ASSESSMENT OF THE ENVIRONMENTAL IMPACTS OF THE HART-MILLER ISLAND CONTAINMENT FACILITY

SEVENTH ANNUAL INTERPRETIVE REPORT
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MARYLAND WATER RESOURCES ADMINISTRATION

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BY
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TIDEWATER ADMINISTRATION

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FOREWORD

Maryland is rich in natural resources. Its wild game, woods, beaches, rivers, and Chesapeake Bay with its abundant aquatic resources provide a bountiful outdoor environment for our citizens. The task of the Department of Natural Resources is to manage these resources in such a way that their enhancement, conservation, use and development ensure the greatest good for the greatest number of Marylanders, now and in the future. The employees of DNR are personally and professionally committed to this task, and, with public understanding and support, we will achieve our goal.

Torrey C. Brown
Secretary
Department of Natural Resources

ACKNOWLEDGMENTS

We are grateful to the scientists who contributed to and critically reviewed this report. We thank the following people for their indispensable help in the completion of this report: Patricia Matthews, Rosalee Anderson, and Pat Delpino for typing and Lenora Dennis for data input.

EXECUTIVE SUMMARY

The Hart-Miller Island Containment Facility was designed to receive material from channel dredging projects in the Baltimore Harbor and its approaches. The disposal site is located northeast of the Baltimore Harbor in the Chesapeake Bay. This report contains the results of a seventh year of monitoring to assess the impacts to the biological and sedimentary environment exterior to the dike. As in previous years, samples of sediments and the benthic population were taken at a number of sites in the vicinity of Hart and Miller Islands during Fall 1987 and Spring 1988. A beach erosion study, initiated in the spring of 1984, was continued. Data collected from this and the previous six years of monitoring indicate that there have been no significant changes in the environment.

No significant changes were observed in the sedimentary environment surrounding the Hart-Miller Island Containment Facility. Generally, the sediments around the facility remained siltier than pre-construction sediments. The blanket of fluid mud was still very distinct and radiographic examination of this layer revealed no increase in bioturbation levels compared with the sixth year. The reworking by benthic activity that does exist is largely restricted to the upper 10-15 cm. Average zinc enrichment factors for the fluid mud remained lower than pre-construction values. However, slight increases in enrichment factors were observed in the bioturbated zone of the fluid mud layer, indicating that benthic activity contributed to the enrichment of sediments with Zn and, by association, others as well. This is consistent with the sixth year monitoring data and results.

With respect to beach erosion, wave activity and sheet wash, the two major natural processes operating on the beach were responsible for the erosional features observed during the study period. Wave action during high tides eroded most of the sediment from the beach. Sheet wash during storms resulted in the development of gullies, which grew in depth and headward extent throughout the monitoring year. By steepening the lower dike face, bulldozing amplified the effects of these two geomorphic processes.

The sampling locations, sampling techniques and data analysis for benthic monitoring were again designed to be as similar as possible to those for the previous two years. The results presented in this report are quite similar to those presented in both the fifth year and sixth year reports. Salinity variations on yearly and seasonal time scales appear to determine the position of dominance of the major species. There was a general overall decline from the high number of bivalves reported in August 1987. The decline appeared at both the nearfield and reference stations and may be a result of less favorable salinities in the region.

The benthic data indicated significant differences in stations in the southwest region of the Hart-Miller Island facility near Back River. Epifaunal species were quite similar in terms of distribution at the nearfield and reference stations for all three sampling periods. At present, there do not appear to be any discernible differences in the nearfield and reference populations resulting directly from the containment facility. Barge activity churns up and scours the area, but the opportunistic species inhabiting this oligohaline region of the Bay appear to be readily capable of repopulating disturbed areas.

The levels of 43 individual trace organic contaminant compounds were determined in 110 samples of sediment and biota. Biological samples (fish, benthos) were also analyzed for concentrations of six metals: chromium, copper, iron, manganese, nickel, and zinc. All the sediment samples showed pollutant levels below the detection limits. This was also the case for biota except for chlordane and PCB's (Total). B-BHC was detected in one tissue sample of *Rangia* species Consistently higher levels of chlordane and PCB's showed up in the April and August, 1988 biota samples. These levels were lower than baseline levels for the entire Bay. This suggests the biota are accumulating the extremely low levels found in the sediment to a detectable level in the biota samples. Data collected prior to dike construction indicated that some of these contaminant levels were much higher than current levels, so the relation of these findings to facility operations is not clear.

RECOMMENDATIONS

It is imperative that good lines of communication be maintained between the researchers and the managers of Hart-Miller Island, so that both groups can benefit from any information acquired through the surveys they conduct. It is therefore recommended that the Exterior Monitoring program meet at least yearly with the Technical Advisory Committee.

Monitoring of the sedimentary environment exterior to the Hart-Miller Island Containment Facility should be continued at its current level through at least 1990, the scheduled completion date of the 50 ft deepening of Baltimore Harbor and its approach channels. Likewise infaunal and epifaunal populations should continue to be sampled at the established locations during this period.

Several of the erosion control measures recommended in previous reports were implemented in September 1988. Construction of two berms parallel to the shoreline will redirect storm runoff. Seeding the beach will stabilize it by reducing sheet wash and gully erosion. However, erosion of the 50-75 ft wide sand beach by wave attack will continue. Sand replenishment and/or the construction of an offshore breakwater may still be necessary to deter erosion.

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TABLE OF CONTENTS

LIST OF FIGURES

PROJECT III: BENTHIC STUDIES

PROJECT IV: ANALYTIC SERVICES

LIST OF TABLES

DEFINITION OF TERMS

Bathymetric - Referring to contours of depth below the water's surface.

Benthos - The bottom of a sea or lake. The organisms living on sea or lake bottoms.

Bioaccumulation - The accumulation of foreign substances, particularly toxic contaminants, within the tissues of organisms. Results from chronic exposure to contaminated food or habitats.

Biogenic - Resulting from the activity of living organisms. For example, bivalve shells are biogenic minerals.

Biometrics - The statistical study of biological data.

Biota - The animal and plant life of a region.

Bioturbation - Mixing of sediments by the burrowing and feeding activities of sediment-dwelling organisms. This disturbs the normal, layered patterns of sediment accumulation.

Brackish - Salty, though less saline than sea water.

Desiccation - The act of drying thoroughly; exhausting or depriving of moisture.

Diversity index - A statistical measure that incorporates information on the number of species present in a habitat with

the abundance of each species. A low diversity index suggests that the habitat has been stressed or disturbed.

Dominant (species) - Designating an organism or a group of organisms which, by their size and numbers or both, determine the character of a community.

Dredge - Any of various machines equipped with scooping or suction devices used in deepening harbors and waterways and in underwater mining.

Effluent - Something that flows out or forth; an outflow or discharge of waste, as from a sewer.

Epifauna - Benthic animals living on the surface of bottom material.

Flocculate - An agglomeration of particles bound by electrostatic forces.

Flocculent - Having a fluffy or wooly appearance.

Gas chromatography - A method of chemical analysis in which a sample is vaporized and diffused along with a carrier gas through a liquid or solid adsorbent for differential adsorption. A detector records separate peaks as various compounds are released (eluted) from the column.

Hydrography - The scientific description and analysis of the physical conditions, boundaries, flow, and related characteristics of oceans, rivers, lakes, and other surface waters.

Infauna - Benthic animals living in bottom material.

Littoral - Of or pertaining to the seashore, especially the region between the highest and lowest levels of spring tides.

Mean low water - The average water level at low tide.

Radiograph - An image produced on a radiosensitive surface, such as a photographic film, by radiation other than visible light, especially by x-rays passed through an object or by photographing a fluoroscopic image.

Revetment - A facing, as of masonry, used to support an embankment.

Salinity - The concentration of salt in a solution. Full strength seawater has a salinity of about 35 parts per thousand (ppt or o/oo).

Sediment - That which settles to the bottom, as in a flask or lake.

Seine - A large fishing net made to hang vertically in the water by weights at the lower edge and floats on the top.

Spawn - To produce and deposit eggs, with reference to aquatic animals.

Spectrophotometer - An instrument used in chemical analysis to measure the intensity of color in a solution.

Spillway - A channel for an overflow of water.

Substrate - A surface on which a plant or animal grows or is attached.

Supernatant - The clear fluid over a sediment or precipitate.

Surficial - The top, or surface, layer of sediment.

Trace metal - A metal that occurs in minute quantities in a substance.

Trawl - A large, tapered fishing net of flattened conical shape, towed along the sea bottom. To catch fish by means of a trawl.

INTRODUCTION

The Hart-Miller Island Containment Facility monitoring program was established to collect and analyze data to determine the effects of the facility on the surrounding environment. The program was launched in 1981 so that environmental data for pre-construction and pre-operational conditions could be compared with the data collected during operation of the facility. The Seventh Annual Interpretive Report presents the results of the environmental monitoring of the Hart-Miller Island Containment Facility from August 1987 through August 1988.

DESCRIPTION OF THE CONTAINMENT FACILITY

The site is environmentally and economically important to Maryland and the Chesapeake Bay region. The State of Maryland contracted for the construction of a diked area at Hart and Miller Islands during 1981-1983, and the facility was completed in 1983. It was designed to receive 52 million cubic yards (mcy) of material, most of which will be bottom sediments produced by deepening the Baltimore Harbor and its approach channels to 50'. Once the facility is filled, it will be converted to a permanent wildlife and recreational area.

The dike is 28' (18' + a 10' perimeter dike) above mean low water and encloses an area of 1,140 acres. It was constructed from sand deposits within and underlying the enclosure. Presumably, the fine sands and silts from the dredged material will fill the pores between the sand grains, forming a semi-permeable dike wall. The Bay-side face is riprapped with stone over filter cloth. The typical side slopes are 3:1 (three horizontal to one vertical) on the exposed outside face, 5:1 on the inside and 20:1 along the recreational beach on the Back River side. The completed dike is approximately 29,000' long and contains 5,800 cubic yards of stone. The facility is divided into North and South containment cells by an interior dike approximately 4,300' long.

DREDGED MATERIAL DISPOSED

Material dredged in 1985 in the amount of 3.7 mcy was deposited into the North Cell. Of the 7.5 mcy of dredged material disposed in 1986, 3.7 mcy was deposited into the North Cell and 3.8 mcy was deposited into the South Cell. The breakdown of dredged material received is listed by project in Table 1. The disposed volumes shown in the table for 1985 represent the entire 1985 and 1986 dredging seasons (April 1985 through September 1985 and June 1986 through January 1987, respectively).

The major 1986 dredging task was to remove material from the main shipping channel to maintain a working depth of 42'. The other projects listed for that year were mainly to remove dredged material allowing shipping companies to make better use of the 42' deep channel. Since the beginning of the project to deepen the channel to 50', shipping companies have been dredging their access channels deeper to make better use of the 50' channel depth. The 50' contract #1 represents the first of two contracts to increase the Maryland shipping channel to a depth of 50'. The addition of the dredged material from these projects produced sufficient quantity of supernatant to cause a discharge from spillway #1 during the seventh monitoring year. Discharge of the supernatant was initiated on October 25, 1986. Monitoring of the discharge is required to fulfill the State Discharge Permit #86-DP-2294.

The 1987 disposal operations included projects from the inner harbor area. This included the following projects: Seagirt Marine terminal, Amstar, and the Bethlehem Steel Shipyard. The operations also included disposing of 125,000 cy of material from the Hart-Miller North Unloading pier. This material was removed to allow access to the north pier for additional operations related to the 50 foot channel project. The first contract of the fifty foot channel project totaled 9.9 mcy and 54,000 cy of material that was used to relocate utilities related to the deepening of the fifty foot channel.

The 1988 disposal operations included projects from the inner harbor area These projects were Baltimore Gas & Electric Company, Canton waterfront, CSX coal pier, and Toyota. The operations included disposals from the maintenance of the 42' channel along with 6.2 mcy of material from the 50' channel project.

TABLE 1

DISPOSAL OPERATIONS

YEAR	PROJECT NAME	CUT QUANTITY DISPOSED (Cubic Yards)
1983	Hart-Miller Personnel Pier	24,000
1984	Hart-Miller South Unloading Facility	164,000
1984	Dundalk Marine Terminal	500,000
1984	42' Channel Maintenance and Brewerton Eastern Extension	3,908,000
	TOTAL 1984	4,596,000
1985	42' Channel Maintenance	3,145,000
1985	Bethlehem Steel	596,000
	TOTAL 1985	3,741,000
1986	42' Channel Maintenance	7,000,000
1986	Eastern Avenue Bridge	18,000
1986	Canton-Seagirt	500,000
1986	South Locust Point	185,000
1986	Hess Oil	7,200
1986	Bethlehem Steel Ore Pier	5,250
1986	Rukert Terminal	16,632
	TOTAL 1986	7,732,082

Table 1 (cont.)

1987	Seagirt	2,617,000
1987	Eastern Avenue Bridge	22,000
1987	Aquarium Pier 4	5,763
1987	HMI North Unloading facility	125,000
1987	Amstar	28,170
1987	Bethlehem Steel Shipyard	378,461
1987	50-ft Contract #1	9,900,000
1987	50-ft Channel Utilities	54,000
	Total 1987	13,130,394
1988	Seagirt	
1988	Baltimore Gas and Electric	1,833,000
1988	Brandon Shore/Wagner pt.	18,464
1988	Canton Waterfront	2,500
1988	CSX Coal Ore Pier	28,030
1988	Clinton Street	1,000
1988	Toyota (MD Shipbuilding)	70,000
1988	50-ft Contract #1	6,212,230
1988	42-ft Channel Maintenance	125,000
	Brewerton, Swann Point	
	Total 1988	8,342,724
	Grand Total*	37,541,200

* through December 31, 1988

SUMMARY OF MONITORING PROGRAMS

The State determined, as prescribed in authorizing permits for the facility, that there was a need for "a comprehensive environmental monitoring program for the Hart-Miller Containment Facility prior, during and following commencement of operations." The responsibility for the monitoring was assigned to the Water Resources Administration. The monitoring program is divided into two complementary portions: (a) monitoring to ensure compliance with federal and state laws; and (b) monitoring for environmental impacts. The operational permits requiring monitoring were issued by the Maryland Department of the Environment (MDE) (formerly Maryland Department of Health and Mental Hygiene (DHMH)) and the Water Resources Administration (WRA) of the Department of Natural Resources (Dept. of Trans. et. al., 1979). The Maryland Environmental Service (MES) is responsible for monitoring water quality within the diked area.

