Sea Food Co., jointly) to develop a "....scope of work for the completion of the environmental assessment on the impact of the use of the site for disposal." This work would enable EPA to prepare an appropriate environmental document (EIS or negative declaration) prior to obtaining a final site designation in American Samoa. This letter has been reviewed by both Van Camp Seafoods and Star-Kist, and we have agreed that this will be our joint submittal under Paragraph 9d of the Special Conditions.

The permittee has been dumping DAF sludge at the rate of about 20,000 to 30,000 gallons per day at the interim site since December 1980. Discharge occurs at a rate of 500 gallons per minute at a vessel speed of 5 knots to obtain maximum dispersion of the material. The special permit allows disposal of up to 51,700 gallons of DAF sludge, 25,740 gallons of cooker juice and 23,790 gallons of press liquor per day. The disposal site is a one nautical mile diameter circle with its center at 14°22'00" S.lat., 170°41'00" W. longitude.

The Ocean Dumping Regulations (FR Jan. 11, 1977), under Section 228.13, describe the content of the trend assessment survey that is to be undertaken as a part of all ocean dumping site designations. As this particular dumping operation takes place in waters that are essentially "deep open ocean", we would expect that certain forms of monitoring typically performed would not be appropriate. The following is our proposed scope of assessment monitoring that would be completed to fulfill the requirements of Paragraph 9d of the special conditions of the permit. I shall address each aspect of Section 228.13 in turn.

a) Timing. The baseline survey was accomplished in February and July of 1979. This should have encompassed the "wet" and "dry" seasons in American Samoa for purposes of measuring water quality parameters. The original baseline survey found no water column stratification to a depth of 100 feet. We would expect to make two field evaluations in American Samoa: one in the months of June-September and one in the months November-March.

b) Duration. As the disposal site is quite small, we would expect that each site visit should require one to three days. The combination of very deep water and rapid currents would undoubtedly keep the dumped material from being deposited upon the ocean bottom in any detectable way so that we would not propose sampling of bottom sediments.

c) Numbers and Locations of Sampling Stations. We expect that one station at the center of the disposal area in addition to one reference station located about 1.2 nautical miles away at 14°21'34" S. latitude, 170°40'00" W. longitude should be adequate. The on-site station will actually consist of the mass of the discharge plume, as determined in the field under dumping conditions.

d) Measurement in the Water Column at and near the Dumpsite. Initial range finder tests will determine the extent of the disposal plume. Measurements of temperature, salinity, pH, dissolved oxygen, ammonia, color and BOD or COD will be made at several depth increments throughout the plume. The extent of oxygen depletion vs time will be measured. Due to the remoteness of the site, chemical oxygen (COD) demand may be performed at a stateside laboratory. Alternatively, 5-day BOD tests may be performed in American Samoa if sufficient laboratory capacity is available. All other tests will be performed in-situ or on board the survey vessel. Two surveys would be made at about six months apart, as above.

e) Measurements of the Benthic Region. Due to the great depth (over 4000 ft.) of the disposal site and rapid current velocity, we would not expect that the discharge would have a measurable effect upon the benthos.

f) Other Measurements. The currents were previously measured in drogues during the baseline survey. The present routine monitoring program during actual dumping has indicated that the material rapidly sinks below the surface and has not been observed along the shoreline.

Observations will be made for the sea state, wind conditions and the fate of any floating solids or slick formed resulting from the actual dumping operation.

g) Survey Procedures and Techniques. The methodology proposed are as follows:

Temperature	Martek Probe
Salinity	" "
pH	" "
Dissolved Oxygen	" "
Ammonia	Grab Sample/Ion electrode
Color	Forel-Uhle scale
Visual Observations	
COD or BOD	Grab Sample/Standard Methods

h) Quality Assurance. Split samples will be submitted to EPA or other laboratories if requested. Dissolved oxygen probe will be calibrated daily against a Winkler titration. Other probes will be calibrated daily against known standards. COD tests will be run partially in duplicate.

../..

It is our intent to publish a comprehensive report detailing the results of the assessment monitoring plus the experience gained during routine monitoring of the dumping operation. We would expect that the report would be available within three months after the second site visit and completion of laboratory analyses.

The report will concentrate upon providing information suitable for allowing the EPA to evaluate the site for continued ocean dumping.

As we would desire to commence field monitoring in early July of 1981, we hope that prompt review by your office can be accomplished. I would hope that you could contact me by telephone (213) 548-4411 as soon as possible to discuss the acceptability of the proposed scope of work.

Sincerely,

STAR-KIST FOODS, INC.

Jeffrey R. Naumann

Jeffrey R. Naumann, Manager
Environmental Engineering

JRN:rg.

cc: D . Ballands
Bob Diehl, Van Camp, San Diego
Frank Hackman, Ralston-Purina

bcc: Dorothy Soule / Nici Ogori

C9

Star-Kist Foods, Inc.

TERMINAL ISLAND, CALIFORNIA 90731

Cable Address "FRENCHSACO"

Telex: 68-6265

Answerback: Star-Kist Term.

December 17, 1980

Mr. Chris Vais
Permits Branch
Environmental Protection Agency
Region IX
215 Fremont St.
San Francisco, CA. 94105

RE: Ocean Dumping Permit NO. OD 79-01/02 Special

Dear Chris:

Paragraph 9a of the Special Conditions of the subject permit would require that the permitee fulfill monitoring of the sludge material dumped. That section specifies that analyses for PH, bulk density, suspended solids, volatile solids, total organic carbon, aluminum, mercury, total phosphorus, total kjeldahl nitrogen, BOD_5, oil and grease, MBAS and cadmium be performed on a quarterly basis. Since American Samoa is several thousand miles from the nearest commercial laboratory and since our laboratory and staff on the island are not capable of completing all these analyses, we would ask that the list be trimmed to accomodate only those parameters that can be monitored on-island. Our laboratory staff and equipment are set up to perform analyses of the following parameters:

pH
Bulk Density
Total Solids
Total Phosphorus
Total Kjeldahl Nitrogen
BOD_5
Oil and Grease

We would therefore request that the list of parameters required for quarterly analysis include only those constituents that can be accomplished with existing staff and equipment. Since the sludge material to be dumped has been determined to not be accutely toxic, and since we would not expect any dramatic changes to occur in the

quality of this material, we believe that those parameters that can be monitored in American Samoa, are sufficent to show whether any changes in the quality of the sludge material are occuring.

If you have any comments relative to this request, please contact me directly.

Sincerely,

STAR-KIST FOODS, INC.

Jeffrey R. Naumann, Manager
Environmental Engineering

JRN/lf

cc: Dave Ballands, Star-Kist Foods, Inc.
F. Hackman, Ralston Purina
Larry Krogsdale, Star-Kist Samoa, Inc.
Alan White, Star-Kist Samoa, Inc.
Judy McGonigal, Star-Kist Samoa, Inc.
Bob Diehl, Van Camp Seafoods, San Diego

C11

Star-Kist Foods, Inc.

TERMINAL ISLAND, CALIFORNIA 90731

Cable Address "FRENCHSACO"

Telex: 68-6265

Answerback: Star-Kist Term.

December 17, 1980

Mr. Chris Vais
Permits Branch
Environmental Protection Agency
Region IX
215 Fremont St.
San Francisco, CA. 94105

RE; Ocean Dumping Permit No. OD 79-01/02 Special

Dear Chris:

Paragraph 9d of the Special Conditions of the subject permit would require that a scope of work be submitted within 120 days of the date of the issuance of this permit. This scope of work would cover completion of the Environmental Assessment of impact of the use of the site for disposal of cannery sludges. That assessment would provide sufficient information for the preparation of either a Negative Declaration or Environmental Impact Statement, should EPA Headquarters require one. Since the actual date of initiation of ocean dumping has been delayed considerably more than originally hoped, we would request that a time extension be granted so that the development of this scope of work could be derived after actual dumping experience has been gained.

In addition, since the National Oceanagraphic and Atmospheric Administration has expressed considerable interest in making an on-site visit to American Samoa to investigate the fate of dump materials in this instance, we believe it would be beneficial that their work be completed before this scope of work for any additional assessment is drafted.

We have inquired as to what the cost might be of having a consultant make site visits to American Samoa and complete field work foward completion of this assessment. This would be somewhere in the neighborhood of $10,000. per visit. Since this is a considerable amount of money we believe that an extension of the deadline for the development of this scope is warranted so that costs can be kept to an essential level.

At this time, it would seem that NOAA plans to make their visit to American Samoa in the last week or two of January, 1981. We would expect that reduction of data from that visit may take approximately three months. This would mean that we could expect to have a useable compilation of the data, or report, somewhere around the first of May; or, an additional 120 days past the original deadline of January 1, 1981. At least another 30 days would be required to review the NOAA report and come up with a reasonable scope of work for further assessment, if required. Therefore, we would ask for an extension of 150 - 180 days to fulfill the requirements of special condition 9d.

Since the interim site designation of this permit is for a period of 3 years we believe that there is sufficient time within this period to develop a proper scope of work and complete the assessment, leaving sufficient time for EPA to develop any environmental documents that may be required toward arriving at a permanent ocean dumping site designation.

As January 1st is close at hand, we hope that you will be able to consider this request for extension within a short period of time. If you have any questions on our request, please contact me directly.

Sincerely,

STAR-KIST FOODS, INC.

Jeffrey R. Naumann

Jeffrey R. Naumann, Manager
Environmental Engineering

JRN/lf

cc: Dave Ballands, Star-Kist Foods, Inc.
F. Hackman, Ralston Purina
L. Krogsdale, Star-Kist Samoa, Inc.
Alan White, Star-Kist Samoa, Inc.
Judy McGonigal, Star-Kist Samoa, Inc.
Bob Diehl, Van Camp Seafoods, San Diego

C13

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IX

215 Fremont Street

San Francisco, Ca. 94105

In Reply Refer to: E-4-2 PEA 4-5

Dave Ballands
General Manager, Engineering Services
Star-Kist Foods, Inc.
Terminal Island, Ca 90731

F. H. Hackmann, Director
Environmental Affairs
Corporate Engineering
Ralston Purina Co.
Checkerboard Square
St. Louis, Missouri 63188

10 SEP 1980

Dear Messers. Ballands and Hackmann:

In accordance with the provisions of the Marine Protection, Reasearch, and Sanctuaries Act (33USC 1401 et. seq.), the Environmental Protection Agency has reviewed the following applications for an Ocean Dumping permit.

Applicant	Permit No.
Van Camp Sea Food Co.	Joint
Star-Kist Samoa, Inc.	OD 79-01/02

This Agency has published a public notice of tentative determinations regarding the above applications. After consideration of the expressed views of all interested persons and agencies, pertinent Federal statutes and regulations, and State action regarding comments or certification of the proposed action, the Regional Administrator had made his final determinations.

Pursuant to 40 CFR 221.1, the Regional Administrator is issuing a joint permit to these applications, including certain terms and conditons which he has determined are necessary to carry out the guidelines and requirements of the Act. This action does not constitute a significant change from the tentative determinations set forth in the public notice.

No ocean dumping may take place under this permit until the Administrator has designated an approved interim disposal site. We expect that a proposed site designation will be published in the Federal Register shortly and that there will be a 60 day comment period. A final determination on the proposed site will follow completion of the review of all public comment.

Should you have any questions regarding this matter please contact Mr. Chris Vais at (415) 556-3454.

Sincerely yours,

William H. Pierce
Chief Permits Branch
Enforcement Division

cc: Commander (mep) CGD 14
Commanding Officer USCG Station Pago Pago
WMFS - Honolulu
COE - Honolulu
NWF
Diehl Van Camp (certified mail)
Faiai GAS
Richmond GAS (certified mail)
Van Camp American Samoa (certified mail)
Star-Kist American Samoa (certified mail)

C15

Certified Mail No. 474981

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
215 Fremont Street
San Francisco, Ca. 94105

In Reply`E-4-2
Refer to: PEA 4-5

Pati Faiai
Executive Secretary
Environmental Quality Commission
Office of the Governor
Pago Pago, American Samoa 96799

10 SEP 1980

Dear Mr. Faiai:

Enclosed is the Ocean Dumping permit issued jointly to Star-Kist and Van Camp. Although the permit has been issued, no dumping may take place because designation of the ocean dumping site has not been completed by our headquarters office.

The designation will very shortly be published as a proposed rule in the Federal Register, with a 60 day comment period. A final determination on the proposed designation will be made upon completion of review of all comments which have been submitted.

We will keep you advised as to the progress of the designation and will notify you when it has been completed. Should you have any questions regarding this matter please contact Mr. Chris Vais at (415) 556-3454.