This report describes studies designed to assess impacts to the biota and sediments exterior to the dike. This assessment is performed under a separate agreement between the Maryland Department of Natural Resources and the Maryland Port Administration. Liaison and coordination were maintained among all agencies having roles in site management, operations, monitoring, sampling and oversight programs related to the Hart-Miller Island Facility, primarily through periodic meetings with the Technical Review Committee. Four projects were implemented to assess the environmental effects of construction and operation of the facility and are briefly described in the following sections.

PROJECT I: SCIENTIFIC COORDINATION AND DATA MANAGEMENT

The Tidewater Administration is responsible for maintaining a data base on the natural resources of Maryland, especially within the coastal zone. Data stored include fish, benthos, water quality, climate, sediments and hydrography. It is also responsible for conducting applied scientific investigations necessary for developing information for management purposes. The compilation,

data input, and long-term storage of all data related to the exterior monitoring effort are included in these responsibilities.

During the first six years of the Hart and Miller Islands environmental assessment program, data collected by the Department of Natural Resources and research institutions were stored in the Tidewater Administration's "Resource Monitoring Data Storage System" (RMDSS). This storage system makes data readily available to interested parties and also serves as a permanent repository from which baseline and trend information can be retrieved for comparison and evaluation.

The Tidewater Administration provides overall scientific planning, review and coordination of the exterior monitoring activities for the Hart-Miller Island Facility, as well as compiling and distributing the annual Interpretive and Data Reports. This also includes the analyses of any lab data that is not interpreted by the other principal investigators.

PROJECT II: SEDIMENTARY ENVIRONMENT

The Coastal and Estuarine Geology Program of the Maryland Geological Survey has been involved in monitoring the physical and chemical behavior of the sediments around the Hart-Miller Containment Facility since 1981. This work has been conducted in two parts: sedimentary environment study and beach erosion study.

Monitoring and documentation of the sedimentary environment are necessary to detect any changes which may occur as a result of the operation of the containment facility. Currently, highly organic, fine-grained sediments from the approach channels to Baltimore Harbor are being placed inside the dike. Improper handling or leakage of these dredged materials from the dike may produce changes in sand to mud ratios and the physical appearance of the surrounding sediments, as well as increase the levels of trace metals and organic contaminants. In seven years of monitoring, however, no major changes

have been detected within the sedimentary environment as a result of construction or operation of the facility. However, monitoring did reveal a fluid mud layer that was deposited during dike construction. This fluid mud layer was described in earlier exterior monitoring reports.

Sediment samples are collected not only at various sites around the containment facility, but also at several reference sites outside the immediate area of the facility. These samples are put through a rigorous series of tests including organic contaminants (testing done under Project IV), trace metal, textural and radiographic analyses. Textural and trace metal data from the 1987-88 monitoring year indicate that no major changes occurred again this year.

The beach erosion study, initiated in the spring of 1984, yielded additional data which can be interpreted to define geomorphic (natural) processes and anthropogenic (human) activities that shape the beach. Erosion continues, and appear to be related to slope, textural characteristics of the beach material, littoral drift, rainfall and wind direction. The main agent of erosion on the beach has been wave attack on the foreshore by wind generated waves. The dike face is being altered primarily by pluvial and aeolian processes (rain and wind). During the sixth year of monitoring, erosion of the beach increased dramatically, resulting in a steeper, more gravelly beach. A beach stabilization effort was initiated in 1988 in cooperation with the Baltimore County Soil Conservation Service. Beach grass is being planted to prevent erosion from aeolian processes.

PROJECT III: BIOTA

PART 1. BENTHIC STUDIES

Benthic studies have been included in the monitoring program since August 1981. The primary objectives are to survey abundance and distribution of

benthic organisms in this area and to monitor any effects of construction and operation of the disposal facility.

These studies are important for two reasons. First, many adult stages of benthic organisms live a sedentary life, either attached to hard substrates (epifauna) or buried in the sediments (infauna). Consequently, these organisms cannot readily move to avoid sudden physical and chemical changes in their environment. Thus, they are good indicators of possible adverse environmental conditions. The second reason for careful, long-term monitoring of these benthic populations is to be able to determine if any sudden change in population structure or abundance is a result of the containment facility or of natural environmental variations. The upper region of the Chesapeake Bay is a highly variable physical environment subject to sudden changes in salinity, wind-related wave action, high summer water temperatures and ice formation in winter to name a few. As a result, the benthic populations undergo large seasonal and annual variations in abundance. Also, estuarine areas such as the Hart-Miller Island site, with wide seasonal salinity changes and vast shallow soft-bottom shoals, are important to protect because they serve as important breeding and nursery grounds rich in nutrients for many commercial and non-commercial species of invertebrates and migratory fish.

Since the beginning of the project in 1981, the dominant benthic species have remained relatively stable. Epifaunal populations on pilings have followed the same yearly pattern. During the winter, the populations living at the upper ends of the pilings are removed by ice scour and/or desiccation at low tide. In the spring, the populations are re-established by larval settlement and/or recolonization by mobile species. This year's results clearly indicate that the containment facility produces only localized and temporary effects on the benthos are a result of the containment facility. These effects are primarily limited to the area near the rehandling pier, are a result of propeller wash from tugboats.

Infaunal and epifaunal benthic populations should be monitored no less critically in the upcoming year, since discharge of supernatant from the

containment island will continue. The first release of supernatant release occurred on October 25, 1986. Data from pre-construction through construction and early operation of the facility are a valuable baseline and will be essential for the assessment of possible future benthic population changes.

PART 2. FISH AND CRAB POPULATION STUDIES

This study was discontinued after the fifth monitoring year. The inherent variability in the data and the high mobility of the fish community make such an effort difficult to design so as to function effectively as a monitoring tool to determine impacts from the facility (EA Engineering, 1985). Populations of fish and crabs in the vicinity of Hart and Miller Islands were studied between 1981 and 1986. The extensive data collected since the beginning of the project provides a detailed description of the quantity and composition of the populations.

PROJECT IV: ANALYTIC SERVICES

Beginning with the seventh monitoring year a contractual laboratory (specifically Martel Laboratories) was hired to perform the metals analyses on biota and the organic analyses on both biota and sediment. Martel provided sample containers which were filled by the principal investigators then returned to the MES staff at Hart-Miller Island for transfer to Martel. This process proved to be highly efficient, reducing the time required for analysis to as little as three months. Project III - Benthic Studies currently collects finfish and benthic material for organic and metals analysis. Project II - Sedimentary Environment provides sediment samples for organic analyses, the metals analysis is performed as a part of the sedimentary monitoring.

PROJECT I

SCIENTIFIC COORDINATION AND DATA MANAGEMENT

SEVENTH YEAR INTERPRETIVE REPORT

BY

DEPARTMENT OF NATURAL RESOURCES

TIDEWATER ADMINISTRATION

580 TAYLOR AVENUE

TAWES STATE OFFICE BLDG., B-3

ANNAPOLIS, MD 21401

JANUARY 1989

Development and implementation of a monitoring program which is sufficiently sensitive to the environmental effects of dredged material containment at Hart-Miller Island continues to be a complex and difficult undertaking. The environmental monitoring activities have evolved over the seven years of the project. Ongoing studies have included physical and chemical characterization of sediments and population studies of benthos and finfish. Baseline data on water column nutrients and productivity, submerged aquatic vegetation, trace metals and organic contaminants were included in the First and Second Interpretive Reports (Cronin et al., 1981-1983). Bathymetric studies were completed in the first three monitoring years to identify pre- and post-construction changes in currents and erosion.

Scientific planning, review and coordination of the monitoring activity is provided by Tidewater Administration. Sampling procedures, data analysis, and future directions of the program are discussed with the principal investigators. Descriptions of any changes in sampling methods are included in the individual investigator project reports that follow. Compilation, editing, technical review, and printing of the Interpretive and Data Reports are the responsibilities of the Tidewater Administration. During the first six years of the environmental assessment program, data collected by the Department of Natural Resources and research institutions were stored in the Tidewater Administration's "Resource Monitoring Data Storage System." The IBM-OS File/SAS Data Base is used for computer storage and analysis of data. The Tidewater Administration staff assumes responsibility for the long-term storage of data related to the exterior monitoring program. Permanent storage of the data in a readily accessible form provides a continuous, documented record of baselines and trends in biota, sediments and contaminant levels. Data from the 1987-1988 monitoring year are included in the Seventh Year Data Report, which is compiled and printed separately from the Interpretive Report.

The Scientific Coordination Committee meets quarterly with the principal investigators, Water Resources Administration (WRA), and Maryland Port Administration (MPA) to discuss issues related to the exterior monitoring

program. Once a year the Scientific Coordination Committee meets in conjunction with the Technical Review Committee to provide that committee with detailed information about the exterior monitoring program.

Conclusion and Recommendations

It is imperative that good lines of communication be maintained between the monitoring researchers and the managers of Hart-Miller Island, so that both groups can benefit from any information acquired through the surveys they conduct. It is therefore recommended that the Exterior Monitoring Program meet at least yearly with the Technical Advisory Committee.

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THREE-DIMENSIONAL UPPER BAY HYDRODYNAMIC MODEL

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THREE-DIMENSIONAL UPPER BAY HYDRODYNAMIC MODEL

Background

In a 1985 report to the Maryland Port Administration (EA, 1985), dye dispersion studies were recommended to evaluate dilution and dispersion of effluents from the Hart-Miller Islands Containment Facility. Two potential sources of effluent were to be assessed: these were seepage through the dike and point discharges over the dike through effluent weirs. These studies were recommended by the technical review committee to determine the concentrations of contaminants from the effluent within the mixing zone. Current DNR Regulations dictate that water quality standards may not be exceeded by more than 10 percent of the cross-sectional area of the receiving water (Jordan, 1986).

In June of 1986, DNR proposed a change in methodology and recommended the use of a 3-D hydrodynamic model to assess effluent dispersion and dilution around the Hart-Miller Island Containment Facility in lieu of the dye study. Funding for the dye study occurred during the fifth monitoring year and was supplemented by DNR funds. The modeling project for Hart-Miller Island was to be a modification of an Upper Bay 3-D Model which was already under development (initiated in 1985). In return for the additional funding, "finer detail" or smaller grids would be produced for the area surrounding Hart-Miller, on the Upper Bay 3-D model currently under development.

Proposal to Apply 3-D Hydrodynamic Model in Lieu of Dye Studies

With minor modifications, the 3-D Upper Bay Hydrodynamic Model would provide substantially more comprehensive information on the fate of conservative contaminant discharges than the proposed dye studies. The dye study included two 10-day dye releases which necessarily would apply only to the field conditions under which they were performed. Many potential variations in wind, tides, currents, and salinity gradients that could affect effluent dispersion cannot be estimated with confidence by limited short-term dye studies. Inherent with dye studies of such a large and dynamic environment is the possibility that dye recovery will be insufficient to provide adequate confidence in the results.

The advantages of a model are that it can be run to simulate virtually any set of climatic conditions; run for any length of time (subject to constraints on computer resources); will be supported by actual field data used in calibration and verification; and has the potential for incorporating modifications to assess the fate of non-conservative contaminants.

The specifications for this model included: (1) boundary fitted coordinate system; (2) average cell area 5 km longitudinal by 500 m latitudinal; and (3) five cells in the vertical. The first phase of this model development involved construction, calibration and verification of a two-dimensional, vertically averaged model. The second phase consists of construction and verification of a three-dimensional model.

The specific modifications to required to support the proposed application to Hart-Miller Islands Containment Facility are: (1) addition of grid points in the area of the Facility to improve spatial resolution; and (2) incorporation of the dike and effluent weirs as sources of conservative contaminants. The work began in 1985, but became delayed in April 1988 when initial funding ran out.

Contractual Agreements

In June of 1985, DNR's Water Resources Administration and Tidewater Administration entered into an agreement with the U.S. Army Corps of Engineers to develop a three-dimensional computer hydrodynamic model of the Upper Chesapeake Bay, north of the Chesapeake Bay Bridge. The 3-D Hydrodynamic Model of the Upper Chesapeake Bay was designed to assist in several ongoing and planned studies. These will include the impact of salinity intrusion on water supply, effect of the Chesapeake and Delaware (C&D) Canal on the Upper Bay hydrodynamics, striped bass larval transport, and the transport-dispersion of effluent from the Hart-Miller Island Containment Facility. In addition, flow fields generated by the hydrodynamic model are required by water quality models that the DNR may apply in the Upper Bay (Jordan, 1986).

In December of 1987 this contract was amended to include "finer detail" around Hart-Miller Island. Enclosed at the end of this summary are the specific tasks or modifications to the Upper Bay Model related to the 3-D modeling surrounding Hart-Miller Island, and a summary of the Upper Bay 3-D Hydrodynamic Model. The Upper Bay Model Agreement, as amended, was scheduled to be in effect from June 27, 1985 through December 31, 1988. This deadline was extended to July 31, 1989. Progress reports from Waterways Experiment Station (WES) were submitted from June 1988 through April 1989. Two meetings were scheduled between Dr. Billy Johnson of WES and the Hart-Miller Island Technical Review Committee to answer questions related to the Hart-Miller portion of the Upper Bay 3-D Model. It was determined that Pooles Island may have an effect on the hydrodynamic modeling; therefore it was added to the 3-D grid. The description of the model provided by Dr. Johnson is included in Appendix A to provide answers to specific technical questions.

WES has agreed to provide both the calibration and verification data sets that were used to test the model and a module to generate graphical display of the data.

Technical Summary of 3-D Upper Bay Hydrodynamic Modeling Project

A planform view of a preliminary grid of the Upper Bay that was generated using the code developed by Thompson and Johnson is shown in Figure 1. The grid contains approximately 600 points, and when extended, 5 vertical layers. The grid is made up of a layer thickness of 1-3 m, a lateral spacing of perhaps 500 m, and a longitudinal spacing of about 3,000 m. Economical computations with time-steps of about 5 minutes can be made for periods extending over several days.

The boundary-fitted transformation is employed only in the horizontal plane. Sigma-stretching was used in the vertical direction to smoothly represent the bottom topography (Johnson, 1985). This method proved to be unsatisfactory, and therefore WES used variable layering instead of sigma-stretching. This method was employed in the full 3-D Chesapeake Bay Model.

The Upper Bay 3-D Hydrodynamic Model contains several components. A Laterally Averaged Environmental Model (LAEM) is used to generate boundary conditions at the C&D canal and the Chesapeake Bay Bridge. These conditions are then saved and used to provide information on conservative constituents. A second component is the hydrodynamic program which generates output from the boundary conditions (produced by the LAEM), inflows from the Patapsco, Susquehana, etc. and wind data (probably from BWI Airport). The model also has components to generate graphical displays of the data. Calibration and verification data sets will also be provided by WES. The data generated may then be used with the EPA's Water Quality Model (WQM) for the full bay to produce information on water quality parameters. A full technical description of the Upper Bay 3-D Hydrodynamic Model is included in Appendix A. This summary was used as a proposal, and therefore may not reflect the current status of the model.

This model will only produce information on hydrodynamics. It will only have the ability to trace conservative constituents (salt, conductivity, etc.) through the water column. This model can possibly be linked with a water

quality model produced for the EPA to provide information on various other parameters. Modifications were made to the model code to eliminate problems related to calibration tests. The model was then modified to accommodate multiple layers to eliminate problems detected in the calibration phase of the model.

Conclusions

By the end of July, 1989, WES will have completed work on the Upper Bay 3-D Hydrodynamic Model, including Hart-Miller Island, and will begin training personnel on use of this model. This model is closely related to the full bay hydrodynamic model, and therefore, any modification to the full bay model will affect the upper bay model. WES will also provide a users manual and limited technical assistance as required. This Upper Bay 3-D Hydrodynamic Model can be used to predict transport-dispersion of effluent from the Hart-Miller Island containment facility.

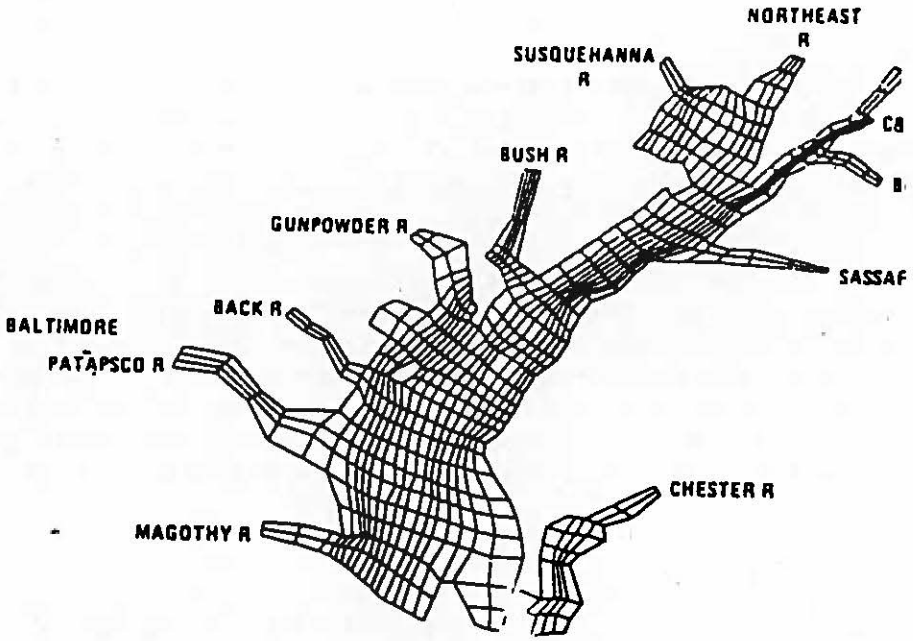

Figure 1 Planform boundary-fitted grid of Upper Chesapeake Bay

Appendix A

An Approach for Modeling the Upper Chesapeake Bay

Billy H. Johnson,* M. ASCE

Abstract

A three-dimensional time-varying hydrodynamic model of that portion of the Chesapeake Bay lying north of the Bay Bridge at Annapolis, Maryland, is being developed for the Maryland Department of Natural Resources. To resolve the bay geometry with a minimum number of grid points, boundary-fitted coordinates are employed. A major question is how to prescribe tidal boundary conditions at the Bay Bridge and how to handle the Chesapeake and Delaware (C&D) Canal in an economical fashion when applying the model in a predictive mode. The approach discussed involves first applying a two-dimensional laterally averaged model of the complete Chesapeake and Delaware system. The computed water-surface elevation and vertical distribution of salinity at the Bay Bridge and the entrance to the C&D Canal are then saved and applied as boundary conditions in the three-dimensional Upper Bay model.

Introduction

The Department of Natural Resources (DNR) of the State of Maryland desires a three-dimensional (3D) numerical hydrodynamic model of the Upper Chesapeake Bay (Figure 1) to assist in several ongoing and planned studies. These include the impact of salinity intrusion on water supply, effect of the Chesapeake and Delaware (C&D) Canal on the Upper Bay hydrodynamics, striped bass larval transport, and the transport-dispersion of effluent from the Hart-Miller Island containment area. In addition, flow fields generated by the hydrodynamic model are required by water quality models that the DNR may apply in the Upper Bay.

The code selected for application on the Upper Bay is called CH3D and was developed by Sheng (1986) for the US Army Engineer Waterways Experiment Station. A unique feature of CH3D is that computations are made on a curvilinear grid that approximately follows the irregular shoreline of the Upper Bay and its tributaries. Such grids are often referred to as boundary-fitted grids and in general are nonorthogonal. The boundary-fitted coordinates feature of the model provides enhancement to fit navigation channels, as well as the irregular shoreline, and permits adoption of an accurate and economical grid schematization.

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Figure 1. Upper Chesapeake Bay

Theoretical Aspects of CH3D

CH3D is briefly described as follows. Sheng (1986) presents more detailed descriptions of the theoretical basis. The model solves the time-varying 3D initial-boundary value problem in which the governing equations are the continuity equation, the momentum equations, conservation equations for salinity and temperature, and an equation of state.

To enable a more accurate handling of irregular boundaries and internal features, the code employs boundary-fitted coordinates. As illustrated in Figure 2, rather than making computations on a physical boundary-fitted grid, the governing equations are transformed so that computations are made on a transformed rectangular mesh with square grid spacing.

In an earlier development of a vertically averaged model by Johnson (1980), only the independent variables, i.e., the Cartesian coordinates, were transformed. For example, in two dimensions the governing equations of motion are easily transformed from the Cartesian (x,y) system to the (ξ,η) curvilinear system using

$$f_x = \frac{1}{J}\left[\left(fy_\eta\right)_\xi - \left(fy_\xi\right)_\eta\right] \tag{1}$$

$$f_y = \frac{1}{J}\left[-\left(fx_\eta\right)_\xi + \left(fx_\xi\right)_\eta\right] \tag{2}$$

where f is an arbitrary function of (x,y), all subscripts denote differentiation,

and

$$J = x_\xi y_\eta - x_\eta y_\xi$$

In CH3D the transformation is carried an additional step by also transforming the flow velocity such that the contravariant rather than the physical components of the velocity are computed. The physical components of the velocity are not parallel to the grid lines in the transformed (ξ,η) system whereas the contravariant ones are. As the skewness of the boundary-fitted grid increases, the transformation employed in CH3D becomes more appropriate, especially in the specification of boundary conditions along solid boundaries. As noted by Sheng (1986), the relationship between the contravariant components V^i and the physical components V_j of the velocity is given by

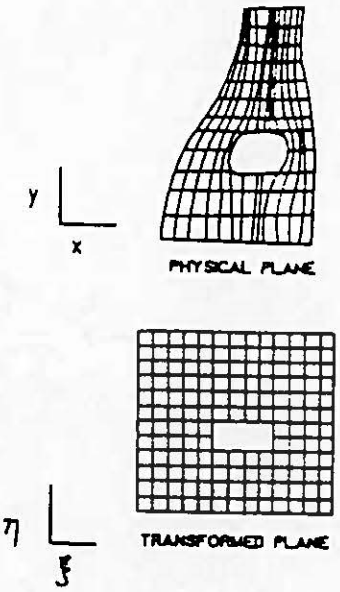

Figure 2. Transformation of physical domain to computational domain

$$V^i = \frac{\partial \xi i}{\partial x j} V_j \qquad (3)$$

The boundary-fitted transformation is employed only in the horizontal plane. Sigma-stretching is used in the vertical direction to smoothly represent the bottom topography. Thus, the vertical transformation is given by

$$\sigma = \frac{z - \zeta}{H + \zeta} \qquad (4)$$

where σ takes on values between 0 and 1, z is the Cartesian coordinate, H is the water depth referenced to some datum, and ζ is the change in water surface relative to that datum.

A factored or time split implicit scheme in the horizontal directions and a fully implicit finite difference scheme in the vertical direction is employed for numerical solution. Computations are performed first for an external mode which consists of vertically averaged computations. These are then used to drive the internal computations.

Application to the Upper Bay

A planform view of a preliminary grid of the Upper Bay that was

elevations and vertical salinity distributions from a laterally averaged model of the complete Chesapeake-Delaware system. A schematic of the system is presented in Figure 4. The model consists of longitudinal spatial steps ranging from 4,000 m to 8,000 m and a vertical grid spacing of 2 m. The particular code being applied is called LAEM and was developed by Edinger and Buchak (1981). Successful applications of LAEM include channel deepening studies on the Lower Mississippi River and the Savannah River Estuary by Johnson, Boyd, and Keulegan (1987) and Johnson, Trawle, and Key (1986), respectively.

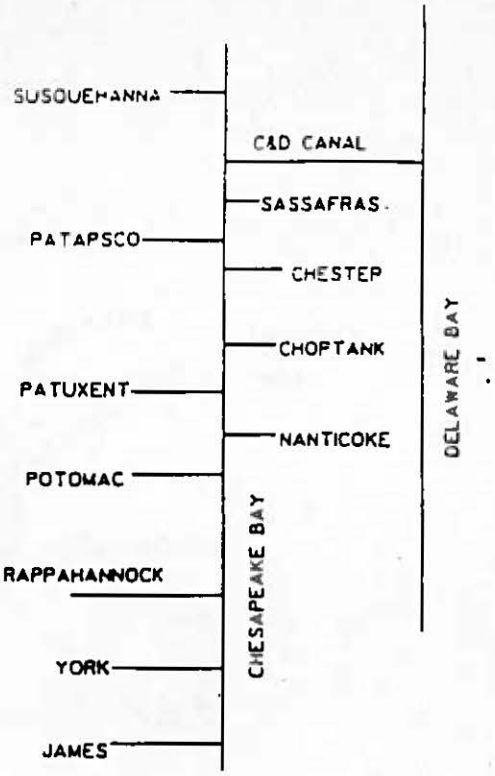

Figure 4. Schematic of laterally averaged model of Chesapeake-Delaware system

The procedure for making predictive computations in the Upper Bay will be first to apply LAEM with ocean boundary conditions imposed at the mouths of the Chesapeake and Delaware Bays. Computed water-surface elevations and vertical salinity distributions at the Bay Bridge and at the entrance to the C&D Canal will be saved and applied as boundary conditions in the subsequent application of CH3D. Although field data reveal some lateral variation in salinity at the Bay Bridge, it is believed that this approach will provide adequate predictive boundary conditions for the 3D Upper Bay model in an economical manner.

Summary

To satisfy the requirement of making accurate and economical 3D flow computations in the Upper Chesapeake Bay, a numerical model that makes computations on boundary-fitted grids is being applied. Such grids allow an accurate representation of irregular shorelines and internal features with a minimum number of grid points. A grid containing approximately 600 horizontal points and 5 vertical layers appears to be adequate to capture the Upper Bay geometry.

To be able to use the model to address the impact on Upper Bay hydrodynamics of changes to the system, a laterally averaged model of the complete Chesapeake-Delaware system is being developed to provide boundary conditions at the Bay Bridge and the C&D Canal. In this way, economic predictive 3D hydrodynamic computations on the Upper Chesapeake Bay can be made.

The study described is an ongoing one and no results were available when this paper was written. However, results will be presented at the conference.

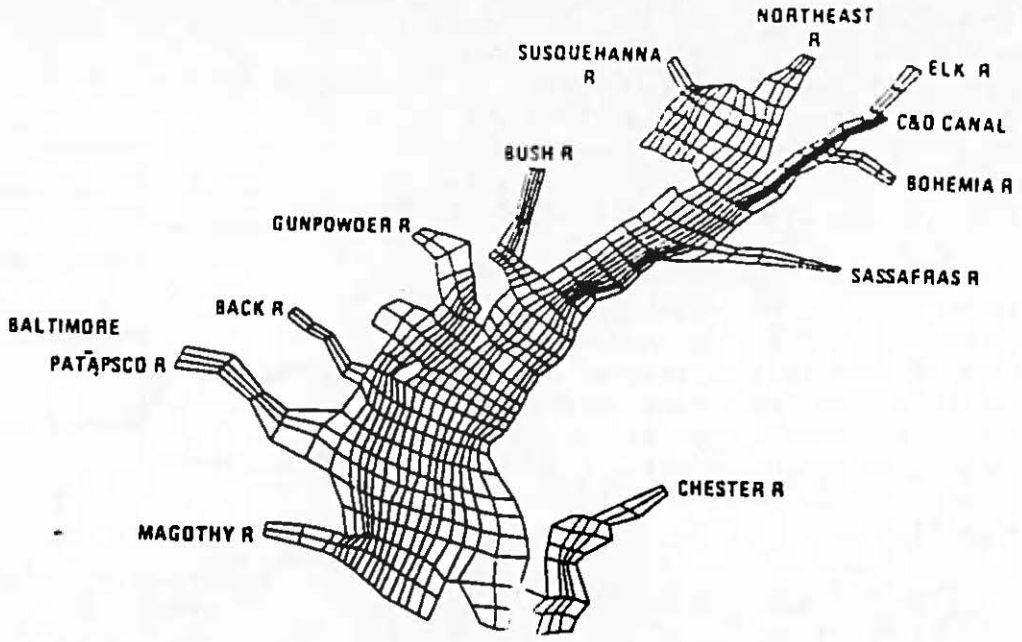

Figure 3. Planform boundary-fitted grid of Upper Chesapeake Bay

generated using the WESCORA code developed by Thompson and Johnson (1985) is shown in Figure 3. The grid contains approximately 600 points, and when extended to 5 vertical layers, it should satisfy the grid constraints imposed by the Maryland DNR; namely, a layer thickness of 1-3 m, a lateral spacing of perhaps 500 m, and a longitudinal spacing of about 3,000 m. Economical computations with time-steps of about 5 minutes can be made for periods extending over several days.

As can be seen from Figure 3, several tributaries such as the Patapsco, Chester, and Susquehanna contribute to the freshwater inflow into the Upper Bay. In fact, the Susquehanna contributes approximately 70 percent of the freshwater inflow to the entire Chesapeake Bay. In addition to these tributaries, the C&D Canal connecting the Chesapeake and Delaware Bays is a major contributing factor to the hydrodynamics of the Upper Bay.