Sincerely yours,

William H. Pierce
Chief Permits Br.
Enforcement Division

cc: Governor P.T. Coleman
Van Camp, American Samoa
Star-Kist, American Samoa
Lyle Richmond GAS

MARINE PROTECTION, RESEARCH AND SANCTUARIES ACT (OCEAN DUMPING) PERMIT

PERMIT NO. AND TYPE: OD 79-01/02 Special

EFFECTIVE DATE: SEP 03 1980

EXPIRATION DATE: SEP 03 1983

REAPPLICATION DATE: MAR 03 1983

APPLICANTS:	Star-Kist Samoa, Inc P.O. Box 368 Pago Pago American Samoa 96920	Van Camp Sea Food Co Pago Pago American Samoa 96920
WASTE GENERATOR(S):	Star-Kist Samoa, Inc P.O. Box 368 Pago Pago American Samoa 96920	Van Camp Sea Food Co Pago Pago American Samoa 96920
WASTE GENERATED AT:	Star-Kist Samoa, Inc P.O. Box 368 Pago Pago American Samoa 96920	Van Camp Sea Food Co Pago Pago American Samoa 96920
PORT OF DEPARTURE:	Pago Pago Tutuila island American Samoa	
WASTE TRANSPORTER(S):	Antony Steffaney Inter Island Transport Pago Pago American Samoa 96799	

and any person owning or operating a towing vessel employed for the purpose authorized herein.

This permit authorizes the transportation and dumping into ocean waters of certain material pursuant to the Marine Protection, Research, and Sanctuaries Act of 1972, 33 U.S.C. 1401-1444, (hereinafter referred to as "the Act"), regulations promulgated thereunder, and the terms and conditions set forth below.

GENERAL CONDITIONS

1. All transportation and dumping authorized herein shall be consistent with the terms and conditions of this permit. The applicant(s), waste generator(s) and waste transporter(s) designated above shall be the permittees liable for compliance with such terms and conditions. The liability of each is set forth in the Special Conditions. Compliance by any permittee with one or more but less than all of the conditions with which such permittee must comply will not constitute a ground or grounds of defense in any proceeding against that permittee for violation of the provisions of this permit.

2. Any person who violates any provision of the Act, the Final Regulations issued thereunder, or any term or condition of this permit shall be liable for a civil penalty of not more than $50,000 for each violation. Additionally, any knowing violation of the Act, Final Regulations, or permit may result in a criminal action being brought with penalties of not more than $50,000 or one year in prison, or both.

3. a. Transportation to, and dumping at any location other than that authorized by this permit, shall constitute a violation of the terms and conditions of this permit.

   b. Transportation and dumping of any material more frequently than or in excess of that identified and authorized by this permit, or dumping of material not authorized by this permit, shall constitute a violation of the terms and conditions of this permit.

   c. Permittee will be liable for violations of any condition of this permit, and the existence of any contractual agreement as to responsibilities under this permit shall not relieve permittee of liability in the event violations of the permit occur.

4. Nothing contained herein shall be deemed to authorize, in any way, the transportation from the United States for the purpose of dumping into the ocean waters, into the territorial sea, or into the contiguous zone, of the following material:

a. High-level radioactive wastes.

b. Materials, in whatever form, produced for radiological, chemical or biological warfare.

c. Persistent synthetic or natural materials which may float or remain in suspension in the ocean.

5. The applicant may not apply for, nor any permittee simultaneously hold, a permit from another EPA Regional office for any of the material to which this permit is applicable, nor may the applicant or any permittee transfer material from one EPA Region to another if a permit for the transportation or dumping of such material has been denied by one EPA Region.

6. After notice and opportunity for a hearing, this permit may be modified, suspended, or revoked in whole or in part, during its term, as the result of a determination by the Administrator or Regional Administrator that:

a. The cumulative impact of the permittee's dumping activities or the aggregate impact of all dumping activities at the dump site designated in the permit should be categorized as Impact Category I, as defined in 40 CFR 228.10(c)(1); or

b. There has been a change in circumstances relating to the management of the disposal site designated in the permit; or

c. The dumping authorized by the permit would violate applicable water quality standards; or

d. The dumping authorized by the permit can no longer be carried out consistent with the criteria set forth in 40 CFR 227 and 228.

7. The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize any injury to private or public property or any invasion of personal rights, nor any infringement of Federal, State or local laws or regulations.

8. This permit does not authorize or approve the construction of any onshore or offshore physical structures or

facilities, or except as authorized by this permit, the undertaking of any work in any navigable waters.

9. If the dumping of material which is regulated by this permit is dumped due to emergency to safeguard life at sea in locations or in a manner not in accordance with the terms of this permit, the permittee shall make a full report in accordance with the provisions of 18 U.S.C. 1001, within 30 days to the Regional Administrator of the emergency and the actions taken.

10. The reporting requirements contained in this permit are in addition to any reporting requirements of any other State or Federal Agency.

11. In the event any portion of the authorized dumping or transportation is done by a person, firm or corporation other than the named permittee, any and all reports required hereunder shall be jointly executed by both permittee and such other person, firm or corporation in accordance with the provision of 18 U.S.C. 1001 by an office or employee of such other person, firm or corporation.

12. The performance of any transportation or dumping authorized by this permit, by any person, firm or corporation other than the named permittee shall not relieve permittee from full responsibility for compliance herewith, nor shall the existence of any contractual or other relationship between permittee and any other such person, firm or corporation operate to relieve either party from responsibility for compliance with this permit or the Act or both.

13. Terms used in this permit which are defined in Section 3 of the Act shall have the same meaning herein.

14. The authorization of this permit does not preclude any legal action, nor relieve the permittee from any liability, penalty or responsiblity for any other action, not expressly hereby permitted, which is otherwise prohibited by law.

15. Each permittee shall at all times maintain in good working order and operate as efficiently as possible all facilities, including vessels, used by such permittee in achieving compliance with the terms and conditions of this permit.

16. This permit, or a true copy thereof, shall be placed in a conspicuous place on the vessel which will be used for the transportation and dumping authorized by this permit. If the dumping vessel is an unmanned barge, the permit or true copy of the permit shall be transferred to the towing vessel or an additional true copy shall be available on board the towing vessel.

17. Every scow or boat engaged in the transportation of wastes for ocean disposal shall have its name and number painted in letters and numbers at least fourteen inches high on both sides of the scow or boat. The name and number shall be kept distinctly legible at all times, and no scow or boat not so marked shall be used to transport or dump any such material.

18. The permittee(s) shall allow the Regional Administrator, the U.S. Coast Guard, and/or their authorized representatives, upon the presentation of credentials:

    a. To enter into, upon, or through the permittee's premises, vessels, or other premises or vessels under the control of the permittee, where, or in which, a source of material to be dumped is located or in which any records are required to be kept under the terms and conditions of this permit or the Act;

    b. To have access to and copy any records required to be kept under the terms and conditions of this permit or the Act;

    c. To inspect any monitoring equipment or monitoring method required in this permit;

    d. To sample any materials discharged or to be discharged; and

    e. To inspect any dumping and navigation equipment installed on board any towing vessel, barge, or self-propelled vessel utilized in ocean dumping activities authorized under this permit.

19. This permit shall be subject to suspension by the Regional Administrator or his delegate if he determines that the permitted dumping has resulted, or is resulting, in imminent and substantial harm to human

health or welfare or the marine environment. Such suspension shall be effective subject only to the provisions of 40 C.F.R. 223.2 et seq.

20. The authority conferred by this permit may, at the discretion of the Regional Administrator or his delegate, be transferred to a waste transporter other than that (those) named herein, provided that a request for such a transfer be made, in writing, by the applicant at least 10 days prior to the requested transfer date.

SPECIAL CONDITIONS

1. The material to be dumped shall consist of waste materials resulting from the operation of the permittee's fish canneries on Tutuila Island, American Samoa.

2. Description and Limitations:

   In accordance with all other terms and conditions of this permit, the permittee is authorized to transport for dumping and to discharge into ocean waters DAF sludge, cooker juice, and press water.

   a. Said materials shall not exceed the following limits:

DAF sludge	51,700 gallons/day
cooker juice	25,740 gallons/day
press water	23,790 gallons/day

   b. The transportation for dumping and the discharge of DAF sludge taken from sludge ponds on the island of Tutuila is prohibited.

   c. The transportation for dumping and the discharge of floatables, garbage, domestic trash, waste chemicals, toxic materials and solid waste is prohibited.

   d. Characteristics

      1. DAF sludge
         pH - 5.8 to 6.2 standard units
         bulk density - 0.773 to 1.017 gm/ml
         suspended solids - 9.6 to 21.4 % wet wt.
         volatile solids - 79.4 to 96.5 % of suspended solids
         Total Organic Carbon (TOC) - 456 to 799 gm/kg dry wt.
         Total Phosphorus - 739 to 1,031 mg/kg
         Total Kjeldahl Nitrogen - 587 to 769 mg/kg
         NO_3 & NO_2 - 0.77 to 1.24 mg/kg
         BOD_5 - 105,000 to 258,000 mg/l
         Protein - 1.48 to 4.72 % wet wt.
         Fat - 5.80 to 6.50 % wet wt.
         Methylene Blue Active Substance (MBAS) - 6.5 to 13.4 mg/l

Al - 711 to 10,400 mg/kg dry wt.
Cd - 1.3 to 6.4 mg/kg dry wt.
Hg - 0.011 to 0.050 mg/kg dry wt.
DDT - N.D.
DDE - N.D.

2. Cooker juice
Fat 1% volume
Moisture 93% volume
Solids 6% volume

3. Press water
Fat 12% volume
Moisture 76% volume
Solids 12% volume

3. Disposal Site:

Transportation for the purpose of ocean dumping shall terminate at, and waste disposal shall be confined to, the area described below:

One nautical mile diameter circle with its center at 14°22'00"S.Lat., 170°41'00"W.Long.

4. Method of Disposal:

a. The waste transporter shall use only the following vessel(s)/barge(s) for transportation and dumping of wastes and authorized under this permit:
Vessel Misamoa

b. During transportation and loading operations, there shall be no loss of material to any waterway.

c. Permittee shall commence discharge of the material authorized by this permit no earlier than one-half hour after sunrise. No dumping shall commence unless it can be completed one hour prior to sunset. Sunrise and sunset shall be defined by the National Weather Service.

d. Permittee shall discharge the material authorized by this permit at a rate no greater than 500 gpm from a vessel moving at 5 knots.

5. Notification:

Permittee shall notify the Commanding Officer, USCG Station Pago Pago at least 2 hours prior to the departure from permittee's facility of any vessel for the purpose of dumping. Included in such notification shall be:

a. The trip number

b. The names and registry numbers of the vessels scheduled for departure.

c. The estimated time of arrival at the dump site and the estimated time of return to port.

d. A statement of the amount of material to be dumped.

e. In the event that the Coast Guard establishes a fixed schedule for the dumping authorized herein, this requirement for notification shall be waived.

6. Permittee shall cause the Master of the vessel to stay in radio contact with the USCG Station Pago Pago for vessel movements in accordance with Coast Guard surveillance requirements and to notify USCG Station Pago Pago when dumping commences.

7. The permittee shall maintain complete records, which shall be available for inspection and copying by the Regional Administrator or his designee, of:

a. The nature, and volume of materials dumped pursuant to the permit.

b. The precise times and locations of dumping.

c. Any information relevant to the assessment of the impact of permittee dumping activities on the marine environmental or human health or welfare.

8. The waste generators shall submit quarterly reports (on a calendar basis) of volumes removed from their facilities by the waste transporter under this permit and the waste transporter shall submit similar reports of volumes transported by it to the dump site specified in Special Condition No. 3. Such volumes shall be ex-

pressed in gallons and tons. Such reports shall be submitted within 20 days of the end of the reporting period to:

Regional Administrator
U.S. Environmental Protection Agency
215 Fremont Street
San Francisco, California 94105
Attn: Water Branch, E-5
Telephone: (415)556-7450.

Commander (mep)
14th Coast Guard Disctict
677 Ala Moana Blvd.
Honolulu, HI 96813

Environmental Quality Commission
Government of American Samoa
Tutuila, Pago Pago
American Samoa 96920

9. Monitoring Requirements

a. Analyses shall be conducted quarterly (on a calendar basis) by the waste generators on a representative sample of vessel/barge load for the following parameters:

pH	Total Phosphorus
bulk density	Total Kjeldahl Nitrogen
suspended solids	BOD_5
volatile solids	Oil and grease
TOC	MBAS
Aluminum	Cadmium
Mercury	

b. Analyses shall be conducted by the waste generators whenever there is a change in plant capacity, process configuration, waste treatment, or general material condition of the waste generators facility. Such analyses shall be for the parameters listed in 9.a. above, and shall include a bioassay (96 hr LC_{50} mg/l) using organisms and procedures approved by EPA Region IX.

c. Within 90 days of the date of issuance of this permit, the permittee shall provide the Regional Administrator with a plan for a monitoring and

surveillance program which will define the fate of waste dumped under a variety of climatic and sea conditions. Upon approval by the Regional Administrator such a program shall become a condition of this permit.

d. Within 120 days of the date of issuance of this permit, the permittee shall provide the Regional Administrator with a scope of work for the completion of the environmental assessment of the impact of the use of the site for disposal. The environmental assessment shall provide sufficient information for the preparation of an EIS should EPA policy require one. Appendix A of this permit identifies the information necessary for the preparation of an EIS. Upon approval of the Regional Administrator such scope of work shall become a condition of the permit.

e. Required monitoring reports shall be submitted to:

Regional Administrator
U.S. Environmental Protection Agency
215 Fremont Street
San Francisco, California 94105
Attn: Water Branch, E-5
Telephone: (415)556-7450

Environmental Quality Commission
Government of American Samoa
Tutuila, Pago Pago
American Samoa 96920

10. Liability

a. The waste generators and waste transporter shall be jointly and severally liable for compliance with Special Conditions Nos. 1, 2, 5, 6, 7, and 8, as well as all applicable General Conditions.

b. Any person owning or operating a towing vessel employed for purposes of the activities authorized by this permit shall be, for purposes of each discharge, a joint permittee and severally liable together with the waste transporter for compliance with Special Conditions Nos. 3, 4(b) & (c), and 5, as well as all applicable General Conditions.

c. The waste transporter shall be solely liable for compliance with Special Condition No. 4.

d. The waste generators shall be solely liable for compliance with Special Condition No. 9.