When the Upper Bay model is applied to historical events, no particular problems should arise in the specification of boundary conditions at the Bay Bridge and in the handling of the C&D Canal. Observed data for the tide and salinity can be used. However, to use the model to address hypothetical questions, e.g., the effect of major changes in freshwater inflow from the Susquehanna and the impact of deepening the C&D Canal, another approach must be devised since such changes will influence conditions at the boundaries. One approach would be to extend the grid to include much, if not all, of the complete Chesapeake-Delaware system. However, from an economic viewpoint, such an approach is not practical since 3D computations on large grids can become quite costly.

The approach taken here is to generate the required water-surface

Acknowledgment

This study is being funded by the State of Maryland Department of Natural Resources. Permission to publish this paper was granted by the Chief of Engineers.

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PROJECT II

SEDIMENTARY ENVIRONMENT
SEVENTH YEAR INTERPRETIVE REPORT
(NOVEMBER 1987 - OCTOBER 1988)

BY

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POWER PLANT AND ENVIRONMENTAL REVIEW DIVISION
TAWES STATE OFFICE BUILDING
ANNAPOLIS, MARYLAND 21401

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ABSTRACT

The Coastal and Estuarine Geology Program of the Maryland Geological Survey has been involved in monitoring the physical and chemical behavior of near-surface sediments around the Hart-Miller Island Containment Facility as part of the State's environmental assessment of the facility. In a separate effort, the program's staff has also documented the erosional and depositional changes along the recreational beach between Hart and Miller Islands. The results of these two studies during the seventh year of monitoring are presented in this report.

Textural and trace metal data from sediments collected around the exterior perimeter of the dike show that no major changes have occurred within the sedimentary environment as a result of operation of the facility, although a blanket of fluid mud deposited during dike construction is still distinguishable. The top of the fluid mud layer has been reworked by benthic organisms (bioturbated). The level of activity does not appear to have increased during the seventh year, compared to last year's observations.

The range and distribution of Zn enrichment factors in the sediments were similar to those reported previously. Generally, the average enrichment factors for Zn remain lower for the fluid muds. A slight increase in enrichment factor values, associated with the bioturbated zone of the fluid mud layer, is attributed to benthic activity.

Data collected during beach monitoring indicate that erosion accelerated during the first three years of study, then levelled off. This year, 3,129 yd^3 (2,394 m^3) of sediment were lost between regrades, compared to 3,472 yd^3 (2,656 m^3) last year. Gully erosion, although extensive, accounted for only 94 yd^3 (72 m^3) of sediment lost; an additional 773 yd^3 (591 m^3) were eroded from the nearshore. Since the study's inception in June 1984, a total of 11,244 yd^3 (8,602 m^3) has been eroded from the recreational beach.

PART 1: SEDIMENTARY ENVIRONMENT

INTRODUCTION

The areal distribution and characteristics of estuarine bottom sediments reflect the complex interaction of physical, chemical, and biological processes, acting singly or in combination. In addition to these natural processes, anthropogenic activities may produce sudden changes in the nature of bottom sediments. During construction of the containment facility at Hart and Miller Islands, dredging of the nearshore bottom for suitable building material and overboard disposal of that material were necessary. Those activities changed the local sedimentary environment.

Documentation of construction-related changes was necessary in order to establish a baseline against which environmental changes during the project's operational phase could be evaluated. Since the facility began operating in 1983, fine-grained sediments, highly enriched in trace metals and organic carbon, have been dredged from Baltimore Harbor and its approach channels and placed inside the dike. Improper handling of this dredged material or leakage from the dike could result in detectable changes in the physical and chemical characteristics of the surrounding sediments (e.g., sand:mud ratio, appearance, trace metal and organic carbon content).

PREVIOUS WORK

Changes in the sedimentary environment around the Hart-Miller Island Containment Facility were documented during the first six years of the state's monitoring effort and are detailed in several reports (Kerhin et al., 1982a; Wells et al., 1984-1987; Hennessee et al., 1988). Knowledge of the physical characteristics and areal distribution of sediment types prior to the construction of the facility was based on data collected by the Maryland Geological Survey (MGS) in 1978 (Cuthbertson, 1987). The sediments graded from nearshore sand to sand-silt-clay to silty clay just northeast of the islands. On the Hawk Cove and southern sides of the complex, the sediment graded from nearshore sand to silty clay. The latter were described as dark gray muds with high water content. Live bivalves, *Rangia cuneata* and *Macoma balthica*, were common (Kerhin et al., 1982b).

Radiographic examination of cores taken in the area around the islands before construction began revealed low levels of bioturbation (reworking of sediments by organisms) in the Back River-Hawk Cove area and higher bioturbation levels elsewhere. Also, at several sampling locations south of the island complex, death assemblages of *R. cuneata* were found at the sediment surface.

During active construction of the dike, which began in the fall of 1981, minor changes in the relative proportions of sand, silt, and clay were detected in sediments collected at established stations around the island complex. Sediments became siltier, particularly at stations adjacent to areas of active construction. In the summer of 1982, gross changes in the physical appearance of the sediments were observed. Fine-grained sediments collected prior to the summer of 1982 were consistently described as dark gray muds. However, sediments collected in July 1982, south of and adjacent to the dike wall, were very fluid, light gray to pink muds, resembling pre-Holocene sediments that had been dredged for dike construction. It was determined that a blanket of this "fluid mud" had accumulated south and east of the dike structure as a result of construction (Wells and Kerhin, 1983 and 1985). Radiographic examination of the fluid mud accumulations revealed little or no bioturbation.

Trace metal analyses of sediment samples, presented as enrichment factors, indicated that sediments collected before and after dike construction were similar, except in the area of fluid mud accumulation. There, the enrichment factors dropped below the current regional average (see Results and Discussion).

The dike was completed in the spring of 1983. Since then, monitoring has revealed little additional change in sediment characteristics. The layer of fluid mud introduced during dike construction is still evident, the only observed changes being slight color variations attributed to biogenic activity. Radiographic analyses of sediment cores taken around the dike structure have been consistent from one monitoring year to the next. Bioturbation levels in the cores taken within the fluid mud layer have increased over time. Nonetheless, enrichment factors have remained lower for the fluid mud accumulation. In areas beyond the blanket of fluid mud, enrichment factors for Zn have remained consistent with pre-construction values.

OBJECTIVES

The purpose of the seventh year study was to continue monitoring the vertical and areal distribution of sediments and their geochemical components. The primary objectives were:

1. to identify the sedimentological and geochemical conditions of the near-surface sedimentary column in the vicinity of the project area and

2. to obtain information that would permit an assessment of gross environmental changes, should any occur during the life of the project.

METHODOLOGY

FIELD METHODS

Surficial sediment samples were collected twice during the seventh monitoring year, on November 3, 1987, and on April 12, 1988. Twenty-nine stations were occupied during each cruise. A new station (28), selected to coincide with Benthic Station XIF5297, was added to monitor any effects of discharging from spillway no. 1. Although station 21B is located near the spillway, penetration of the sandy bottom there is frequently difficult. Also, trace metals have a lesser affinity for sandy sediments than for muddy ones and so would be less likely to accumulate at station 21B.

Sampling sites, shown in Figure 1-1, were located in the field by means of the LORAN-C navigational system. (LORAN-C coordinates, latitude and longitude of each station may be found in the Seventh Year Data Report.) The repeatability of LORAN-C navigation, that is, the ability to return to a location at which a navigation fix has previously been obtained, is affected primarily by seasonal and weather-related changes along the signal transmission path. Data recorded in 1982 from the U.S. Coast Guard Harbor Monitor at

Yorktown, Virginia provide an approximate range of repeatable error. That year variations in the X-lines amounted to 0.256 units and, in the Y-lines, 0.521 units. In the central Chesapeake Bay, one X-TD unit equals approximately 285 m (312 yd) and one Y-TD unit, 156 m (171 yd). Thus, when a vessel reoccupies an established station in the Bay region, it should be within about 100 m (109 yd) of its original location (Halka, 1987).

Undisturbed samples of the upper 8-10 cm of the sediments were obtained with a dip-galvanized Peterson sampler. At least one grab sample was collected at each station and subsampled for textural and trace metal analyses. At eight stations (3, 19, 21B, 23, 24, 28, BC-3, and BC-6), a second grab sample was taken for organic contaminant analysis. At five stations (11, 24, 28, BC-3, and BC-6), triplicate grab samples were collected.

Sediment and trace metal subsamples were taken below the flocculent layer and away from the sides of the sampler to avoid possible contamination by the grab sampler. They were collected using plastic scoops rinsed with distilled water and placed in 18-oz "Whirl-Pak" bags. Samples designated for textural analysis were stored out of direct sunlight at ambient temperatures. Those intended for trace metal analysis were refrigerated and maintained at 4°C until processing.

Subsamples for organics analysis were collected with an aluminum scoop (also rinsed with distilled water), placed in pre-treated glass jars, and immediately refrigerated. They were delivered to the Maryland Environmental Service (MES) at the end of the sampling day and later transferred to Martel Laboratory Services, Inc. for analysis.

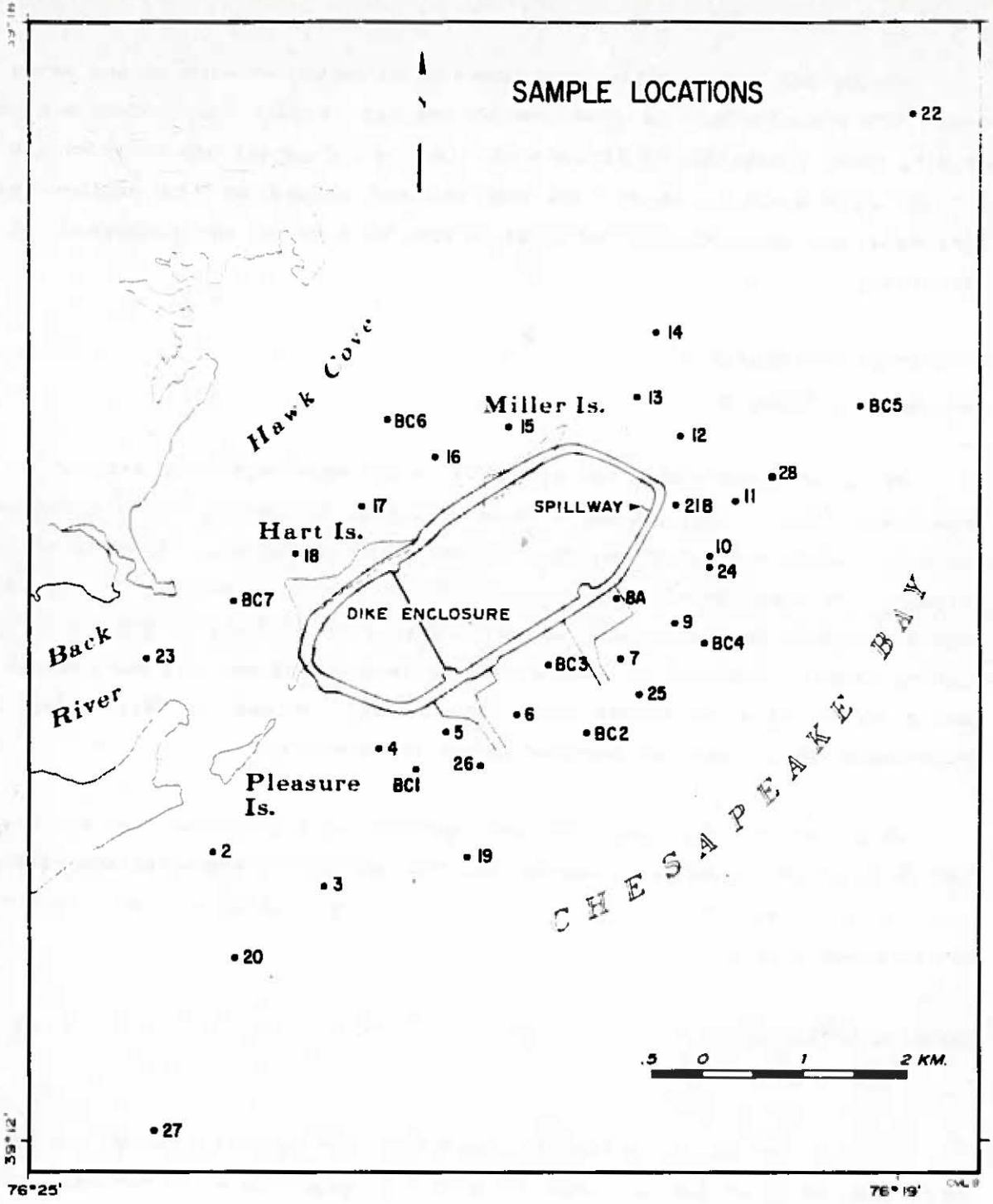

Figure 1-1: **Hart-Miller Island Containment Facility and vicinity showing locations of the surficial sediment and core stations sampled during the seventh year of exterior monitoring.**

During the April cruise, one core was collected at each of the seven box core (BC) stations and at stations 12 and 21B (Figure 1-1) using a Benthos gravity corer (Model #2171) fitted with clean cellulose acetate butyrate liners, 6.7 cm in diameter. Each core was cut and capped at the sediment-water interface and refrigerated until it could be x-rayed and processed in the laboratory.

LABORATORY PROCEDURES

Radiographic Technique

Prior to processing, the upper 50 cm of each core were x-rayed at the Department of Radiology, Johns Hopkins Hospital, Baltimore, using a CTR kv x-ray unit (x-ray settings: 60 kV, 400 mA, 40-cm distance). A negative x-ray image of the core was obtained by xeroradiographic processing. On a negative xeroradiograph, denser objects or materials, such as sand or shells, produce lighter images. Objects of lesser density (e.g., burrows, gas bubbles) permit easier penetration of x-rays and, consequently, appear as darker features. Photographs of the xeroradiographs appear in Appendix A.

Each core was then extruded, photographed, and described (see the Seventh Year Data Report). Sediment samples for textural and trace metal analyses were taken at selected intervals from each core, on the basis of radiographic and visual observations.

Textural Analysis

In the laboratory, subsamples from both the surficial grabs and gravity cores were analyzed for (1) water content, (2) sand-silt-clay content, and (3) organic and carbonate content.

Water content was calculated as the percentage of the water weight to the total weight of the wet sediment:

$$Wc = \frac{Ww}{Wt} \times 100$$

where Wc = water content (%)

Ww = weight of water (g)

Wt = weight of wet sediment (g).

Water weight was determined by weighing approximately 25 g of the wet sample, drying the sediment at 65°C, and reweighing it. The difference between total wet weight (Wt) and dry weight equals water weight (Ww). Bulk density was also determined from water content measurements.

The relative proportions of sand, silt, and clay were determined using the sedimentological procedures described by Kerhin et al. (1988). The sediment samples were pre-treated with hydrochloric acid and hydrogen peroxide to remove carbonate and organic matter, respectively. Then the samples were wet sieved through a 62-μm mesh to separate the sand from the mud (silt and clay) fraction. The finer fraction was analyzed using the pipette method to determine the silt and clay components (Blatt et al., 1980). Each fraction was weighed; percent sand, silt, and clay were determined; and the sediments were categorized according to Shepard's (1954) classification (Figure 1-2). Organic plus carbonate content was approximated by the percent weight loss due to sample preparation (i.e., pre-treatment with acid and peroxide).

Trace Metal Analysis

Sediment solids were analyzed for six trace metals - iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), and nickel (Ni) - using a lithium metaborate fusion technique, followed by standard flame (Fe, Mn, Zn) or furnace (Cr, Cu, Ni) atomic absorption spectrophotometry. This procedure, based on methods developed by Suhr and Ingamells (1966) for whole rock analysis, was refined specifically for the analysis of Chesapeake Bay sediments (Sinex et al., 1980; Sinex and Helz, 1981; Cantillo, 1982).

The MGS laboratory followed the steps below in handling and preparing the trace metal samples:

1. Samples were homogenized in the "Whirl-Pak" bags in which they were stored and refrigerated (4°C).

2. Approximately 10 g of wet sample were drawn into a modified "Leur-Loc" syringe fitted with a 1.25 mm polyethylene screen, used to remove shell material and large pieces of detritus.

3. Sieved samples were disaggregated in high-purity water and dried at 110°C overnight in teflon evaporating dishes.

4. Dried samples were then hand ground with an agate mortar and pestle and stored in "Whirl-Pak" bags.

5. Samples were weighed (0.2 ± 0.0002 g) into a drill-point graphite crucible (7.8 cc vol.) and mixed with $LiBO_2$ (1.0 ± 0.01 g).

6. The crucibles were placed in a highly regulated muffle furnace at 1050 ± 5°C for 30 min.

7. The molten beads produced by heating were poured directly into teflon beakers containing 100 ml of a solution composed of 4% HNO_3, 1000 ppm La (from $La(NO_3)_3$, and 2000 ppm Cs (from $CsNO_3$), and stirred for 10 min. If dissolution did not occur within 30 min., the solution and bead were discarded and the sample was re-fused.

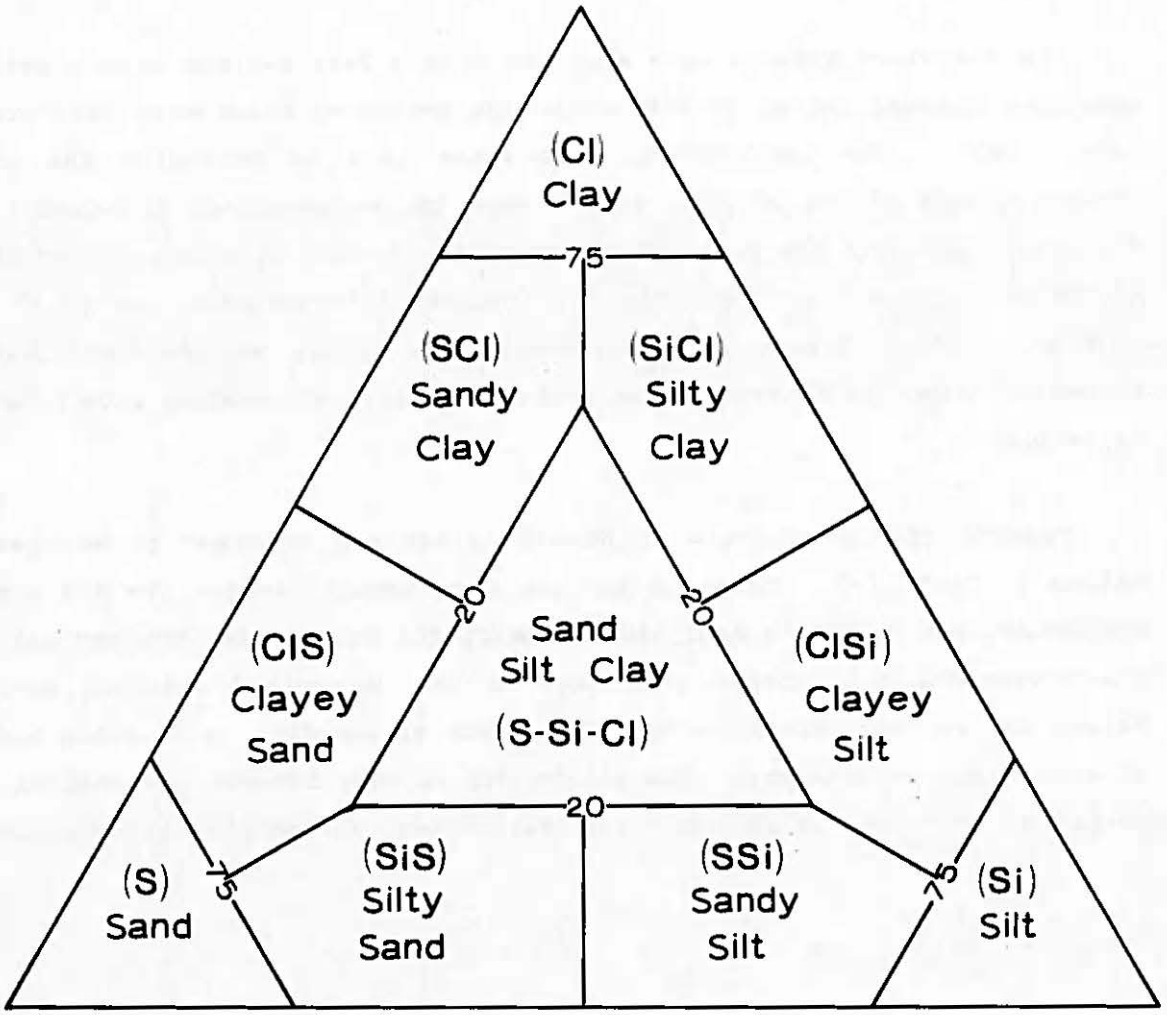

Figure 1-2: Shepard's (1954) classification of sediment type.

8. The dissolved samples were transferred to polyethylene bottles and stored for analysis.

All surfaces that came in contact with the samples were acid washed (3 days 1:1 HNO_3; 3 days 1:1 HCl), rinsed six times in high purity water (less than 5 mega-ohms), and stored in high-purity water until use.

The dissolved samples were analyzed with a Perkin-Elmer atomic absorption spectrophotometer (Model #3030B) using the method of bracketing standards (Van Loon, 1980). The instrumental parameters used to determine the solution concentrations of Cr, Ni, Zn, and Cu were the recommended, standard F.A.A.S. conditions given in the Perkin-Elmer manuals. Fe and Mn were analyzed using an acetylene-nitrous flame in order to eliminate interferences due to Al and Si (Butler, 1975). Blanks were run every 12 samples, and National Bureau of Standards Reference Material #1646 (Estuarine Sediment) was run five times every 24 samples.

Results of the analysis of NBS-SRM #1646 are compared to NBS certified values in Table 1-1. There is excellent agreement between the NBS certified concentrations and MGS's analytical results for Cr, Cu, Fe, Mn, and Ni; all of these elements fall within the range of the determined standard deviation. Values for Zn, consistent for all three sets of samples, fall within the range of analytical uncertainty. The slight discrepancy between the analytical and certified Zn values is thought to be due to loss during the fusion process.

Table 1-1: RESULTS OF THE MGS ANALYSIS OF NBS-SRM #1646 COMPARED TO THE CERTIFIED VALUES.

Element analyzed	NBS certified concentrations*	MGS results November 1987 surficials	April 1988 surficials	April 1988 cores
Cr	76±3	74±2	77±1	79±3
Cu	18±3	18±3	19±1	19±1
Fe	3.35±0.10%	3.25±0.02%	3.24±0.02%	3.24±0.02%
Mn	375±20	378±6	376±8	376±8
Ni	32±3	31±2	29±2	27±2
Zn	138±6	110±4	113±3	113±3

* concentrations in ug/g dry weight unless otherwise noted

RESULTS AND DISCUSSION

SEDIMENT DISTRIBUTION

Surficial Sediments

November 1987 (Cruise 17)

Sediment samples collected during the fall cruise were very similar texturally to those collected previously. A ternary diagram showing sediment type in November 1987 resembles the plot depicting samples in June 1983 (Cruise 8), immediately following completion of the dike (Fig. 1-3). Grain size composition ranges from very sandy (>95% sand) to very muddy (<1% sand). Sample points are scattered about a dashed line drawn from the "sand" apex to the opposite side of the triangle. Such lines represent constant clay:mud ratios (Pejrup, 1988), in this case, the mean clay:mud ratio for all samples collected during the cruise. The mean clay:mud ratio for cruise 8 is 0.51 and for cruise 17, 0.50 - on the average, half of the muddy fraction of the sediment consisted of clay. (In contrast, the mean pre-construction clay:mud ratio is 0.67 (Figure 1-3 a).)

Each of the ternary diagrams presented in Figure 1-3 summarizes the sand-silt-clay composition of bottom sediments at a particular point in time. The diagrams are especially useful in revealing widespread and radical changes in sedimentary environment, such as those that occurred during dike construction. Comparisons between these diagrams, however, should be made with caution. Because the stations themselves are not identified, the diagrams mask the variability at any one station over time. For an extreme example, the point representing station 12 is indicated on each of the diagrams in Figure 1-3. Sediments collected at this site have varied from sand to sand-silt-clay to silty clay. Without labels this behavior is not evident.

To detect possible localized effects of dike operation, the sediment composition at each station was examined over time. Box-and-whisker plots depicting the percentages of sand, silt, and clay at each station were constructed using data from cruises 8 through 18. A box-and-whisker diagram consists of a narrow box divided in two by a horizontal line (Fig. 1-4). The

dividing line represents the median value of the variable (e.g., % sand) at that station. The ends of the box are located at the 25th and 75th percentiles. "Whiskers" extend from the ends of the box to the nearest value lying beyond the box boundary. Extreme values, beyond 1.5 x the interquartile range, are plotted as separate points (Tukey, 1977).

Outliers associated with cruise 17 samples were identified at stations 12 and BC-3. The extreme sand value (18%) for station BC-3 is not particularly troublesome. Triplicate grab samples were collected at that location, and sand values for the other two replicates (8% and 14%) were typical for that site. In the field, no buoy was used to mark the sampling location. Boat drift during the retrieval of three samples could easily account for the differences in sand content.

At station 12, clay content increased dramatically at the expense of sand between April and November 1987. The station's proximity to spillways 1 and 3 suggests that suspended sediment discharged from the dike may have settled temporarily at the site, only to be resuspended and transported out of the area later. Geochemical data, however, do not corroborate that explanation. If the dike were the source of the fine-grained sediment deposited at station 12, then, theoretically, the enrichment factor for zinc would be either much higher or much lower than the regional average. However, at station 12, the enrichment factors for zinc have remained more or less constant since completion of the dike.

Another possibility is failure to reoccupy the same station during sampling. Variability in the LORAN-C signal over a one-year period translates into a possible maximum locational error of 100 m (see Methodology - Field Methods). In the Hart-Miller Island vicinity, sediment type varies considerably over short distances. A 100-m difference in sampling location could produce very different results. Stations 10 and 24, for example, are about 100 m apart. Since the first cruise,

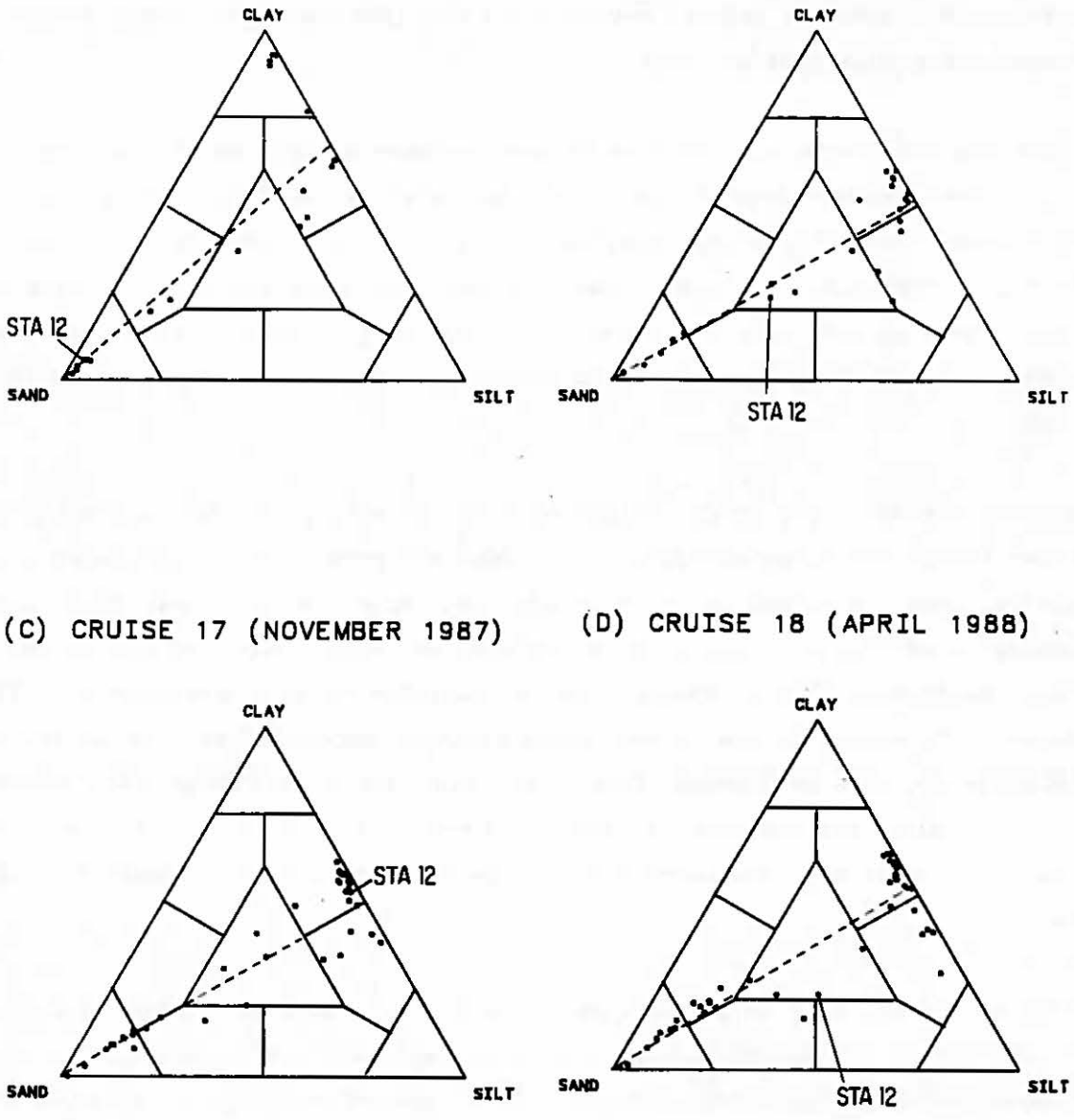

Figure 1-3: Ternary diagrams showing sediment type of samples collected in (A) August 1981 -Cruise 1, prior to the onset of dike construction, (B) June 1983 - Cruise 8, immediately following completion of the dike, (C) November 1987 - Cruise 17, and (D) April 1988 - Cruise 18.