Signed this 3 day of Sept. 1980

For the Regional Administrator

Clyde B. Eller

Clyde B. Eller
Director, Enforcement Division

228.5 and 228.6 set forth the criteria for disposal site selection and must be addressed in the disposal site designation study. The study is the permittee's responsibility. The field survey data collection phase of the disposal site designation study should be conducted so that the results are compatible with ocean disposal site baseline or trend assessment requirements found at 228.13.

(h) "Normal ambient value" means that concentration of a chemical species reasonably anticipated to be present in the water column, sediments, or biota in the absence of disposal activities at the disposal site in question.

§ 228.3 Disposal site management responsibilities.

Management of a site consists of regulating times, rates, and methods of disposal and quantities and types of materials disposed of; developing and maintaining effective ambient monitoring programs for the site; conducting disposal site evaluation and designation studies; and recommending modifications in site use and/or designation (e.g., termination of use of the site for general use or for disposal of specific wastes).

Each site, upon interim or continuing use designation, will be assigned to either an EPA Regional office or to EPA Headquarters for management. These designations will be consistent with the delegation of authority in § 220.4. The designated management authority is fully responsible for all aspects of the management of sites within the general requirements specified in § 220.4 and this section. Specific requirements for meeting the management responsibilities assigned to the designated management authority for each site are outlined in §§ 228.5 and 228.6.

§ 228.4 Procedures for designation of sites.

(a) *General Permits.* Geographical areas or regions within which materials may be dumped under a general permit will be published as part of the promulgation of each general permit.

(b) *Special and Interim Permits.* Areas where ocean dumping is permitted subject to the specific conditions of individual special or interim permits, will be designated by promulgation in this Part 228, and such designation will be made based on environmental studies of each site, regions adjacent to the site, and on historical knowledge of the impact of waste disposal on areas similar to such sites in physical, chemical, and biological characteristics. All studies for the evaluation and potential selection of dumping sites will be conducted in accordance with the requirements of §§ 228.5 and 228.6.

The Administrator may, from time to time, designate specific locations for temporary use for disposal of small amounts of materials under a special permit only without disposal site designation studies when such materials satisfy the Criteria and the Administrator determines that the quantities to be disposed of at such sites will not result in significant impact on the environment. Such designations will be done by promulgation in this Part 228, and will be for a specified period of time and for specified quantities of materials.

(c) *Emergency Permits.* Dumping sites for materials disposed of under an emergency permit will be specified by the Administrator as a permit condition and will be based on an individual appraisal of the characteristics of the waste and the safest means for its disposal.

(d) *Research Permits.* Dumping sites for research permits will be determined by the nature of the proposed study. Dumping sites will be specified by the Administrator as a permit condition.

(e) *Dredged Material Permits.*

(1) Areas where ocean dumping of dredged material is permitted subject to the specific conditions of Dredged Material permits issued by the U.S. Army Corps of Engineers will be designated by EPA by promulgation in this Part 228, and such designation will be made based on environmental studies of each site, regions adjacent to the site, and on historical knowledge of the impact of dredged material disposal on areas similar to such sites in physical, chemical, and biological characteristics. All studies for the evaluation and potential selection of dredged material disposal sites will be conducted in accordance with the appropriate requirements of §§ 228.5 and 228.6, except that:

(i) Baseline or trend assessment requirements may be developed on a case-by-case basis from the results of research, including that now in progress by the Corps of Engineers.

(ii) An environmental impact assessment for all sites within a particular geographic area may be prepared based on complete disposal site designation or evaluation studies on a typical site or sites in that area. In such cases, sufficient studies to demonstrate the generic similarity of all sites within such a geographic area will be conducted.

(2) In those cases where a recommended disposal site has not been designated by the Administrator, or where it is not feasible to utilize a recommended disposal site that has been designated by the Administrator, the District Engineer shall, in consultation with EPA, select a site in accordance with the requirements of §§ 228.5 and 228.6(a). Concurrence by EPA in permits issued for the use of such site for the dumping of dredged material at the site will constitute EPA approval of the use of the site for dredged material disposal only.

(3) Sites designated for the ocean dumping of dredged material in accordance with the procedures of paragraphs (e)(1) or (e)(2) of this section shall be used only for the ocean dumping of dredged material under permits issued by the U.S. Army Corps of Engineers.

§ 228.5 General criteria for the selection of sites.

(a) The dumping of materials into the ocean will be permitted only at sites or in areas selected to minimize the interference of disposal activities with other activities in the marine environment, particularly avoiding areas of existing fisheries or shellfisheries, and regions of heavy commercial or recreational navigation.

(b) Locations and boundaries of disposal sites will be so chosen that temporary perturbations in water quality or other environmental conditions during initial mixing caused by disposal operations anywhere within the site can be expected to be reduced to normal ambient seawater levels or to undetectable contaminant concentrations or effects before reaching any beach, shoreline, marine sanctuary, or known geographically limited fishery or shellfishery.

(c) If at anytime during or after disposal site evaluation studies, it is determined that existing disposal sites presently approved on an interim basis for ocean dumping do not meet the criteria for site selection set forth in §§ 228.5–228.6, the use of such sites will be terminated as soon as suitable alternate disposal sites can be designated.

(d) The sizes of ocean disposal sites will be limited in order to localize for identification and control any immediate adverse impacts and permit the implementation of effective monitoring and surveillance programs to prevent adverse long-range impacts. The size, configuration, and location of any disposal site will be determined as a part of the disposal site evaluation or designation study.

(e) EPA will, wherever feasible, designate ocean dumping sites beyond the edge of the continental shelf and other such sites that have been historically used.

§ 228.6 Specific criteria for site selection.

(a) In the selection of disposal sites, in addition to other necessary or appropriate factors determined by the Administrator, the following factors will be considered:

(1) Geographical position, depth of water, bottom topography and distance from coast;

(2) Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile phases;

(3) Location in relation to beaches and other amenity areas;

(4) Types and quantities of wastes proposed to be disposed of, and proposed methods of release, including methods of packing the waste, if any;

(5) Feasibility of surveillance and monitoring;

(6) Dispersal, horizontal transport and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any;

(7) Existence and effects of current and previous discharges and dumping in the area (including cumulative effects);

(8) Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance and other legitimate uses of the ocean;

(9) The existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys;

(10) Potentiality for the development or recruitment of nuisance species in the disposal site;

(11) Existence at or in close proximity to the site of any significant natural or cultural features of historical importance.

(b) The results of a disposal site evaluation and/or designation study based

[Sec. 228.6(b)]

on the criteria stated in paragraphs (1)–(11) will be presented in support of the site designation promulgation as an environmental assessment of the impact of the use of the site for disposal, and will be used in the preparation of an environmental impact statement for each site where such a statement is required by EPA policy. By publication of a notice in accordance with this Part 228, an environmental impact statement, in draft form, will be made available for public comment not later than the time of publication of the site designation as proposed rulemaking, and a final EIS will be made available at the time of final rulemaking.

§ 228.7 Regulation of disposal site use.

Where necessary, disposal site use will be regulated by setting limitations on times of dumping and rates of discharge, and establishing a disposal site monitoring program.

§ 228.8 Limitations on times and rates of disposal.

Limitations as to time for and rates of dumping may be stated as part of the promulgation of site designation. The times and the quantities of permitted material disposal will be regulated by the EPA management authority so that the limits for the site as specified in the site designation are not exceeded. This will be accomplished by the denial of permits for the disposal of some materials, by the imposition of appropriate conditions on other permits and, if necessary, the designation of new disposal sites under the procedures of § 228.4. In no case may the total volume of material disposed of at any site under special or interim permits cause the concentration of the total materials or any constituent of any of the materials being disposed of at the site to exceed limits specified in the site designation.

§ 228.9 Disposal site monitoring.

(a) The monitoring program, if deemed necessary by the Regional Administrator or the District Engineer, as appropriate, may include baseline or trend assessment surveys by EPA, NOAA, other Federal agencies, or contractors, special studies by permittees, and the analysis and interpretation of data from remote or automatic sampling and/or sensing devices. The primary purpose of the monitoring program is to evaluate the impact of disposal on the marine environment by referencing the monitoring results to a set of baseline conditions. When disposal sites are being used on a continuing basis, such programs may consist of the following components:

(1) Trend assessment surveys conducted at intervals frequent enough to assess the extent and trends of environmental impact. Until survey data or other information are adequate to show that changes in frequency or scope are necessary or desirable, trend assessment and baseline surveys should generally conform to the applicable requirements of § 228.13. These surveys shall be the responsibility of the Federal government.

(2) Special studies conducted by the permittee to identify immediate and short-term impacts of disposal operations.

(b) These surveys may be supplemented, where feasible and useful, by data collected from the use of automatic sampling buoys, satellites or in situ platforms, and from experimental programs.

(c) EPA will require the full participation of permittees, and encourage the full participation of other Federal and State and local agencies in the development and implementation of disposal site monitoring programs. The monitoring and research programs presently supported by permittees may be incorporated into the overall monitoring program insofar as feasible.

§ 228.10 Evaluating disposal impact.

(a) Impact of the disposal at each site designated under section 102 of the Act will be evaluated periodically and a report will be submitted as appropriate as part of the Annual Report to Congress. Such reports will be prepared by or under the direction of the EPA management authority for a specific site and will be based on an evaluation of all data available from baseline and trend assessment surveys, monitoring surveys, and other data pertinent to conditions at and near a site.

(b) The following types of effects, in addition to other necessary or appropriate considerations, will be considered in determining to what extent the marine environment has been impacted by materials disposed of at an ocean disposal site:

(1) Movement of materials into estuaries or marine sanctuaries, or onto oceanfront beaches, or shorelines;

(2) Movement of materials toward productive fishery or shellfishery areas;

(3) Absence from the disposal site of pollution-sensitive biota characteristic of the general area;

(4) Progressive, non-seasonal, changes in water quality or sediment composition at the disposal site, when these changes are attributable to materials disposed of at the site;

(5) Progressive, non-seasonal, changes in composition or numbers of pelagic, demersal, or benthic biota at or near the disposal site, when these changes can be attributed to the effects of materials disposed of at the site;

(6) Accumulation of material constituents (including without limitation, human pathogens) in marine biota at or near the site.

(c) The determination of the overall severity of disposal at the site on the marine environment, including without limitation, the disposal site and adjacent areas, will be based on the evaluation of the entire body of pertinent data using appropriate methods of data analysis for the quantity and type of data available. Impacts will be categorized according to the overall condition of the environment of the disposal site and adjacent areas based on the determination by the EPA management authority assessing the nature and extent of the effects identified in paragraph (b) of this section in addition to other necessary or appropriate considerations. The following categories shall be used:

(1) *Impact Category I:* The effects of activities at the disposal site shall be categorized in Impact Category I when one or more of the following conditions is present and can reasonably be attributed to ocean dumping activities:

(i) There is identifiable progressive movement or accumulation, in detectable concentrations above normal ambient values, of any waste or waste constituent from the disposal site within 12 nautical miles of any shoreline, marine sanctuary designated under Title III of the Act, or critical area designated under section 102(c) of the Act; or

(ii) The biota, sediments, or water column of the disposal site, or of any area outside the disposal site where any waste or waste constituent from the disposal site is present in detectable concentrations above normal ambient values, are adversely affected by the toxicity of such waste or waste constituent to the extent that there are statistically significant decreases in the populations of valuable commercial or recreational species, or of specific species of biota essential to the propagation of such species, within the disposal site and such other area as compared to populations of the same organisms in comparable locations outside such site and area; or

(iii) Solid waste material disposed of at the site has accumulated at the site or in areas adjacent to it, to such an extent that major uses of the site or of adjacent areas are significantly impaired and the Federal or State agency responsible for regulating such uses certifies that such significant impairment has occurred and states in its certificate the basis for its determination of such impairment; or

(iv) There are adverse effects on the taste or odor of valuable commercial or recreational species as a result of disposal activities; or

(v) When any toxic waste, toxic waste constituent, or toxic byproduct of waste interaction, is consistently identified in toxic concentrations above normal ambient values outside the disposal site more than four hours after disposal.