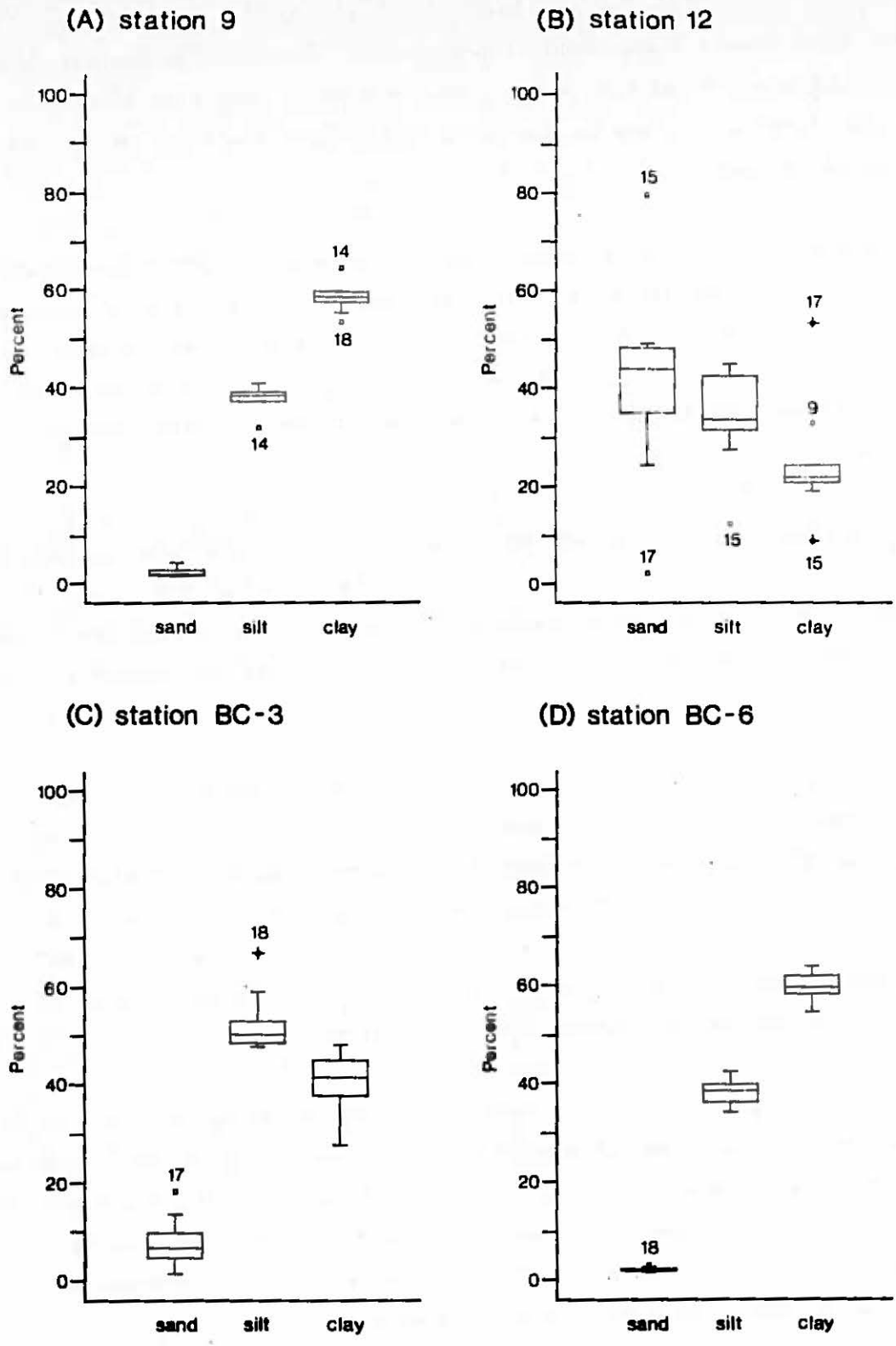

Figure 1-4: Box-and-whisker plots of percent sand, silt, and clay for stations with extreme values, based on data from cruises 8-18: (A) station 9, (B) station 12, (C) station BC-3, (D) station BC-6.

sands have always been found at station 10. However, sediments retrieved at station 24 have varied from sand to clayey sand to sand-silt-clay to silty clay, not just from one cruise to the next, but during the same cruise (triplicates are collected here).

Fortunately, an independent check can be made of LORAN coordinates during any one cruise. Station 2 is located between two closely-spaced channel markers south of Pleasure Island. The boat is always positioned between the markers when a sample is taken at that site. On cruise 17, the LORAN readings at station 2 were identical to the target coordinates. LORAN then was operating as expected.

At station 12, the LORAN readings recorded at the time of sampling were within 0.1 X-TD units (28 m) and 0.2 Y-TD units (31 m) of the target coordinates - quite close. It is still possible that variability in sediment type over a short distance accounts for the anomalous sample. It is, however, by no means certain.

Although we were unable to determine its exact cause, the change in grain size composition at station 12 was short-lived. By the following spring, the grain size distribution had reverted to a more typical sand-silt-clay (Figure B-4). Textural analysis of subsamples from a core collected at the site in April 1988 shows that the fine-grained sediments found in November 1988 were not preserved in the sediment column (Figure 1-5). The minimum sand content of the three splits nearest the sediment-water interface was 23%.

The areal distribution of sediment types in November 1987 is shown in Figure 1-6. The siltiest sediments (clay:mud ratio < 0.50) were, for the most part, collected at stations 4, 5, 8A, and BC-3, located within the zone of fluid mud accumulation. Coarser, i.e. sandier, sediments were concentrated around the northeastern tip of the dike. With a few exceptions, predominantly clayey sediments (% clay > 50%) were found elsewhere.

Compared to the preceding cruise (April 1986), sediment type changed at four stations (3, 5, 12, and 22). For the first time since monitoring began, silty sand was found at station 3. However, a Shepard's diagram of sediment

composition at that station shows that the sample is very similar texturally to others collected previously at the site (Figure B-1). The reclassification is due, not to a change in conditions affecting sediment deposition, but to the arbitrary subdivisions of Shepard's diagram. At station 5, sediment type characteristically alternates between silty clay and clayey silt (Figure B-2). Clayey sand recurs periodically at station 22 (Fig. B-6). The only real anomaly, station 12, was discussed earlier.

April 1988 (Cruise 18)

The physical features of bottom sediments outside the dike changed very little between the fall and spring cruises. Shepard's diagram of the sand-silt-clay composition of samples collected in April 1988 resembles both its June 1983 and November 1987 counterparts (Fig. 1-3). The average clay:mud ratio for the April 1988 samples is 0.52, compared with 0.50 for the November 1987 cruise.

Box-and-whisker plots reveal three stations (9, BC-3, and BC-6) with extreme percent sand, silt, or clay values (Fig. 1-4). None of these anomalies is significant. Clay content was comparatively low at station 9. Nonetheless, the sample falls within the silty clay category, along with all the other samples collected at that station since dike completion (Fig. B-3).

Percent silt (67%) was high for one of the BC-3 triplicates. Though not identified as an outlier in Figure 1-4, a second grab at that site also had a higher than usual silt content (59%). However, silt percentages of the third grab (51%) and of the top 4 cm of a gravity core retrieved at the same location two days later (55%) both lay within two standard deviations of the mean percent silt at BC-3. Despite these somewhat ambiguous results, the sediments at this station have remained clayey silts ever since the dike was constructed (Fig. B-10). Perhaps this is the beginning of a trend toward increasingly silty sediments. At this time, suggesting that dike operations may have been responsible for higher silt content at the site is unwarranted.

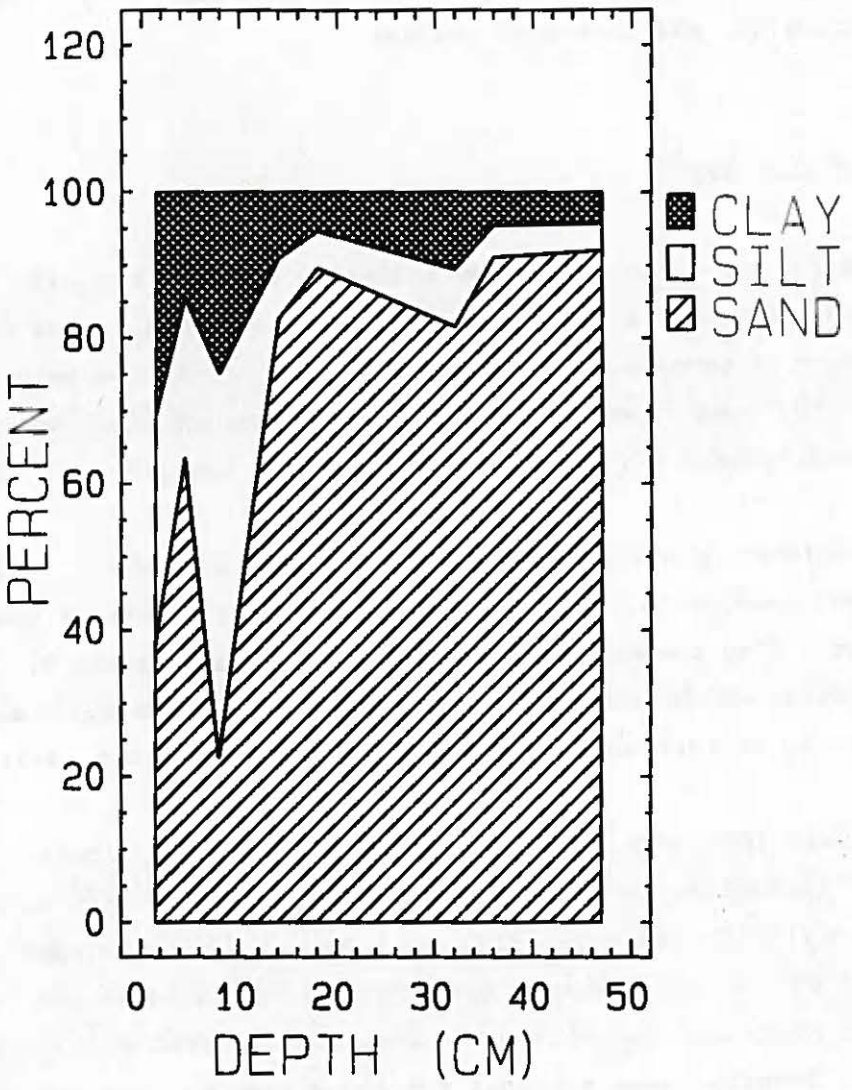

Figure 1-5: Component diagram showing down-hole variations in percent sand-silt-clay at station 12.

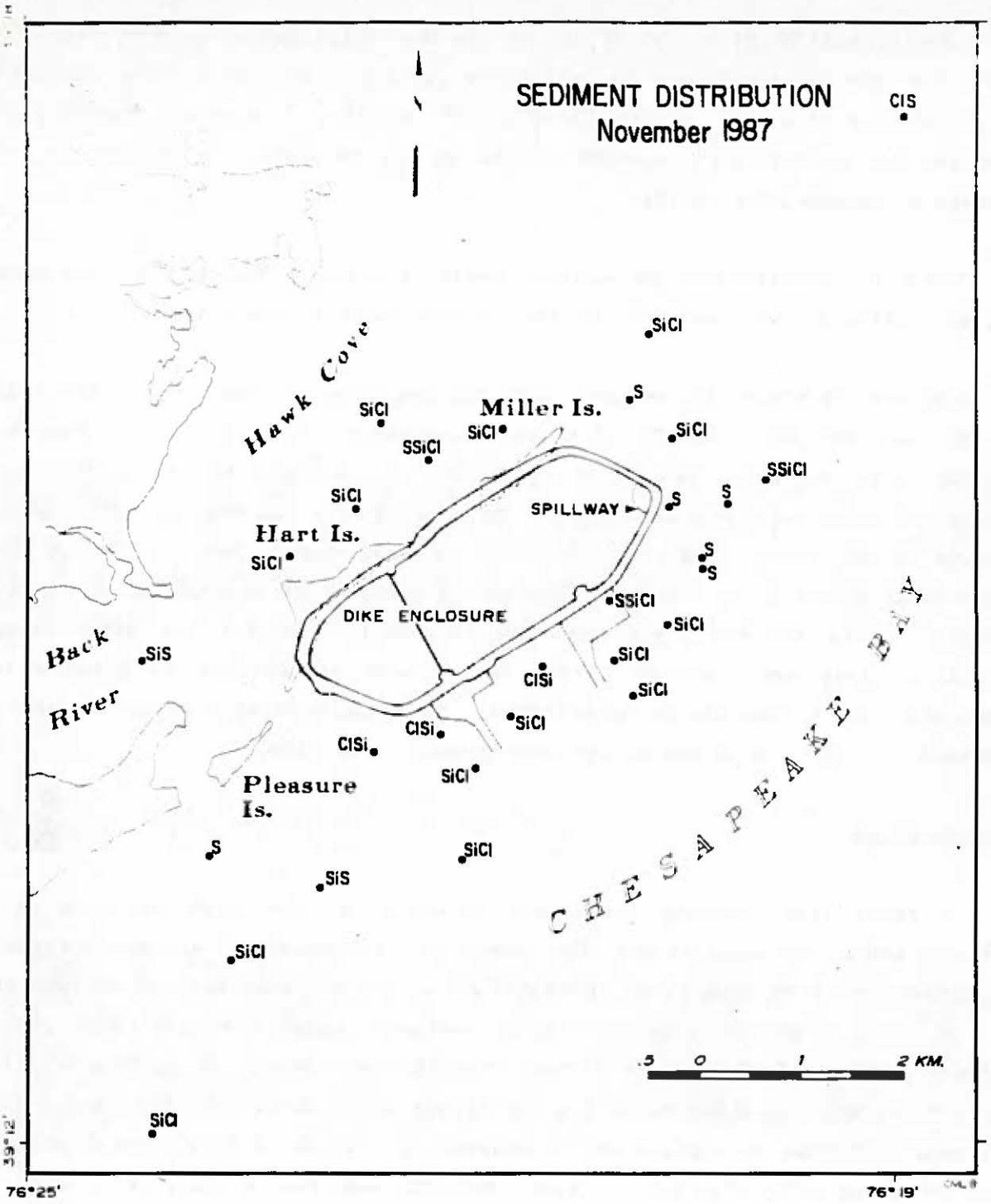

Figure 1-6: Map showing sediment type of surficial samples collected on November 3, 1987 (Cruise 17).

Lastly, sand content (3%) of one of the BC-6 triplicates was comparatively high. In fact, percent sand for all three replicates lay beyond two standard deviations of the mean percent sand (1.9%) at BC-6. However, the actual increase in sand content was so slight as to be almost imperceptible on Shepard's diagram (Fig. B-11).

The areal distribution of sediment types is shown in Figure 1-7. The same general patterns described for the fall cruise recur in the spring.

Compared to cruise 17, sediment type changed at seven stations (3, 12, 21B, 22, 23, 24, and 28). At all of these sites except station 28, the observed sediment type had occurred before (Appendix B). In fact, the classification changes at stations 3 and 12 represent returns to more typical sediment types. Station 28 was established at the start of this monitoring year. Although the grain size composition was very different from that determined for the fall samples, it is too early to speculate on the reasons for the difference. Several cruises are required before the natural variability in grain size composition at a site can be established. Sediment type at station 28, as at stations 3 or 22, for example, may vary greatly over time.

Gravity Cores

In April 1988, gravity cores were collected at the seven box core (BC) stations and at stations 12 and 21B. Based on a comparison of xeroradiographs, the cores were very similar to those collected the previous spring, indicating that no major changes have occurred in the sediment column during the past year. Cores collected at stations BC-2, BC-4, BC-5, and BC-6 consisted of dark grayish silty clays and contained surface shell layers (Figs. A-2, A-4, A-5, and A-6). The core collected at station BC-7 consisted of a layer of dark grayish clayey silt overlying silty clay and contained only isolated shells (Fig. A-7). Highly reticulated networks of burrows and tubes, indicative of high bioturbation levels, were present in all of these cores.

At stations BC-1 and BC-3, cores penetrated the fluid mud layer. Both cores consisted of an upper layer, approximately 20 cm thick, of finely laminated, brown to gray, smooth mud overlying a firmer, more darkly-colored

layer (Figs. A-1 and A-3). All of the subsamples analyzed from core BC-1 were categorized as silty clays. In core BC-3, the upper layer was siltier than the underlying one (clayey silt versus silty clay). The top 8-9 cm of both cores were disrupted or mixed by biogenic activity.

An eighth core was collected at station 21B, adjacent to spillway #1. The hard substrate precluded deep penetration - only 14 cm of sediment were retrieved, consisting of muddy fine sand and containing many *R. cuneata* shells (Fig. A-9). The ninth core, collected at station 12 in an effort to explain the sudden drop in sand content in the fall grab sample, was discussed earlier.

TRACE METALS

Six trace metals, expressed as enrichment factors, were analyzed as part of the ongoing effort to monitor the sedimentary environment surrounding the containment facility and to assess any operational effects. Enrichment factors have been used in lieu of actual elemental concentrations to facilitate the interpretation of changes from one sampling period to the next. An enrichment

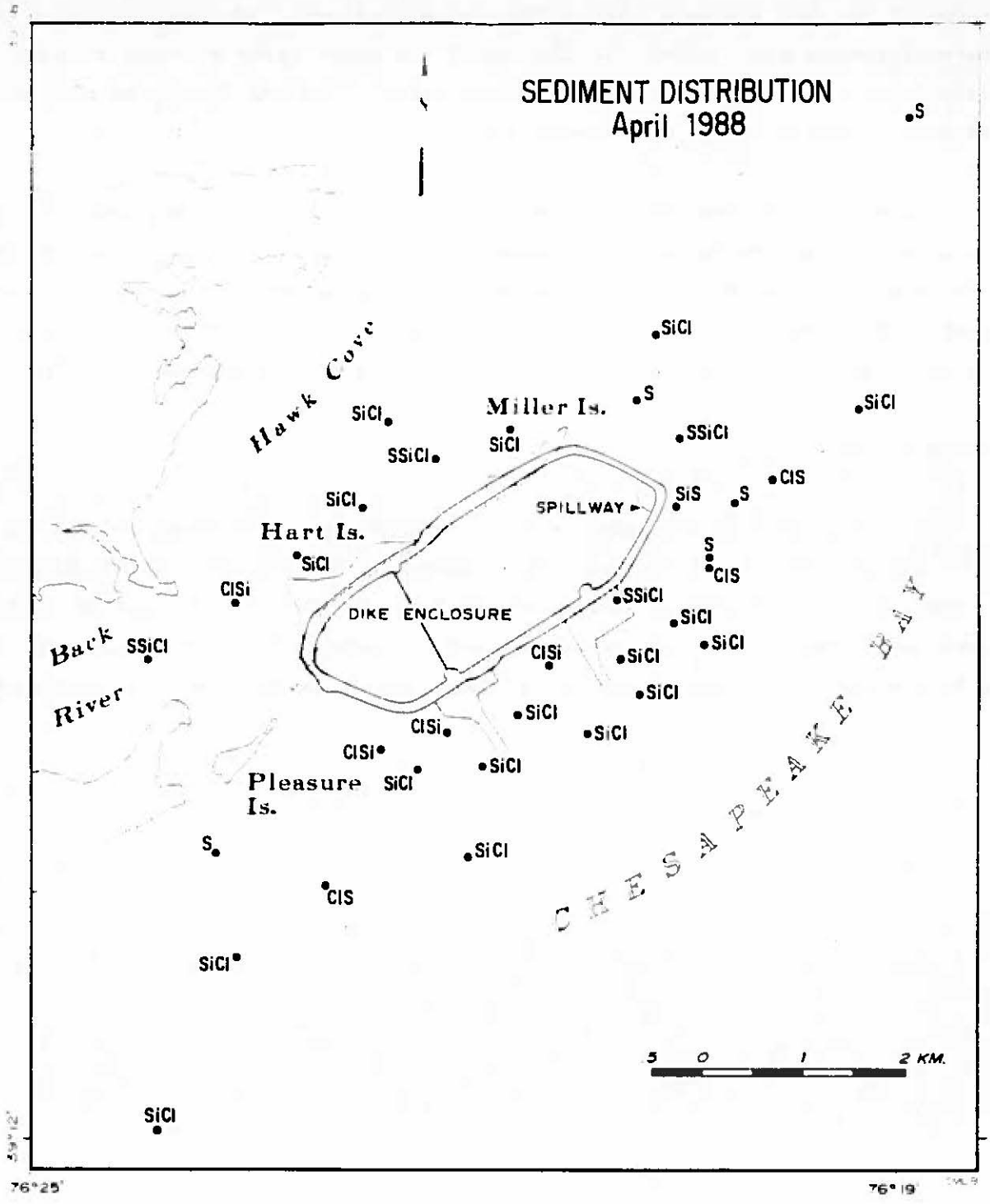

Figure 1-7: Map showing sediment type of surficial samples collected on April 12 and 14, 1988 (Cruise 18).

factor is defined as follows:

$$EF(X)\ ref = \frac{(X/Y)sample}{(X/Y)ref}$$

where X = the element of interest;

Y = an immobile element, such as Al or Fe, that is not affected by anthropogenic inputs;

(X/Y)sample = the analytically determined ratio of the concentration of X to Y in the sample; and

(X/Y)ref = the ratio of the concentration of X to Y in a reference material, such as an average rock type (Turekian and Wedepohl, 1961).

For the Hart-Miller Island samples, enrichment factors are based on Fe (=Y) and referenced to an average shale composition. Fe was analyzed in studies dating back to 1976 that monitored surficial sediments in the vicinity of Hart-Miller Island. Average shale was selected as the reference material because the composition of Bay sediments closely resembles that of shale.

Using enrichment factors rather than elemental concentrations is advantageous for several reasons:

1. Sample levels are normalized to a reference material. Therefore, enrichment factors are direct comparisons with a known material, in this case, "pristine" levels in the average shale.

2. The ratio of elemental concentrations acts as a check on the reliability of a set of analytical results and also permits comparisons of data sets obtained by different analytical techniques (Wells et al., 1986).

3. Differences in elemental concentrations due to grain size variations are minimized.

4. Variations in enrichment factors from the reference material indicate perturbation by natural processes and/or anthropogenic activity.

These characteristics make enrichment factors useful for examining spatial and temporal trends in trace metal levels in sediments.

The enrichment factor for Zn is used in the following discussion as an indicator of change in sediment chemistry. As elaborated in previous reports (Kerhin et al., 1982a; Wells et al., 1984), there are a number of reasons for focusing on Zn:

1. Of the chemical species measured, Zn has been the least influenced by variation in analytical technique. Since 1976, at least four different laboratories have been involved in monitoring the region around Hart-Miller Island. The most consistent results have been obtained for Zn (and Fe).

2. Variation in the Zn enrichment factor due to differences in reference material, i.e. sandstone versus shale, is small (less than 20%).

3. Zn is one of the few metals in the Bay that has been shown to be affected by anthropogenic input.

4. There is a significant down-Bay gradient in the Zn enrichment factor that can be used to detect the source of imported material.

5. Zn concentrations are highly correlated with other metals of environmental interest.

Figure 1-8 shows maps of the Zn enrichment factor for surficial samples collected in November 1987, April 1988, and, for comparison, April 1987. The sedimentary environment has remained stable for the past year. Broad, gentle contours, similar to pre-construction conditions, characterize all three sampling periods. There is no evidence of spillage or any other localized event that might have affected the sediment by producing a plume or hot spot.

Trace metal analysis of core subsamples yields information on the long-term net accumulation of sediment in the Hart-Miller Island vicinity, providing an historical record of change. Figure 1-9, a series of plots of the enrichment factor for Zn versus depth in the core, summarizes data collected during an eight-year period at the seven box core (BC) locations. Based on cores retrieved from the mainstem of the Bay and other unperturbed sedimentary environments, enrichment factors should be highest at the surface and decrease monotonically down-hole to the "pristine" value of 1, denoted in the diagrams by a dot-dash line. This expected down-hole behavior is exhibited by cores BC-2, BC-4, and BC-6. The scatter in these three plots results from (1) analytical uncertainty (approximately ± 1) due to methodological differences; (2) variability in sampling location; and (3) an imperfect knowledge of sedimentation rates - samples are plotted by depth in the core, not with reference to a distinctive event or time horizon.

Evidence of events that have affected the sedimentary environment around the island complex can be found in the four remaining cores. The most notable event, documented previously (Wells and Kerhin, 1985), was the redeposition of pre-Holocene sediments disturbed during dike construction. This material, referred to as "fluid mud", is free from the influence of anthropogenic inputs. Its enrichment factor, therefore, is near 1. From xeroradiographs and visual descriptions of the cores, the fluid mud layer is clearly distinguishable in cores BC-1 and BC-3. The depth to which this layer is observed in the April 1987 xeroradiographs is marked on the plots as a dashed horizontal line. Above this horizon, enrichment factors are generally lower than the areal average (3.36) and much closer to 1. Below the layer, enrichment factors decrease monotonically with depth to a value of 1, indicating that the observed horizon is probably the pre-deposition surface in both of these cores.

In BC-5, the horizontal line (at 8 cm) corresponds to the depth of Bay floor scouring apparent in the April 1987 xeroradiographs. The enrichment factors of sediments deposited above the scoured surface are low. On the basis of the expected monotonic down-hole trend, the pre-event surface occurs at about 15 cm. Between this horizon and the depth of scouring, there are two unexpectedly low samples. These points may be indicative of other episodes of

scouring/redeposition before cores were collected in April 1986, but neither the xeroradiographs nor the visual descriptions clearly indicate this.

BC-7 profiles are the most anomalous, showing the reverse of the expected trend; enrichment factors at the surface are relatively lower than those found at depth. Nonetheless, the enrichment factor of the surface sediment equals the area average. The sediments at this site probably reflect input from Back River. Approaching the surface from depth, the decreasing enrichment factors indicate either that the anthropogenic loading of Zn in Back River has declined over time or that the Bay has become increasingly important as a sediment source to the site.

Generally, the spatial distribution of the Zn enrichment factors through time and the down-hole profiles show neither leakage nor spillage of dredged materials. Trace metal behavior indicates that the sedimentary environment around the facility has been relatively stable since its construction.