(2) *Impact Category II:* The effects of activities at the disposal site which are not categorized in Impact Category I shall be categorized in Impact Category II.

§ 228.11 Modification in disposal site use.

(a) Modifications in disposal site use which involve the withdrawal of designated disposal sites from use or permanent changes in the total specified quantities or types of wastes permitted to be discharged to a specific disposal

Disposal Area "G". Calcasieu River and Pass, La. Maintenance dredging disposal area 1 mile wide by 0.5 mile long, parallel to the bar channel and located on the west side. Beginning at 29°44'54" N., and 93°20'36" W., following channel centerline (azimuth 351°50') of the first tangent gulfward in the gulf entrance channel to 29°44'42" N., and 93°20'36" W., thence to 29°44'42" N., and 93°20'48" W., following channel centerline again to 29°44'30" N., and 93°20'48" W., thence to 29°44'24" N., and 93°21'30" W., thence to 29°44'48" N. and 93°21'30" W., thence to the point of beginning.

Crescent City Harbor—41°43'15" N., 124°12'10" W. (1,000 yd. diameter)

Crescent City 100 fathom—41°43'50" N., 124°28'00" W. (1,000 yd. diameter)

Humboldt Bay Harbor—40°45'44" N., 124°15'42" W. (500 yd. diameter)

Noyo River—39°25'45" N., 123°49'42" W. (500 yd. diameter)

Farallon Islands—37°31'45" N., 122°59'00" W. (1,000 yd. radius)

San Francisco Channel Bar—37°45'06" N., 122°35'45" W. (5,000 yds. x 1,000 yds.)

Moss Landing 100 fathom—36°47'53" N., 121°49'04" W. (500 yd. radius)

Moss Landing—36°48'05" N., 121°47'22" W. (500 yds. seaward of pier)

Port Hueneme—34°05'00" N., 119°14'00" W. (1,000 yd. radius)

Los Angeles—33°37'06" N., 118°17'24" W., (1,000 yd. radius)

Newport Beach—33°31'42" N., 117°54'48" W., (1,000 yd. radius)

San Diego—Point Loma—32°35'00" N., 117°17'30" W. (1,000 yd. radius)

San Diego 100 fathom—32°36'50" N., 117°20'40" W. (1,000 yd. radius)

Honolulu Harbor—21°14'30" N., 157°54'30" W. (1,000 yd. radius)

Kauai—Nawiliwili—21°55'30" N., 159°17'00" W. (1,000 yd. radius)

Kauai—Hanapepe—21°50'18" N., 159°35'30" W. (1,000 yd. radius)

Guam—Apra Harbor—13°29'30" N., 144°34'30" E. (1,000 yd. radius)

American Samoa—Pago Pago Harbor—14°23'00" S. 170°39'30" W. (1,000 yd. radius)

Mouth of Columbia River—46°14'57" N., 124°10'34" W.; 46°13'53" N., 124°10'01" W.; 46°13'43" N., 124°10'26" W.; 46°14'28" N., 124°10'59" W.

Mouth of Columbia River—46°13'03" N., 124°06'17" W.; 46°12'50" N., 124°05'55" W.; 46°12'13" N., 124°06'43" W.; 46°12'26" N., 124°07'05" W.

Mouth of Columbia River—46°15'43" N., 124°05'21" W.; 46°15'36" N., 124°05'11" W.; 46°15'11" N., 124°05'53" W.; 46°15'18" N., 124°06'03" W.

Mouth of Columbia River—46°12'12" N., 124°09'00" W.; 46°12'00" N., 124°08'42" W.; 46°11'48" N., 124°09'00" W.; 46°12'00" N., 124°09'18" W.

Mouth of Columbia River—46°12'05" N., 124°05'46" W.; 46°11'52" N., 124°05'23" W.; 46°11'35" N., 124°06'14" W.; 46°11'25" N., 124°08'35" W.

Chetco River Entrance—42°01'55" N., 124°16'33" W.; 42°01'56" N., 124°16'09" W.; 42°01'38" N., 124°16'09" W.; 42°01'38" N., 124°16'33" W.

Rogue River Entrance—42°24'16" N., 124°26'49" W.; 42°24'04" N., 124°26'36" W.; 42°23'40" N., 124°27'13" W.; 42°23'52" N., 124°27'26" W.

Coquille River Entrance—43°07'54" N., 124°27'04" W.; 43°07'50" N., 124°26'27" W.; 43°07'20" N., 124°26'40" W.; 43°07'44" N., 124°27'17" W.

Coos Bay Entrance—43°21'52" N., 124°22'45" W.; 43°21'46" N., 124°21'59" W.; 43°21'35" N., 124°22'05" W.; 43°21'46" N., 124°22'51" W.

Coos Bay Entrance—43°22'44" N., 124°22'18" W.; 43°22'29" N., 124°21'34" W.; 43°22'15" N., 124°21'42" W.; 43°22'21" N., 124°22'26" W.

Umpqua River Entrance—43°40'07" N., 124°14'18" W.; 43°40'07" N., 124°13'42" W.; 43°39'52" N., 124°13'42" W.; 43°39'53" N., 124°14'19" W.

Siuslaw River Entrance—44°01'32" N., 124°09'37" W.; 44°01'22" N., 124°09'22" W.; 44°01'14" N., 124°09'07" W.; 44°01'24" N., 124°09'42" W.

Tillamook Bay Entrance—45°34'09" N., 123°59'37" W.; 45°34'09" N., 123°58'45" W.; 45°33'56" N., 123°58'45" W.; 45°33'55" N., 123°59'37" W.

Depoe Bay—44°48'33" N., 124°03'33" W.; 44°48'32" N., 124°03'43" W.; 44°48'15" N., 124°03'45" W.; 44°48'16" N., 124°03'55" W.

Depoe Bay—44°48'09" N., 124°05'05" W.; 44°48'09" N., 124°04'55" W.; 44°47'50" N., 124°04'55" W.; 44°47'50" N., 124°05'05" W.

Yaquina Bay and Harbor Entrance—44°37'31" N., 124°08'04" W.; 44°36'31" N., 124°08'16" W.; 44°36'17" N., 124°05'16" W.; 44°36'17" N., 124°08'04" W.

Port Orford—42°44'38" N., 124°29'38" W.; 42°44'38" N., 124°29'28" W.; 42°43'52" N., 124°29'28" W.; 42°43'52" N., 124°29'38" W.

Willapa Bay—46°44'30" N., 124°10'00" W.; 46°39'00" N., 124°03'00" W.

Nome-West Site—64°30'04" N., 165°25'52" W.; 64°29'18" N., 165°26'04" W.; 64°29'18" N., 165°25'22" W.; 64°29'54" N., 165°24'38" W.

Nome—East Site—64°29'54" N., 165°24'21" W.; 64°29'48" N., 165°23'27" W.; 64°28'57" N., 165°23'29" W.; 64°29'07" N., 165°24'25" W.

Anchorage Harbor—61°14'07" N., 149°53'55" W.; 61°14'18" N., 149°54'15" W.; 61°14'48" N., 149°53'36" W.; 61°14'36" N., 149°53'17" W.

(b) The following sites are designated "Approved Ocean Dumping Sites" for continuing use subject to the listed restrictions:

(1) Gulf Ocean Incineration Site—Region VI. Location—Latitude and Longitude—26°20'00" N. to 27°00'00" N.; 93°20'00" to 94°00'00" W.

Size—(square miles) 1892.

Depth—(feet) 4500.

Primary Use: At sea incineration primarily for organochlorine wastes. Incineration of other wastes will require research studies or equivalent technical documentation to determine acceptability for ocean incineration.

Period of Use: Until September 15, 1981.

Restriction: Only one ship will be permitted to burn wastes at a time, except under extreme emergencies.

(2) Herbicide Orange Incineration Site—Headquarters. Location—Latitude and Longitude—16°46' to 17°45' north latitude; 171°30' to 173°30' west longitude.

Size—14,400 sq. n.mi.

Depth—greater than 15,000 feet.

Use—Solely for at sea incineration of Herbicide Orange by the United States Air Force aboard the *M/T Vulcanus*, owned and operated by Ocean Combustion Service.

Period of Use—May 15, 1977, to September 30, 1977. The designation of this site will be withdrawn after this period of use.

[42 FR 22144, May 2, 1977]

(3) Kwajalein Ocean dumping site—Region IX. Location—Latitude and Longitude—08° 47' north latitude, 167° 36' east longitude.

Size—1,000 yard radius.

Depth—1,655 fathoms (9,930 feet).

Primary use—waste materials resulting from the operation of the Kwajalein Missile Range.

Period of use—Three years after issuance of an ocean dumping permit for use of this site.

[(3) added by 43 FR 33712, August 1, 1978]

(4) Sewage Sludge Site — Region II.

Location: Latitude — 40°22'30"N to 40°25'00"N;

Longitude: 73°41'30"W to 73°45'00"W.

Size: 22.7 square kilometers (6.6 square nautical miles).

Depth: 27 meters (90 feet).

Primary Use: Sewage sludge.

Period of Use: Until December 31, 1981.

Restriction: Disposal shall be limited to sewage sludge generated by those permittees holding ocean dumping permits which were in force on January 1, 1979. Disposal of other wastes at this site is not permitted until adequate studies of the probable impacts of those wastes on the site have been completed.

(5) Alternate Sewage Sludge Site — Region II.

Location: Latitude — 40°10'30"N to 40°13'30"N;

Longitude: 72°40'30"W to 72°43'30"W.

Size: 31 square kilometers (9 square nautical miles).

Depth: 55 meters (180 feet).

Primary Use: Sewage sludge.

Period of Use: Until December 31, 1981.

Restriction: Disposal of sewage sludge at this site shall take place only upon a finding by EPA that the existing site cannot safely accommodate any more sewage sludge without endangering public health or degrading coastal water quality. Disposal of other wastes at this site is not permitted until adequate studies of the probable impacts of those wastes on the site have been completed.

[Section 228.12(b)(4) added by 44 FR 29952, May 18, 1979]

§ 228.13 Guidelines for ocean disposal site baseline or trend assessment surveys under Section 102 of the Act.

The purpose of a baseline or trend assessment survey is to determine the physical, chemical, geological, and biological structure of a proposed or existing disposal site at the time of the survey. A baseline or trend assessment survey is to be regarded as a comprehensive synoptic and representative picture of existing conditions; each such survey is to be planned as part of a continual monitoring program through which changes in conditions at a disposal site can be documented and assessed. Surveys will be planned in coordination with the ongoing programs of NOAA and other Federal, State, local, or private agencies with missions in the marine environment. The field survey data collection phase of a disposal site evaluation or designation study shall be planned and conducted to obtain a body of information both representative of the site at the time of study and obtained by techniques reproducible in precision and accuracy in future studies. A full plan of study which will provide a record of sampling, analytical, and data reduction procedures must be developed, documented and approved by the EPA management authority. Plans for all surveys which will produce information to be used in the

preparation of environmental impact statements will be approved by the Administrator or his designee. This plan of study also shall be incorporated as an appendix into a technical report on the study, together with notations describing deviations from the plan required in actual operations. Relative emphasis on individual aspects of the environment at each site will depend on the type of wastes disposed of at the site and the manner in which such wastes are likely to affect the local environment, but no major feature of the disposal site may be neglected. The observations made and the data obtained are to be based on the information necessary to evaluate the site for ocean dumping. The parameters measured will be those indicative, either directly or indirectly, of the immediate and long-term impact of pollutants on the environment at the disposal site and adjacent land or water areas. An initial disposal site evaluation or designation study should provide an immediate baseline appraisal of a particular site, but it should also be regarded as the first of a series of studies to be continued as long as the site is used for waste disposal.

(a) *Timing*. Baseline or trend assessment surveys will be conducted with due regard for climatic and seasonal impact on stratification and other conditions in the upper layers of the water column. Where a choice of season is feasible, trend assessment surveys should be made during those months when pollutant accumulation within disposal sites is likely to be most severe, or when pollutant impact within disposal sites is likely to be most noticeable.

(1) Where disposal sites are near large riverine inflows to the ocean, surveys will be done with due regard for the seasonal variation in river flow. In some cases several surveys at various river flows may be necessary before a site can be approved.

(2) When initial surveys show that seasonal variation is not significant and surveys at greater than seasonal intervals are adequate for characterizing a site, resurveys shall be carried out in climatic conditions as similar to those of the original surveys as possible, particularly in depths less than 200 meters.

(b) *Duration*. The actual duration of a field survey will depend upon the size and depth of the site, weather conditions during the survey, and the types of data to be collected. For example, for a survey of an area of 100 square miles on the continental shelf, including an average dump site and the region contiguous to it, an on-site operation would be scheduled for completion within one week of weather suitable for on-site operations. More on-site operating time may be scheduled for larger or highly complex sites.

(c) *Numbers and Locations of Sampling Stations*. The numbers and locations of sampling stations will depend in part on the local bathymetry with minimum numbers of stations per site fixed as specified in the following sections. Where the bottom is smooth or evenly sloping, stations for water column measurements and benthic sampling and collections, other than trawls, shall be spaced throughout the survey area in a manner planned to provide maximum coverage of both the disposal site and contiguous control areas, considering known water movement characteristics. Where there are major irregularities in the bottom topography, such as canyons or gullies, or in the nature of the bottom, sampling stations for sediments and benthic communities shall be spaced to provide representative sampling of the major different features.

Sampling shall be done within the dump site itself and in the continuous area. Sufficient control stations outside a disposal site shall be occupied to characterize the control area environment at least as well as the disposal site itself. Where there are known persistent currents, sampling in contiguous areas shall include at least two stations downcurrent of the dump site, and at least two stations upcurrent of the site.

(d) *Measurements in the Water Column at and near the Dump Site*.

(1) *Water Quality Parameters Measured*. These shall include the major indicators of water quality, particularly those likely to be affected by the waste proposed to be dumped. Specifically included at all stations are measurements of temperature, dissolved oxygen, salinity, suspended solids, turbidity, total organic carbon, pH, inorganic nutrients, and chlorophyll *a*.

(i) At one station near the center of the disposal site, samples of the water column shall be taken for the analysis of the following parameters: mercury, cadmium, copper, chromium, zinc, lead, arsenic, selenium, vanadium, beryllium, nickel, pesticides, petroleum hydrocarbons, and persistent organohalogens. These samples shall be preserved for subsequent analysis by or under the direct supervision of EPA laboratories in accordance with the approved plan of study.

(ii) These parameters are the basic requirements for all sites. For the evaluation of any specific disposal site additional measurements may be required, depending on the present or intended use of the site. Additional parameters may be selected based on the materials likely to be in wastes dumped at the site, and on parameters likely to be affected by constituents of such wastes. Analysis for other constituents characteristic of wastes discharged to a particular disposal site, or of the impact of such wastes on water quality, will be included in accordance with the approved plan of study.

(2) *Water Quality Sampling Requirements*. The number of samples collected from the water column should be sufficient to identify representative changes throughout the water column such as to avoid short-term impact due to disposal activities. The following key locations should be considered in selecting water column depths for sampling:

(i) Surface, below interference from surface waves;
(ii) Middle of the surface layer;
(iii) Bottom of the surface layer;
(iv) Middle of the thermocline or halocline, or both if present;
(v) Near the top of the stable layer beneath a thermocline or halocline;
(vi) Near the middle of a stable layer;
(vii) As near the bottom as feasible;
(viii) Near the center of any zone showing pronounced biological activity or lack thereof.

In very shallow waters where only a few of these would be pertinent, as a minimum, surface, mid-depth and bottom samples shall be taken, with samples at additional depths being added as indicated by local conditions. At disposal sites far enough away from the influence of major river inflows, ocean or coastal currents, or other features which might cause local perturbations in water chemistry, a minimum of 5 water chemistry stations should be occupied within the boundaries of a site. Additional stations should be added when the area to be covered in the survey is more than 20 square miles or when local perturbations in water chemistry may be expected because of the presence of one of the features mentioned above. In zones where such impacts are likely, stations shall be distributed so that at least 3 stations are occupied in the transition from one stable regime to another. Each water column chemistry station shall be replicated a minimum of 2 times during a survey except in waters over 200 meters deep.

(3) *Water Column Biota*. Sampling stations for the biota in the water column shall be as near as feasible to stations used for water quality; in addition at least two night-time stations in the disposal site and contiguous area are required. At each station vertical or oblique tows with appropriately-meshed nets shall be used to assess the microzooplankton, the nekton, and the macrozooplankton. Towing times and distances shall be sufficient to obtain representative samples of organisms near water quality stations. Organisms shall be sorted and identified to taxonomic levels necessary to identify dominant organisms, sensitive or indicator organisms, and organism diversity. Tissue samples of representative species shall be analyzed for pesticides, persistent organohalogens, and heavy metals. Discrete water samples shall also be used to quantitatively assess the phytoplankton at each station.

These requirements are the minimum necessary in all cases. Where there are discontinuities present, such as thermoclines, haloclines, convergences, or up-

[Sec. 228.13(d)(3)]

-elling, additional tows shall be made in each water mass as appropriate.

(e) *Measurements of the Benthic Region.*

(1) *Bottom Sampling.* Samples of the bottom shall be taken for both sediment composition and structure, and to determine the nature and numbers of benthic biota.

(i) At each station sampling may consist of core samples, grab samples, dredge samples, trawls, and bottom photography or television, where available and feasible, depending on the nature of the bottom and the type of disposal site. Each type of sampling shall be replicated sufficiently to obtain a representative set of samples. The minimum numbers of replicates of successful samples at each continental shelf station for each type of device mentioned above are as follows:

Cores	3.
Grabs	5.
Dredge	3.
Trawl	30-min. tow

Lesser numbers of replicates may be allowed in water deeper than 200 meters, at those sites where pollution impacts on the bottom are unlikely in the judgment of the EPA management authority.

(ii) Selection of bottom stations will be based to a large extent on the bottom topography and hydrography as determined by the bathymetric survey. On the continental shelf, where the bottom has no significant discontinuities, a bottom station density of at least three times the water column stations is recommended, depending on the type of site being evaluated. Where there are significant differences in bottom topography, additional stations shall be occupied near the discontinuity and on each side of it. Beyond the continental shelf, lesser densities may be used.

(2) *Bathymetric Survey.* Sufficient tracklines shall be run to develop complete bottom coverage of bathymetry with reasonable assurance of accurate coverage of bottom topography, with trackline direction and spacing as close as available control allows. The site itself is to be developed at the greatest density possible, with data to be collected to a suitable distance about the site as is required to identify major changes in bathymetry which might affect the site. Specifications for each bathymetric survey will vary, depending on control, bottom complexity, depths, equipment, and map scale required. In most cases, a bathymetric map at a scale of 1:25,000 to 1:10,000 will be required, with a minimum of 1–5 meter contour interval except in very flat areas. When the foregoing bathymetric detail is available from recent surveys of the disposal site, bathymetry during a baseline or trend assessment survey may be limited to sonar profiles of bathymetry on transects between sampling stations.

(3) *Nature of Bottom.* The size distribution of sediments, mineral character and chemical quality of the bottom will be determined to a depth appropriate for the type of bottom. The following parameters will be measured at all stations: particle size distribution, major mineral constituents, texture, settling rate, and organic carbon.

(i) At several stations near the center of the disposal site, samples of sediments shall be taken for the analysis of the following parameters: mercury, cadmium, copper, chromium, zinc, lead, arsenic, selenium, vanadium, beryllium, nickel, pesticides, persistent organohalogens, and petroleum hydrocarbons. These samples shall be preserved for subsequent analysis by or under the direct supervision of EPA laboratories in accordance with the approved plan of study.

(ii) These parameters are the basic requirements for all sites. For the evaluation of any specific disposal site additional measurements may be required, depending on the present or intended use of the site. Additional parameters may be selected based on the materials likely to be in wastes dumped at the site, and on parameters likely to be affected by constituents of such wastes. Such additional parameters will be selected by the EPA management authority

(4) *Benthic Biota.* This shall consist of a quantitative and qualitative evaluation of benthic communities including macroinfauna and macroepifauna, meiobenthos, and microbenthos, and should include an appraisal, based on existing information, of the sensitivity of indigenous species to the waste proposed to be discharged. Organisms shall be sorted, and identified to taxonomic levels necessary to identify dominant organisms, sensitive or indicator organisms, and organism diversity. Tissue samples of the following types of organisms shall be analyzed for persistent organohalogens, pesticides, and heavy metals:

(i) A predominant species of demersal fish;

(ii) The most abundant macroinfaunal species; and

(iii) A dominant epifaunal species, with particular preference for a species of economic importance.

(f) *Other Measurements.*

(1) *Hydrodynamic Features.* The direction and speed of water movement shall be characterized at levels appropriate for the site and type of waste to be dumped. Where depths and climatic conditions are great enough for a thermocline or halocline to exist, the relationship of water movement to such a feature shall be characterized.

(i) *Current Measurements.* When current meters are used as the primary source of hydrodynamic data, at least 4 current meter stations with at least 3 meters at depths appropriate for the observed or expected discontinuities in the water column should be operated for as long as possible during the survey. Where feasible, current meters should be deployed at the initiation of the survey and recovered after its completion. Stations should be at least a mile apart, and should be placed along the long axis of the dumping site. For dumping sites more than 10 miles along the long axis, one current meter station every 5 miles should be operated. Where there are discontinuities in surface layers, e.g., due to land runoff, stations should be operated in each water mass.

(ii) *Water Mass Movement.* Acceptable methods include: dye, drogues, surface drifters, side scan sonar, bottom drifters, and bottom photography or television. When such techniques are the primary source of hydrodynamic data, coverage should be such that all significant hydrodynamic features likely to affect waste movement are measured.

(2) *Sea State.* Observations of sea state and of standard meteorological parameters shall be made at 8-hour intervals.

(3) *Surface Phenomena.* Observations shall be made of oil slicks, floating materials, and other visible evidence of pollution; and, where possible, collections of floating materials shall be made.

(g) *Survey Procedures and Techniques.* Techniques and procedures used for sampling and analysis shall represent the state-of-the-art in oceanographic survey and analytical practice. Survey plans shall specify the methods to be used and will be subject to approval by EPA.

(h) *Quality Assurance.* The EPA management authority may require that certain samples be submitted on a routine basis to EPA laboratories for analysis as well as being analyzed by the surveyor, and that EPA personnel participate in some field surveys.

PART 229—GENERAL PERMITS

Sec.
229.1 Burial at sea.
229.2 Transport of target vessels.
229.3 Transportation and disposal of vessels.

AUTHORITY: 33 U.S.C. 1412 and 1418.

§ 229.1 Burial at sea.

(a) All persons subject to Title I of the Act are hereby granted a general permit to transport human remains from the United States and all persons owning or operating a vessel or aircraft registered in the United States or flying the United States flag and all departments, agencies, or instrumentalities of the United States are hereby granted a general permit to transport human remains from any location for the purpose of burial at sea and to bury such remains at sea subject to the following conditions:

(1) Except as herein otherwise provided, human remains shall be prepared for burial at sea and shall be buried in accordance with accepted practices and requirements as may be deemed appropriate and desirable by the United States Navy, United States Coast Guard, or civil authority charged with the responsibility for making such arrangements.

(2) Burial at sea of human remains which are not cremated shall take place no closer than three nautical miles from

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Star-Kist Foods, Inc.

TERMINAL ISLAND, CALIFORNIA 90731

Cable Address "FRENCHSACO"

Telex: 68-6265

Answerback: Star-Kist Term.

July 16, 1980

Mr. Chris Vais
Permits Branch
Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, CA 94105

Reference: Ocean Dumping Permit No. OD 79-01/02

Dear Chris:

Paragraph 9(c) of the Special Conditions of the subject permit would require that the permittee establish a plan for a monitoring and surveillance program which will define the fate of waste dumped under a variety of climatic and sea conditions. To accomplish this, I would propose the following:

1. During the first two months of ocean dumping, at least once per week:

   a. Record the time that dumping commences.

   b. Record the time that dumping ceases.

   c. Record the time that any floating matter completely sinks below the surface.

   d. Record the approximate coordinates where the material completely sinks, if outside the designated dumping site.

   e Record wind direction in general terms (on-shore, off-shore, parallel to shore); also, estimated velocity in knots.

   f. Record surface current direction in general terms (on-shore, off-shore, parallel to shore).

   g. Describe the weather (rain, clear, etc.).

   h. Investigate any complaints of material washing on shore that could possibly be from the dumping operation. Determine whether the material is from the dumping operation. Maintain a record on any such complaints that includes time and date of complaint, amount of material, sample of material if possible.

2. After the first two months of dumping, make the above observations at least once per month.

It must be kept in mind that sophisticated monitoring equipment and technical expertise are not readily available in American Samoa.

I have discussed the above program with Karl Eklund of Ralston Purina, and we believe that it will adequately accomplish the intended goals.

If you have any comments relative to this proposed monitoring scheme, please contact me directly.

Sincerely,

STAR-KIST FOODS, INC.

Jeffrey R. Naumann

Jeffrey R. Naumann, Manager
Environmental Engineering

JRN/ac
cc: D. Ballands, Star-Kist Foods
F. Hackman, Ralston Purina
E. Stockwell, Star-Kist Samoa
L. Krogsdale, Star-Kist Samoa

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Star-Kist Foods,

TERMINAL ISLAND, CALIFORNIA 90731

July 2, 1980

Mr. Chris Vais
Permits Branch
Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, CA 94105

Reference: Ocean Dumping Permit No. OD 79-01/02

Having reviewed the drafts for the proposed special dumping permit and public notice, I would offer the following corrections. Hopefully, these minor discrepancies are not serious enough to result in further delay of issuance of the permit:

Public Notice

Page 2, paragraph 2B: The volume percentages do not add up to 100%. The error is probably in the fat content.

Page 5, second and third paragraphs: The letter of transmittal mentions a 45-day review period.

Permit Draft

Special conditions, page 2, paragraph 2d(2): The volume percentages to not add to 100%.

Special conditions, page 2, paragraph 4A: The vessel name is "Misamoa", not "Mi Samoa".

It is my understanding that posting of the proposed permit occurred on June 13, 1980. The 45-day review period would make it possible to issue the permit after July 28, 1980, if no significant public comments are received.

You mentioned that you would contact EPA staff to determine the additional data and work required to complete the environmental assessment. This assessment would be used by EPA to draft an environmental impact statement at the end of the interim ocean dumping permit period (3 years). My understanding is that the EIS

would be necessary to issue a regular ocean dumping permit when the interim permit expires. Your help in defining what is to be done will be appreciated.

I will be in contact with you in the near future towards developing a plan for monitoring and surveillance of the fate of the sludge after dumping, as required under the permit.

Sincerely,

STAR-KIST FOODS, INC.

Jeffrey R. Naumann

Jeffrey R. Naumann, Manager
Environmental Engineering

JRN/ac

cc: Mr. Dave Ballands, Star-Kist Foods
Mr. E. Stockwell, Star-Kist Samoa
Mr. Frank Hackman, Ralston-Purina
Mr. Lyle Richmond, American Samoa Government

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Star-Kist Foods, Inc.

TERMINAL ISLAND, CALIFORNIA 90731
Cable Address "FRENCHSAUCE"
Telex: 68-6265
Answerback: Star-Kist Term.

July 2, 1980

Mr. Chris Vais
Permits Branch
Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, Calif. 94105

Reference: Ocean Dumping Permit No. OD 79-01/02

Dear Chris:

This transmittal of revised and completed bioassay results should fulfill the requirements for bioassay testing prior to issuance of an ocean dumping permit in American Samoa.

The contractor points out that apparently biostimulation occurs at the lowest concentrations of sludge in the tests.

If there is anything additional needed, please call me directly.

Sincerely,

STAR-KIST FOODS, INC.

Jeffrey R. Naumann

Jeffrey R. Naumann, Manager
Environmental Engineering

JRN/ac
encl.
cc: Mr. D. Ballands, Star-Kist Foods
Mr. E. Stockwell, Star-Kist Samoa
Mr. F. Hackman, Ralston-Purina
Mr. Lyle Richmond, American Samoa Government

C39

Star-Kist Foods,

TERMINAL ISLAND, CALIFORNIA 90731

Cable Address "FRENCHSACO"

Telex: 68-6265

Answerback: Star-Kist Term.

June 19, 1980

Mr. Chris Vais
Permits Branch
Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, CA 94105

REFERENCE: OCEAN DUMPING PERMIT NO. OD 79-01/02

Dear Chris:

Transmitted herewith is the report containing bioassay results for sludge from the fish cannery wastewater treatment facilities on American Samoa. You will note that the results are incomplete as definitive tests on *Acartia* have not been successful due to failure of controls. Additional reruns on *Acartia* are being performed in hope of obtaining acceptable results.

As discussed on the phone on June 18, the consultant has calculated an LC 50 by log-probit analysis for the range-finder bioassay on *Acartia*. If this is acceptable, we would like to use it to calculate a conservative dilution ratio unless the current definitive rerun trial is successful. In any event, I shall transmit the results on subsequent trials of *Acartia* when available.

If there is anything further required before the permit can be issued, please contact me directly.

Very truly yours,

STAR-KIST FOODS, INC.

Jeffrey R. Naumann, Manager
Environmental Engineering

JRN/ac
cc: Ed Stockwell - Star-Kist Samoa
Frank Hackman - Ralston Purina
Dave Ballands - Star-Kist Foods
Lyle Richmond - American Samoa Government (w/o attch.)

C40

Star-Kist Foods, Inc.

TERMINAL ISLAND, CALIFORNIA 90731

Cable Address "FRENCHSACO"

Telex: 68-6265

Answerback: Star-Kist Term.

May 7, 1980

Mr. Chris Vais
Permits Branch Enforcement Division
U. S. Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, Calif. 94105

Subject: Star-Kist Samoa, Inc., Amendment to Application for Special Ocean Dumping Permit No. OD-79-02

Dear Chris:

As discussed on the telephone on Wednesday, May 7, 1980, Star-Kist would like to amend our original application for ocean dumping in Samoa by adding cooker juice and press liquor to the materials to be dumped. Our estimates of daily total gallonage of each material are:

	25,000 Gal. per Day of Dissolved Air Flotation Sludge
	14,000 Gal. per Day of Cooker Juice
	13,000 Gal. per Day of Press Liquor
TOTAL:	52,000 Gal. per Day from Star-Kist Samoa

This total quantity should replace our original estimate of approximately 15,000 gal. per day as included in our original application.

I hope that this information is sufficient to change the quantity on the application. If any further information is required, please do not hesitate to call me.

Sincerely yours,
STAR-KIST FOODS, INC.

Jeffrey R. Naumann, Manager
Environmental Engineering

JRN/ac
cc: B. Leamy, D. Ballands, J. Ciko
J. Murray, E. Stockwell, F. Hackman - Ralston Purina

C41

Star-Kist Foods, Inc.

TERMINAL ISLAND, CALIFORNIA 90731

Cable Address "FRENCHSACO"
Telex: 65-6342
Answerback: Star-Kist Term.

March 10, 1980

Mr. Chris Vais
Permits Branch, Enforcement Division
United States Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, California 94105

Subject: Transmittal of Response to E.P.A. Comments on the Ocean Dumping Permit Application for the Star-Kist and Van Camp Operations - American Samoa

Dear Chris:

Transmitted herewith are Dr. Krock's comments relative to your request for further input to the application.

On the bioassay, we intend to have Dr. Soule's group at U.S.C. perform the test using either Samoan sludge, if necessary, or hopefully using Terminal Island tuna sludge. We are now running lab analyses on Terminal Island sludge to use in comparison with the data already existing for Samoan sludge. I will be in contact with you as soon as the lab test results are available.

As you know, we are attempting to expedite completion of the bioassay so that we can meet the end of May deadline for the ocean discharge permit.

Sincerely yours,

STAR-KIST FOODS, INC.

Jeffrey R. Naumann, Manager
Environmental Engineering

JRN/ac
cc: D. Ballands, Star-Kist Foods
F. Hackman, Ralston Purina Co.

M&E Pacific, Inc.

Environmental Engineers

Pacific Trade Center, Suite 600
190 South King Street
Honolulu, Hawaii 96813
(808) 521-3051 Cable MEPAC

March 4, 1980

Mr. Dave Ballands
General Manager, Engineering Services
Starkist Foods, Inc.
582 Tuna Street
Terminal Island, California 90731

SUBJECT: Response to EPA Comments on the Ocean Dumping Permit Application for the Starkist and Van Camp Operations American Samoa

The EPA letter reviewing your ocean dumping permit application noted three areas where more information was required before the final permit will be issued.

The first area was the requirement for an acute bioassay on macroorganisms using diluted sludge or the liquid phase in static or flow-through test systems. A telephone conversation with Chris Vais of EPA Region IX indicated that a test on standard organisms to be conducted by a California laboratory on sludge samples from American Samoa would be acceptable in meeting this requirement. As discussed with you, the details of the bioassay test procedure would be worked out between Chris Vais and the laboratory conducting the tests. It is our understanding that your office will make the necessary arrangements with the laboratory of your choice.

The second area of concern was the possible effect of the surface slick. It should be noted that, during our test discharge, the sludge was not found to be cohesive as suggested by the EPA comment. Rather, as stated in our report, the sludge mixed very readily with the sea water with almost all of the material dispersing and sinking at an initial rate averaging about 40 cm per minute. The slick formed during the surface discharge of the test dump would be minimized by discharging the material below the wind-influenced surface layer, as suggested in the report. The monitoring conducted during the initial portion of the ocean discharge program would be able to observe the fate of any slick that forms, evaluate the dumping procedure, and confirm the location of the site.

The third area noted by the EPA was the 11-item list given in Section 228.6 of the Ocean Dumping Regulations. The accompanying responses were prepared to meet this requirement.

If we can be of further assistance in this matter, please let us know.

HANS-JÜRGEN KROCK, Ph.D.
Senior Engineer

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Attachment

APPLICATION FOR OCEAN DUMPING PERMIT FOR AMERICAN SAMOA STARKIST AND VAN CAMP CANNERIES SLUDGE

This section is in response to the specific criteria for site selection given in Part 228.6 of the EPA Ocean Dumping Regulations and criteria as published in the January 11, 1977 Federal Register.

1. Geographical position, depth of water, bottom topography, and distance from coast

The geographical position of the proposed disposal site is off the southern coast of the island of Tutuila in American Samoa. The proposed site is a circle one nautical mile in diameter centered at:

14°21'.00 S
170°40'.00 W

14°21'~~50"~~ South Latitude
170°40'~~50"~~ West Longitude

The water depth at this location is approximately 4,800 feet. The edge of the one nautical mile diameter circle closest to shore has a depth of about 4,000 feet, while the seaward side is on the order of 5,500 feet deep. The bottom in this area appears to slope downward toward the southeast at a rate of about 25 percent. Because of the great depth, the detailed topography or other bottom characteristics are not known.

The closest shoreline to the center of the proposed site is the airport runway fill area about 2.4 nautical miles to the northwest.

2. Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile phases

The proposed site is located in the open South Pacific Ocean and is characterized by high clarity, very low nutrients, great depth, and very sparse pelagic organism density. The area that might be affected by the proposed discharge supports no known critical development of living resources. Pala Lagoon and Pago Pago Harbor, which may serve as nursery areas, are about 3.1 and 5.5 nautical miles respectively from the center of the proposed site and are not in the direction of transport.

3. Location in relation to beaches and other amenity areas

The Tutuila coastal area closest to the proposed site is the Tafuna coast line and the airport runway fill area to which access is restricted. The coast line is characterized by rugged sea cliffs with almost no sandy areas except for a small area by Fogagogo near Vai Cove adjacent to the existing sewage outfall. Because of the

general lack of ready access, and with the rough coastal and sea conditions, this coastal area is not used for recreational purposes involving water contact. Public amenity areas for beachgoers are rare on Tutuila, with the most used one being in Utulei in Pago Pago Harbor.

4. Types and quantities of wastes proposed to be disposed of and proposed methods of release, including methods of packing the waste, if any

The wastes to be disposed of are sludges resulting from the dissolved air flotation treatment of the wastewaters from the Starkist and Van Camp cannery operations in American Samoa. The principal quality factor of these sludges is the high organic content and resulting oxygen demanding character. There is no evidence of direct toxic effects or significant concentrations of heavy metals or pesticides in these sludges. A more detailed description of quality characteristics is given in Table IV-1 of the report supporting this application.

The average amount of sludge to be disposed is about 400,000 gallons per month, with approximately half coming from each cannery. It is expected that the expansion of operations over the next five years will result in approximately doubling the amount of sludge to be disposed.

The proposed method of release will be to pump the sludge to below the water surface at a rate no greater than 500 gpm from a vessel moving within the disposal area at 5 knots. The controlled release rate, combined with the vessel speed, will insure that adequate initial dilution and subsequent dispersion occur to meet the high oxygen demand while still meeting the water quality standard of at least 80 percent saturation. The subsurface disposal will help minimize the formation of a slick.

5. Feasibility of surveillance and monitoring

It is expected that frequent monitoring and surveillance would be conducted for the first portion of the disposal program in order to confirm the compliance with the dissolved oxygen standard and to observe the fate of any slick that might form. Such monitoring and surveillance would be conducted from a second vessel utilizing a dissolved oxygen meter and probe with measurement and observation locations being established using a sextant to measure horizontal angles between three landmarks.

If the first portion of the disposal program proves effective in meeting EPA and ASG requirements, the frequency of monitoring should be reduced, possibly to four times a year.

6. Dispersal, horizontal transport, and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any

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The horizontal dispersion coefficient was measured in the nearshore area off the Tafuna coast (Figure V-9 of the supporting report) and found to indicate good dispersion conditions. It is expected that dispersion in the open ocean area at the proposed disposal site is somewhat better than in the nearshore area because there are no restrictions on the size of eddy formations and the dispersion coefficient increase with scale can approximate the 4/3 power rate noted by Richardson's Law.

Vertical mixing in the proposed disposal area is not restricted by any salinity or temperature stratification to at least a depth of 300 feet.

Horizontal transport is due to the current structure, which consists of a wind-influenced surface layer overlying an easterly setting lower layer that was measured to have an average speed of about 10 cm/sec at a depth of 100 feet. Since almost all of the sludge of a test discharge was observed to readily disperse and sink, it is expected that the easterly subsurface current will transport the material from the proposed discharge operation offshore and away from the coral communities near the shoreline and on the Taema Bank.

Any slick forming from the proposed discharge will be transported in the downwind direction and will dissipate due to bacteriological breakdown, weathering processes, and solubilization. The original formation of a slick is minimized by the planned subsurface discharge from the moving vessel.

7. Existence and effects of current and previous discharges and dumping in the area (including cumulative effects)

No known discharge or dumping has occurred in the area.

8. Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance, and other legitimate uses of the ocean

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The proposed disposal site was selected specifically to avoid the predominant shipping lanes approaching Pago Pago Harbor (Figure V-1 of the supporting report).

Although the disposal site is within the general area covered by commercial and recreational fishing activity operating out of Pago Pago Harbor, no significant interference is expected. The disposal site is small in comparison to the fishing area and has no unique

characteristics related to fishing activity. The cannery sludge, with proper dilution to minimize dissolved oxygen depletion, has no known detrimental effects on pelagic fish. Ocean disposal of the sludge essentially constitutes the return of a small portion of the organic material that was taken out of the same general area in the form of fish. It might be noted that the only direct interaction with pelagic fish observed during the test discharge of sludge was the apparent attraction of sharks.

No mineral extraction, desalination, or fish and shellfish culture activities occur or are planned in the proposed discharge area. In addition, the site has no unique or special characteristics that would give it scientific importance.

9. The existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys

---

A baseline water quality survey of the waters around American Samoa was conducted. The statistical results are presented in Table V-2 and on Figures V-15 through V-19 of the supporting report. The water quality can generally be characterized as being of high clarity, low nutrient content, and low phytoplankton concentration. Such a dilute base supports a food web of pelagic organisms of correspondingly low population densities. The pelagic fish are highly mobile and are not restricted to a specific location; consequently, they would not be particularly susceptible to any possible detrimental effects that are site specific.

10. Potentiality for the development or recruitment of nuisance species in the disposal site

---

The photic depth (depth to 1 percent incident light) is about 170 feet in the open ocean around American Samoa. Below this depth, the addition of nutrients has no significant effect, except to participate in the bacterial action on organic material. Above the photic depth, the potential for the development of undesirable plankton blooms depends on the average (not maximum) nutrient concentrations and on the exposure time. Since most of the test material was observed to sink, the exposure time in the photic zone is too short for any significant growth response. Since the discharge is to a moving mass of water, no cumulative effect is anticipated from periodic discharges at the same location.

Because of the great depth and the associated increase in sea water density, it is highly unlikely that any significant concentrations of discharged materials will accumulate on the bottom to affect the benthic ecosystem. Rather, it is expected that the organic sludge material will end up, along with much of the other sinking oceanic detritus, at the oxygen minimum zone some 1,000 to 3,000 feet below the surface.

11. Existence at, or in close proximity to, the site of any significant natural or cultural features of historical importance

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No historically important natural or cultural features exist at or near the proposed discharge site.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
215 Fremont Street
San Francisco, Ca. 94105

In Reply Refer to: E-4-2
PEA 4-5

Dave Ballands
General Manager, Engineering Services
Star-Kist Foods, Inc.
Terminal Island, CA 90731

RECEIVED
FEB 11 1980
ENGINEERING DEPT.

Robert Diehl
Director, Division Engineering
Van Camp Seafood Co.
11555 Sorrento Valley Rd.
San Diego, CA 92121

8 FEB 1980

Dear Sirs:

We have reviewed your application for an ocean dumping permit and have determined that it is sufficient to meet application requirements and that your application is complete.

The Marine Protection Branch, EPA Headquarters, has completed its review of the report on ocean disposal of cannery sludge which was submitted in support of the required disposal site designation. The report was found to be adequate for conditional permit approval, however, certain deficiencies were noted as listed in Attachment 1. These must be corrected before the final permit can be issued.

We will proceed with our evaluation of your permit application and within 30 days from the date of this letter, public notice our intent to issue or deny an ocean dumping permit, pending correction of the deficiencies referred to above.

Should you have any questions, please contact Mr. Chris Vais of my staff at (415) 556-8005.

Sincerely yours,

David P. Howekamp
Chief, Permits Branch
Enforcement Division

cc: Marine Protection Branch (WH-548) w/o encl.
Pati Faiai, Governor's Office GAS w/o encl.
Lyle Richmond BQC w/o encl.
Hoeksema, Van Camp, St. Louis w/o encl.

ATTACHMENT # 1

1. The fundamental ecological impact of the sludge has not been adequately addressed. The use of a metabolic test does not conform to the requirements of the Ocean Dumping Criteria. A routine ocean dumping bioassay is required, and should be performed in accordance with procedures specified in Bioassay Procedures for the Ocean Disposal Permit Program (copy enclosed). It may be necessary to prepare dilutions of the sludge in a manner similar to the liquid phase bioassay for dredged material in order to carry out the bioassay. While this method will not represent total sludge impact, it will provide a soluable fraction for testing in either a static or flow-through system. It is this soluable fraction that is most likely to cause acute toxicity. The high BOD/COD will most likely make aeration necessary at all dilutions. The testing procedures and choice of test organisms must be approved by this office prior to testing.

2. The sludge appears to be fairly cohesive, suggesting that a lasting surface slick may result. Wind and current data at the preferred site suggest that the slick could reach the shoreline prior to dispersal. This possibility needs to be more thoroughly evaluated because such an occurrence is considered unacceptable under the regulations and would result in relocation of the site or cessation of dumping.

3. The disposal site is not sufficiently described, see 40 CFR 228.6 for guidance. Each of the 11 items must be considered even if only to state that they don't apply.

C51

Star-Kist Foods, Inc.

TERMINAL ISLAND, CALIFORNIA 90731

Cable Address "FRENCHSACO"

Telex: 69-0342

Answerback: Star-Kist Term.

October 5, 1979

Mr. Chris Vais
Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, CA 94105

RE: Application for Ocean Dumping Permit - Samoa

Dear Mr. Vais:

Please find attached a copy of an evaluation carried out by Metcalf & Eddy in support of the Ocean Dumping Permit which Ralston Purina and ourselves are jointly seeking for our operations in American Samoa.

In providing you with this evaluation in support of our application, we would make the following comments:

1. In view of the problems with space availability for increased storage capacity and the time constraints on completion of the project, we are proposing to enter into a contract in which the sludge hauling vessel will be required to ocean dump the sludge on a daily basis rather than every 3 days as envisaged in the report. The vessel will also be required by conditions of our contract to moor adjacent to our facilities whenever it is not in the process of discharging. Thus, the new storage tanks which we are proposing to install on the vessel together with our existing storage capacity will give a total storage in excess of 80,000 gallons or approximately 4 days.

2. With regard to the proposed discharge mechanism we cannot envisage at this stage a simple and reliable mechanism that will allow discharge at a depth of 50 feet whilst moving at 5 knots. We would, therefore, propose a direct vertical discharge at some shallower depth. Perhaps this is a point that we can discuss during your consideration of this matter and following further engineering evaluation.

Star-Kist Foods, Inc.

Mr. Chris Vais
Page 2
October 2, 1979

We should be pleased to meet with you at your convenience to progress the permit application as swiftly as possible. Although we realize that final approval must come from E.P.A. in Washington, we would appreciate receiving an indication from you at the earliest time that you think our application will proceed without any major difficulty. This will allow us to commence necessary dockside work and our selected contractor to prepare his vessel; we estimate that a time of from 3 to 5 months will be required before we will be ready to commence ocean dumping.

Yours truly,

STAR-KIST FOODS, INC.

Dave Ballands

Dave Ballands
General Manager
Engineering Services

DB/ac

encl.

cc: Mr. T. Brubaker - E.P.A., Region IX
Mr. L. Richmond - E.Q.C., Samoa
Mr. D. Redpath - Ralston Purina
Mr. B. Leamy - SKF
Mr. J. Murray - SKF
Mr. G. Brown - SKF
Mr. E. Stockwell - SKS
Mr. F. Hackman - Ralson Purina
Mr. H. Crock - Metcalf & Eddy, Hawaii
Mr. J. Wass - Van Camp Seafoods

CHAPTER II

SUMMARY AND CONCLUSIONS

The measurements of the quality parameters of the sludges from the Starkist and Van Camp operations in American Samoa showed that the predominent characteristic with respect to environmental effects is the high organic content and the accompanying oxygen demand and slick forming materials. The present wastewater treatment scheme using alum and dissolved air flotation is very effective in removing suspended material, grease and oil, as well as phosphate from the waste stream. The grease and phosphate tend to be bound up by the alum and do not readily separate to form slicks or contribute to the nutrient loading. The concentrations of potentially toxic compounds such as MBAS, mercury, cadmium, DDT or DDE in the sludges are relatively low. The vigorous biological degradation and high rate of gas production in the sludge is evidence of the low concentration of toxicants.

The present average combined production rate of sludge from the two canneries is about 400,000 gallons per month. This rate may increase by up to 100% over the next five years.

The water quality and transport conditions at the offshore alternative discharge area, Dump Site No. 1, can be characterized as open ocean. The depth is more than 4,000 feet and the current structure is a combination of a wind influenced surface drift over a prevailing subsurface current toward the east. A minimum in the current speed occurs at around 20 to 30 feet where the two current regimes interfere. The water quality shows no evidence of stratification to at least 100 feet and probably to 300 feet. The photic zone is down to about 170 feet and the water is low in turbidity, nutrients and chlorophyll-a. Fish population densities are correspondingly sparce. Water quality parameters can be described by log-normal distributions.

The water quality characteristics at the nearshore alternative discharge area by the present Tafuna outfall are similar to those of the

The recommendations resulting from this study include the designation of Dump Site No. 1 as the ocean disposal area and the use of controlled subsurface discharge of the sludge from a moving vessel. A monitoring program should identify any problem areas which can then be alleviated.

The predominant characteristic of these sludges is the significant concentrations of total organic carbon (TOC) and BOD_5. These sludges are very biologically active and exhibit no signs of inhibiting toxic responses. Gas production is vigorous if these sludges are held without pH adjustment or other biologically inhibiting preservation technique.

Additionally, it should be noted that these sludges contain significant concentrations of total kjeldahl nitrogen (TKN) and especially total phosphorus (TP). The TP content can be largely attributed to the use of alum in the treatment process. If ocean disposal of this sludge is generally to areas below the photic zone, then there should be little effect from these nutrient additions, especially since the material sinks and the phosphorus is tied up with the aluminum.

The most likely effect that this sludge would have on an open ocean disposal area is possible oxygen stress related to BOD and TOC. This problem can best be dealt with by providing adequate dilution and transport and avoiding possible collecting areas for floatables or settleables.

Sludge Quantities

According to information provided by the two companies, the present averages of sludge productions are as shown in Table IV-2.

TABLE IV-2

PRESENT CANNERY SLUDGE QUANTITIES IN AMERICAN SAMOA

Parameter	Units	Starkist	Van Camp	Total
Minimum	US gallons/month	100,000	100,000	200,000
Average	US gallons/month	200,000	200,000	400,000
Maximum	US gallons/month	300,000	300,000	600,000

The values in Table IV-2 indicate that, on a volume basis, Starkist and Van Camp would each account for 50% of the total amount of sludge to be disposed. Van Camp has projected that it expects a doubling of its sludge production over the next five-year period. Although no

CHAPTER VI

EVALUATION OF POSSIBLE IMPACTS

Except for the addition of fresh water and nontoxic quantities of alum, NaOH, and polyelectrolytes, the origin of the sludge is the ocean in the vicinity of American Samoa. Because of the export of canned fish and other products, the effect of the fishing and canning operations is a net decrease in the nutrient content of the already nutrient poor waters around American Samoa. Similarly, these operations result in a net decrease in the amounts of metals and pesticides and other materials that may be contained in the fish caught. Considering the relative quantities of these materials in the surrounding ocean and in the fish caught, it is not likely that the net decrease is significant or even measurable; however, these considerations do show that the materials in the sludge are not alien to the ocean and, in fact, constitute only a small fraction of what was removed with the fish.

The potential difficulties with returning the sludge to the ocean are all related to the possibility of localized, long-term, high concentrations of materials in the water, on the surface, along the shoreline, or on the bottom. The potential effects are both concentration and time dependent. Consequently, alleviation of detrimental effects involves dispersion and transport as well as avoidance of concentrating areas.

The potential difficulties are clearly illustrated by considering the effects on inner Pago Pago Harbor when all the materials in the sludge were discharged into this concentrating area prior to the installation of the D.A.F. plants. Low dissolved oxygen, habitat change due to substrate smothering, shoreline grease collection, water column eutrophication, and generally aesthetically unpleasant conditions resulted. These effects are related to long-term, localized, high concentrations of oxygen demanding material, settleable solids, floatables, or nutrients. They are not indicative of direct toxic effects.

Two types of tests were conducted to evaluate and quantify the possible effects of ocean disposal of the cannery sludge. The first was a test release of sludge to determine the amount and character of floatables, the dispersion characteristics and the settling rate of the settleables. The second was a bioassay to measure the time-related response of

projections are available from Starkist, it is reasonable to expect that it will have a similar rate of increase. Consequently, for planning and permit purposes, the average sludge production is expected to increase from the present 400,000 gallons per month to 800,000 gallons per month in five years.

The operation schedule for both canneries varies from three to six days per week, with an average of five days per week. The schedules for the two plants do not necessarily coincide. This variation in operation schedule as well as the vagaries of the weather means that some storage facilities may be necessary if open ocean sludge disposal is adopted. It is expected that a workable ocean disposal system would also include the capability of land disposal for emergency conditions when the storage capacity is exceeded and lengthy adverse weather periods or boat breakdowns occur.

production rate this would mean a disposal trip every three days on the average. Experience will show whether additional storage capacity is required to achieve acceptable reliability of the system.

It is recommended that an agreement be reached with the American Samoa government to allow for emergency land disposal of the sludge during periods of unusually long-term adverse weather or other conditions preventing the ocean disposal of the sludge. The exercise of such an option should, of course, be kept to a minimum.

Finally, it is recommended that a monitoring program of the discharge area be instituted to measure dissolved oxygen, turbidity and chlorophyll-a as well as to observe the extent and characteristics of any slick formation resulting from the sludge discharge. If adverse effects are detected these data can be used to beneficially alter the treatment or discharge practices or even relocate the discharge area.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
215 Fremont Street
San Francisco, Ca. 94105

In Reply
Refer to: E-4-2
PEA 4-5

Paul T. F. Low
M and E Pacific, Inc.
Pacific Trade Center, Suite 600
190 South King Street
Honolulu HI 96813

Dear Mr. Low:

At the request of Mr. Gerald Brown, Star-Kist Foods, Inc., we have reviewed your Scope of Work for an ocean dumping site designation study, and offer the following comments:

1. Task A should include analysis for TOC, DDE, DDT, surfactants (MBAS) and percent fat, carbohydrate, and protein.

2. The study should include a bioassay of the waste material as required in 40 CFR 227.6. The definitions of each phase may be found at 40 CFR 227.32. No bioassay will be required for a specific phase when it can be demonstrated that the waste material does not exist in that phase.

3. Task C should include measurement of the following parameters to determine water quality: temperature, TOC, D.O., pH, salinity, Nitrogen in the form of ammonia, nitrite, and nitrate, Phosphorus in the form of ortho-phosphate, turbidity and Chlorophyll a.

4. The Scope of Work should include replicate net tows for phytoplankton and zooplankton for qualitative and semi-quantitative analysis.

5. Task E - If a test release of the waste material is conducted, it shall be limited to a one time release not to exceed one thousand (1,000) gallons.

In summary, the designation study must thoroughly address all of the applicable elements set forth in 40 CFR 228.5 and 228.6. Where it is clear that a specific element need not be addressed, the study report should contain a supporting rationale.

Should you have any questions, please contact Mr. Chris Vais at (415)556-3454.

Sincerely,

ORIGINAL SIGNED BY:
DAVID P. HOWEKAMP

David P. Howekamp
Chief, Permits Branch
Enforcement Division

cc: Gerald Brown, Star-Kist Foods, Inc.

C61

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
215 Fremont Street
San Francisco, Ca. 94105

RECEIVED
MAR 12 1979
ENGINEERING DEPT.

In Reply Refer to: E-4-2
PEA 4-5

Gerald C. Brown
Manager Environmental Engineering
Star-Kist Foods Incorporated
582 Tuna Street
Terminal Island, California 90731

MAR 9 1979

Dear Mr. Brown:

This letter acknowledges the receipt of your ocean dumping permit application dated February 9, 1979. Your application has been assigned the number OD-79-02.

We have reviewed your initial submittal and find that it is incomplete in several respects. A detailed evaluation is attached for your information. Major inadequacies are noted as follows:

1. Identification/description of the exact nature of the material to be discharged including potential for incidental contamination, types and quantities of any coagulant aids used in the DAF unit and description and types of any other wastes (i.e., press liquor and stick water) that maybe considered for discharge.

2. Designation of a specific site where dumping operations would be carried out. This should conform to the requirements of 40 CFR 228.4(b), 228.5, and 228.6.

3. Need for proposed dumping should be supported and/or clarified by documentation, where possible, by specific requirements of the Government of American Samoa; lack of suitable alternatives such as reuse, reclamation, recovery or recycle, etc.

4. An environmental assessment of any anticipated impacts or supportive data as to the lack of any such impacts.

In conclusion, Section 221.5 of the ocean dumping rules and regulations requires an initial filing fee of one thousand dollars for each application and an additional three thousand dollars for processing site designations. This office cannot proceed with further consideration of your application until such fees are received as provided by regulation. Should you have any further questions please have your staff contact Mr. Chris Vais or Mr. Ted Durst at (415)556-3454.

Sincerely yours,

David P. Howekamp
Chief, Permits Branch
Enforcement Division

Enclosure

cc: Environmental Quality Commission,
American Samoa

Review of OD-79-02, Star-kist Incorporated

This review is made in context of 40 CFR 221.1 which defines in detail the required content of the ocean dumping permit application. Reference is made to the specific citation, noting adequacy or inadequacy of the application with respect to the specific requirement.

Cite	Comment
221.1(a)	Adequate
221.1(b)	Since the responsible party for transport of the waste material has not been selected, any permit will require the information be provided at least 60 days prior to commencement of disposal operations.
221.1(c)	Inadequate - Application shall identify any and all chemical additives (coagulant aids, etc.) to the DAF unit as well as addressing the potential for contamination from any or all waste streams that may co-mingle with the process waste sludges.
221.1(d)	Adequate, however, this total should be modified to include any additional waste streams such as stick water or press liquor.
221.1(e)	Adequate
221.1(f)	Inadequate - A specific site or sites must be identified and located by coordinates accurate to one second latitude and longitude. Should also define the release zone i.e. "a circle 2,000 yards radius centered at".
221.1(g)	Adequate
221.1(h)	Inadequate - Waste treatment system should be described including process steps, chemical additions, etc. Also all waste streams tributary to the treatment system and/or considered for ocean disposal should be clearly identified.

Cite	Comment
221.1(i)	Adequate
221.1(j)	Generally adequate, however, we request that you expand your discussion to include a statement as to why each of the listed alternatives is unacceptable.
221.1(k)	Inadequate - No assessment has been provided, this could be included in the Site assessment and evaluation required by 40 CFR 228.4(b), 228.5 and 228.6.

C65

Star-Kist Foods, Inc.

TERMINAL ISLAND, CALIFORNIA 90731

Cable Address "FRENCHSACO"

Telex: 65-6342

Answerback: Star-Kist Term.

February 9, 1979

Environmental Protection Agency
Region IX
215 Fremont St.
San Francisco, CA 94105

Attention: Mr. Christopher L. Vais
Environmentalist Enforcement Division

Subject: Star-Kist Samoa, Inc. Application for Special Ocean Dumping Permit

Dear Mr. Vais:

Pursuant to Section 200.03(B) of the Environmental Protection Agency's ("EPA") Ocean Dumping Regulations (41FR2462 ep seq.), Star-Kist Samoa, Inc. ("Star-Kist") hereby formally applies for a special ocean dumping permit.

Pursuant to Section 40 CFR 221.1 of said regulation, Star-Kist submits the following:

A. Applicant is Star-Kist Samoa, Inc., P. O. Box 368, Pago Pago, Samoa.

B. The services of an ocean vessel would be used for the transportation and dumping of the material. The vessel will be owned and operated by an individual and not a corporation retained by Star-Kist Samoa, Inc. and Van Camp Seafoods jointly.

C. The physical and chemical description of the material to be dumped is as follows:

Moisture	-	90.0%
Total Solids	-	10.0%
Fat	-	5.6%
Ash	-	1.5%
Protein	-	2.9%
Salt (nacl)	-	1.0%

D. Approximately 15,000 gallons of this material will be dumped during each 24 hour period, 7 days a week.

E. Dumping shall commence immediately upon approval of EPA and will continue for an indefinite period.

F. Applicant proposes that the dump site approved for dumping be located south of the Tafuna area directly south of the proposed ocean outfall and approximately 2 miles offshore.

G. The material to be dumped shall be pumped from storage tanks within the transporting vessel to a pipe immediately in front of the propeller of such vessel, then dishcarged through this pipe and dispersed by the action of the propeller of the vessel.

H. The material proposed to be dumped is fish cannery sludge. Star-Kist fish cannery sludge is produced by the proper operation of Star-Kist's dissolved air floatation system which is part of Star-Kist's waste water treatment system. Star-Kist installed its waste water treatment system including a dissolved air floatation system in 1972 in order to meet the requirements of its NPDES permit which was issued under authority of PL 92-500.

I. The material proposed to be dumped previously was disposed of in a private landfill site along the Matautuloa ridge.

J. Since the installation of the dissolved air floatation system, Star-Kist has been experiencing increasing difficulty in disposing of the materials generated by the proper operation of its waste treatment system. Proper operation of this system is required in order for Star-Kist to meet the limitations of its NPDES permit. Within the last month Star-Kist has experienced increasing difficulties with its existing sludge disposal ponds.

K. Star-Kist has discussed environmental impact of the proposed dumping of this material in the ocean with the U. S. EPA and representatives of the Government of American Samoa, and has received no adverse comments to the site location.

We are in contact with the consulting firm of Metcalf and Eddy for a proposal to conduct the site analysis for the proposed dumping location. Upon receipt of the proposal from this firm, Star-Kist will submit the scope of action for approval to EPA.

Star-Kist Foods.

C67

We trust that this information is sufficient. If any further information is required, please contact the undersigned or Mr. Dave Ballands.

Sincerely yours,

STAR-KIST FOODS, INC.

Gerald C. Brown

Gerald C. Brown
Manager Environmental Engineering

GCB/ac

cc: B. Leamy
D. Ballands
J. Ciko

APPENDIX D

Quality Assurance

QUALITY ASSURANCE PROGRAM
SEAFOOD WASTE DISPOSAL PROGRAM
NA81RAD00009

Field Measurements

Parameters: Temperature, salinity, dissolved oxygen, pH.

Method: Electrochemical remote probes, Martek Water Quality Analyzer, Mark V or Mark VI.

Calibration:

1. Temperature sensitivity is 0.1°C. The probe is calibrated to a certified mercury thermometer in laboratory prior to each use. The instrument is very stable.

2. Salinity (conductivity), sensativity is 0.01°/₀₀. The probe is calibrated in the laboratory to a sub-standard solution of known salinity before each use. The sub-standard is prepared by using a laboratory salinometer calibrated to Standard (Copenhagen) water.

3. Dissolved oxygen sensitivity is 0.1 ppm. The probe is calibrated in the laboratory by air exposure, per manufacturer's instructions, or by iodometric Winkler titration.

4. pH sensitivity is 0.1 pH unit. The probe is calibrated against pH buffer solutions at two values.

Instruments are returned annually, or more frequently as needed, to the manufacturer for servicing and calibration.

Field Sampling/Laboratory Measurement

Parameters: Ammonia, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), Trace Metals (Aluminum, Cadmium, Mercury).

Sampling: PVC Self-closing device.

Methods and Quality Assurance:

1. Ammonia: Samples in polycarbonate Ehrlenmeyer flasks, acidified to pH2 with HCl; Orion specific ion probe 95-10-00, sensitivity to 20 ppb. Calibration is by Standard solutions per manufacturer's instructions, prior to and during usage.

2. BOD: Standard Methods (APHA, 1981) modified for seawater, marine bacterial culture used for seed.

2. BOD: Quality Assurance: Two or three separate control sites are sampled and pre-dump samples are taken at the dumpsite. Samples are placed in polyethylene bottles in the field. Blanks using dilution water are run for quality control in the field. Sensitivity of BOD measurements in 2 ± mg/liter.

3. COD: Research on methods for high salinity determinations is underway. Calibrations as for BOD.

4. TOC: Wet digestion and IR detection using an oceanographic International Corp Total Carbon Sustem Model 0524. Instrument calibrated according to manufacturer's instructions. Blanks and control sites used as for BOD. There is a great deal of interinstrument variability in TOC measurements. Sensitivity is 0.5 mg/l but variability on the instrument used is between 1-2 mg/l.

5. Trace Metals

Methods: Field sampling is by PVC self-closing sampler. Samples are placed in polyethylene bottles and chilled on board. Atomic absorption spectrophotemetry is used in analysis for aluminum, cadmium and mercury. (Standard Methods, APHA, 1981).

Quality Assurance:

Instruments are calibrated according to manufacturer's instructions. Commercial standards and blanks are used for each field sampling batch. Selected replicates of samples will be sent once a year to the State of California laboratories and/or to a commercial analytical laboratory which has in the past provided good inter-laboratory comparisons. Metals analyses are limited in this project to a few wastewater samples, and to one-time analyses of bioassay tissues.

Standard Methods (APHA, 1981) are followed in all instances, using the required cleaned glassware and chemically pure reagents. Bioassay tests are carried out under polyethylene tents to reduce possible contamination, and analytical transfers are performed in an appropriate hood. No super-clean room is available, however, for this work.

No Standard Reference Materials for marine tissues or sediments are known to be available for use in this work. The large data base here from the local marine environment offers good comparative information, however.