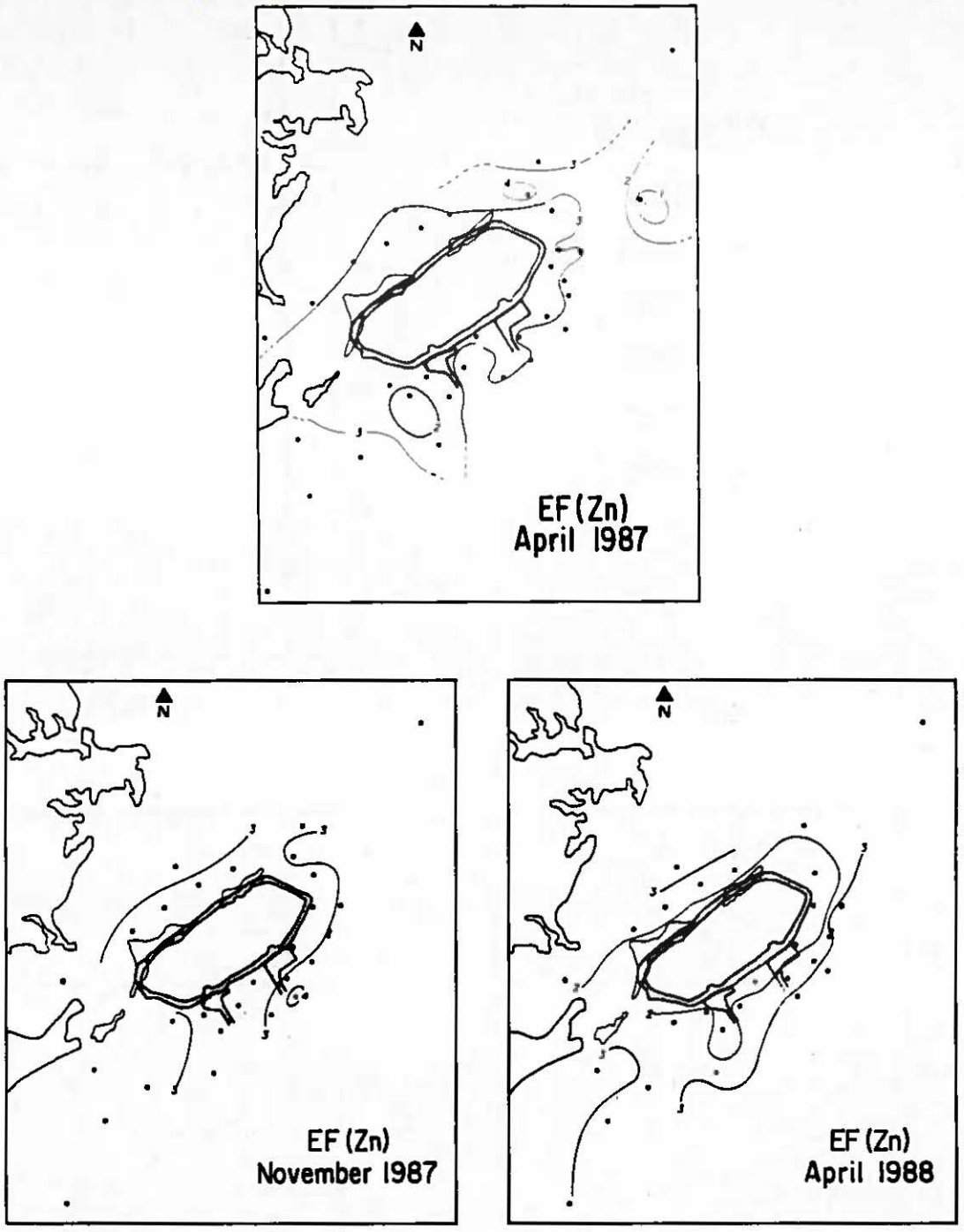

Figure 1-8: Contour maps depicting the spatial distribution of the enrichment factor for Zn, based on surficial sediments collected in (A) April 1987, (B) November 1987, and (C) April 1988.

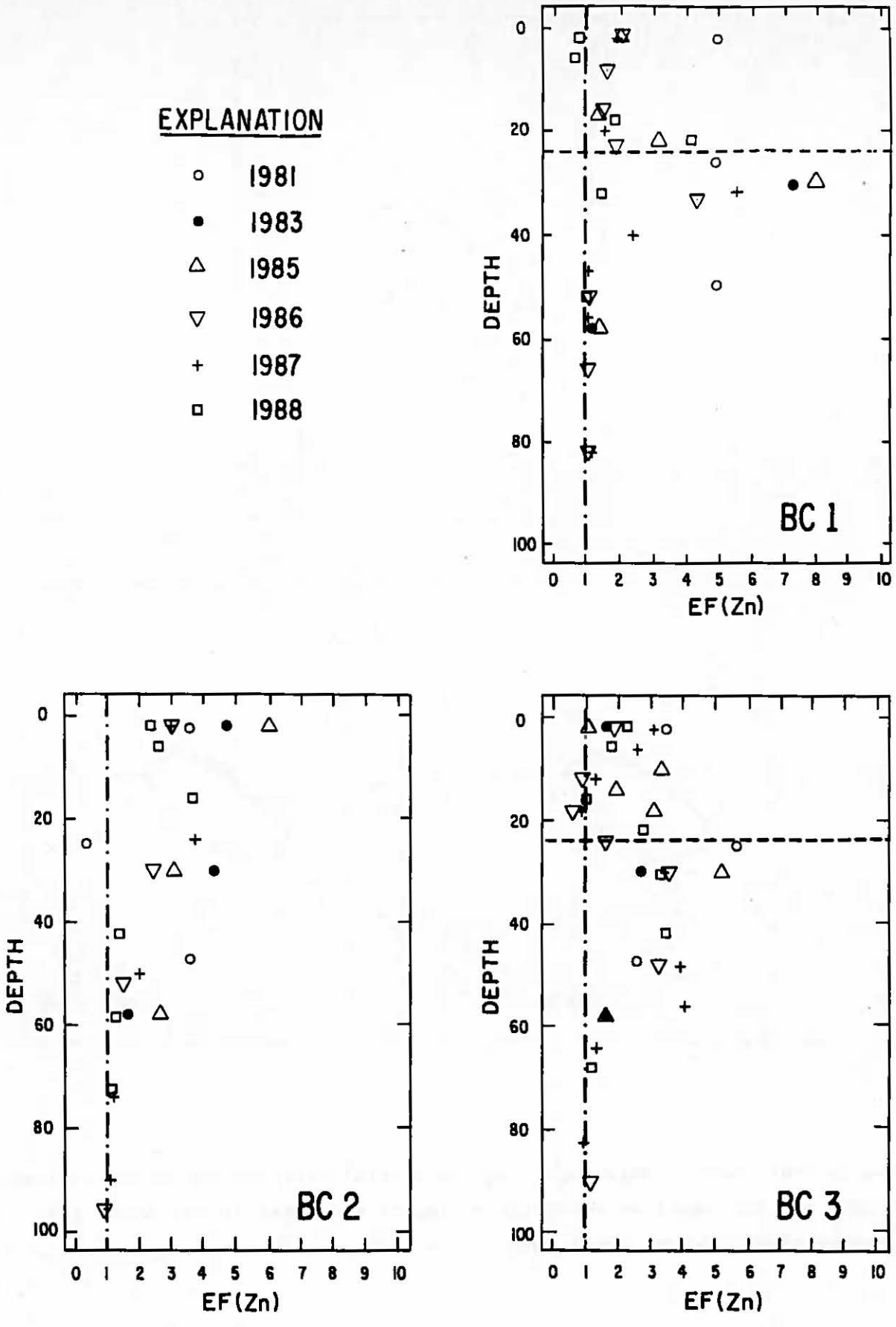

Figure 1-9: Down-hole variations in the enrichment factor for Zn, over time, for the seven box core (BC) stations.

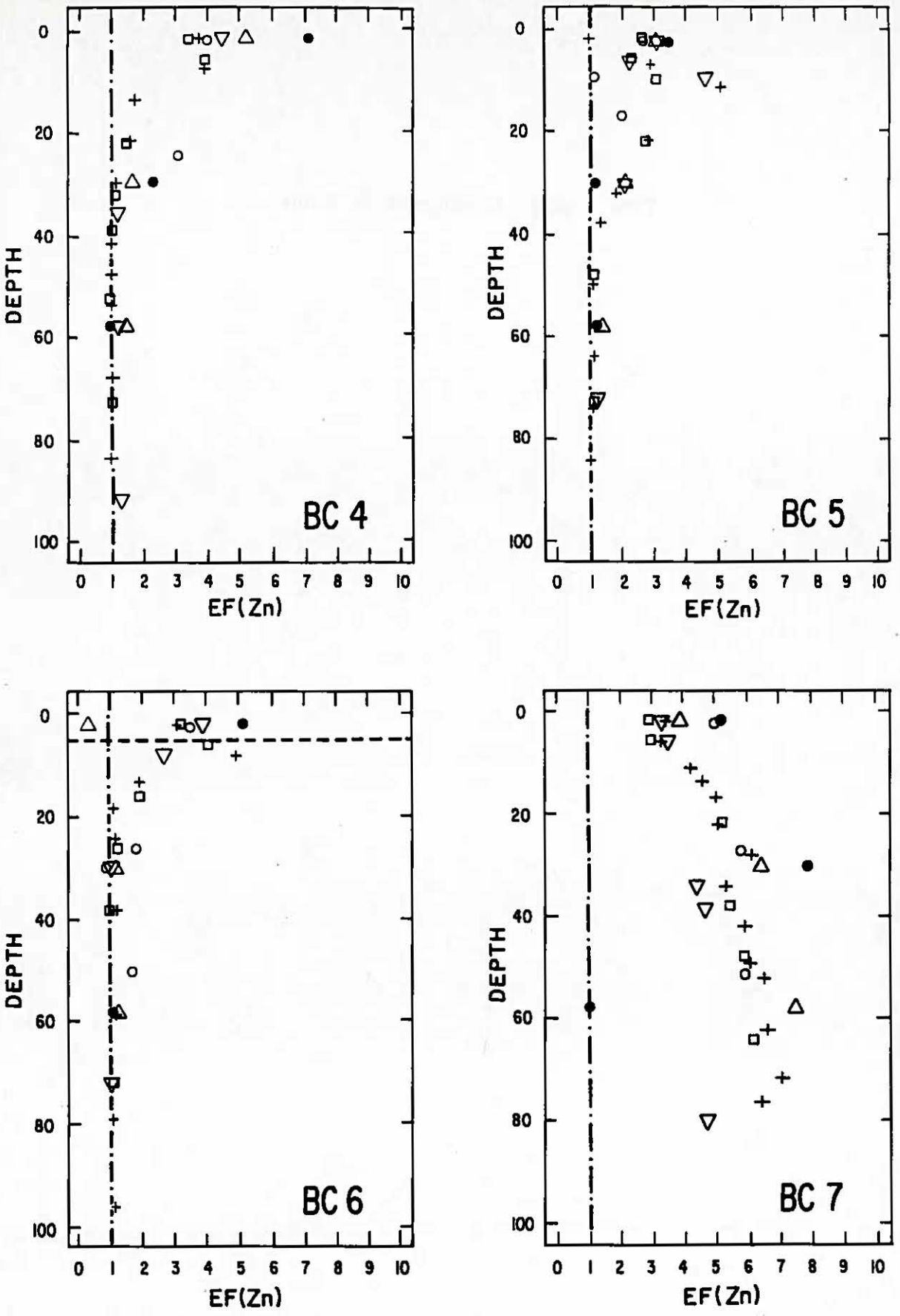

Figure 1-9 (cont.)

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CONCLUSIONS

During the seventh monitoring year, no significant changes were observed in the sedimentary environment surrounding the Hart-Miller Island Containment Facility.

Generally, the sediments around the facility remained siltier than pre-construction sediments (Fig. 1-3). The blanket of fluid mud was still very distinct after 6.5 years. Radiographic examination of the fluid mud layer revealed no increase in bioturbation levels compared with the sixth year. Reworking by benthic activity is largely restricted to the upper 10-15 cm.

The distribution and range of the enrichment factor for Zn in the exterior sediments were similar to those found previously. Average enrichment factors for the fluid mud remained lower than pre-construction values. However, slight increases in enrichment factors were observed in the bioturbated zone of the fluid mud layer, indicating that benthic activity contributed to the enrichment of sediments with that metal and, by association, others as well.

RECOMMENDATIONS

Monitoring of the sedimentary environment exterior to the Hart-Miller Island Containment Facility should be continued at its current level through at least 1990, the scheduled completion date of the 50 ft deepening of Baltimore Harbor and its approach channels. Usage of the facility will be maximal during the 50 ft Project, which is expected to generate another 14.2 mcy between May 1988 and September 1990. Settling and dewatering of the emplaced material will result in a large volume of effluent to be discharged from the dike. If operation of the facility produces any impact on the exterior environment, those effects should be evident during the next few years.

ACKNOWLEDGMENTS

We would like to thank our colleagues at MGS for their assistance, given willingly, during all phases of the project: Captain Jerry Cox and first mate Rick Younger of the R/V Discovery, for their expert seamanship and spirit of cooperation; Bob Conkwright, Bill Panageotou, June Park, and Darlene Wells, for braving the elements during sample collection; Bob Conkwright and June Park, for coaxing the lab equipment to produce results; Kathryn Koczot and Kirstie Jurus, for their careful analysis of sediment samples; Cindy Lang-Bachur, for drafting many of the figures; and Randy Kerhin, for his interest in the project's progress. In addition to MGS staff members, we extend our thanks to Gabby Donovan at the Johns Hopkins Hospital, who never hesitated to stay after hours to x-ray sediment cores.

PART 2: BEACH EROSION STUDY

INTRODUCTION

A recreational beach was created between Hart and Miller Islands during the early stages of construction of the containment facility. Approximately 500,000 yd^3 (382,500 m^3) of sediment were pumped from the dike interior to a section along the outer dike face bordering Hawk Cove. The original plans called for a 250-ft wide beach sloping gently bayward at a grade of 1:15 (gradient = 3.8°). The beach shoreline, parallel to the outline of the dike, was curvilinear - convex at the northern (Miller Island) end of the beach and concave at the southern (Hart Island) end.

Natural processes began modifying the beach almost immediately after its completion. Wave-cut escarpments formed, and sheet wash and gully erosion removed sediment from the dike face. The original outline changed. The northern shoreline receded. Some of the eroded sediments were carried southward and deposited, extending the southern end of the beach outward into Hawk Cove.

The Maryland Geological Survey was asked to monitor the beach and document the erosional and depositional changes occurring along it.

PREVIOUS WORK

Study of the recreational beach began in May 1984. Results of investigations during the first four years of monitoring are reported in Wells et al. (1985, 1986, 1987) and Hennessee et al. (1988). Based on the results of profile surveys, the beach was divided into three geomorphic regions affected by different natural and anthropogenic processes (Fig. 2-1): (1) the outer dike face, extending from the edge of the dike roadway bayward to the high water mark (wave-cut escarpment); (2) the foreshore, between the high water mark and mean low water (0' MLW); and (3) the nearshore, bayward of mean low water.

The outer dike face is affected primarily by pluvial (rain-related) processes and, to a lesser degree, by aeolian (wind-related) ones. Gullies, excavated by rainfall and runoff, are common along most of the beach. Annual regrading contributes to erosion of this zone by increasing the slope of the

dike face. Steeper slopes promote gully formation and lead to more severe erosion.

The foreshore is being modified by wind-generated wave activity. Waves, coupled with high tides, produce escarpments. Smoothing the beach by bulldozing erases the escarpments, but only temporarily.

The nearshore is affected by waves and longshore currents. Sediments eroded from the outer dike face and foreshore are deposited in the nearshore. Longshore currents, running parallel to the beach from north to south, redistribute nearshore sediments.

OBJECTIVES

This report is part of an ongoing study of the erosional and depositional features on and around the recreational beach between Hart and Miller Islands. Erosional problems identified in previous years are re-evaluated in terms of this year's findings. The objectives of this report are to:

1. analyze the beach configuration;

2. re-evaluate the erosional and depositional processes altering the beach; and

3. determine the volume of sediment eroded from the beach.

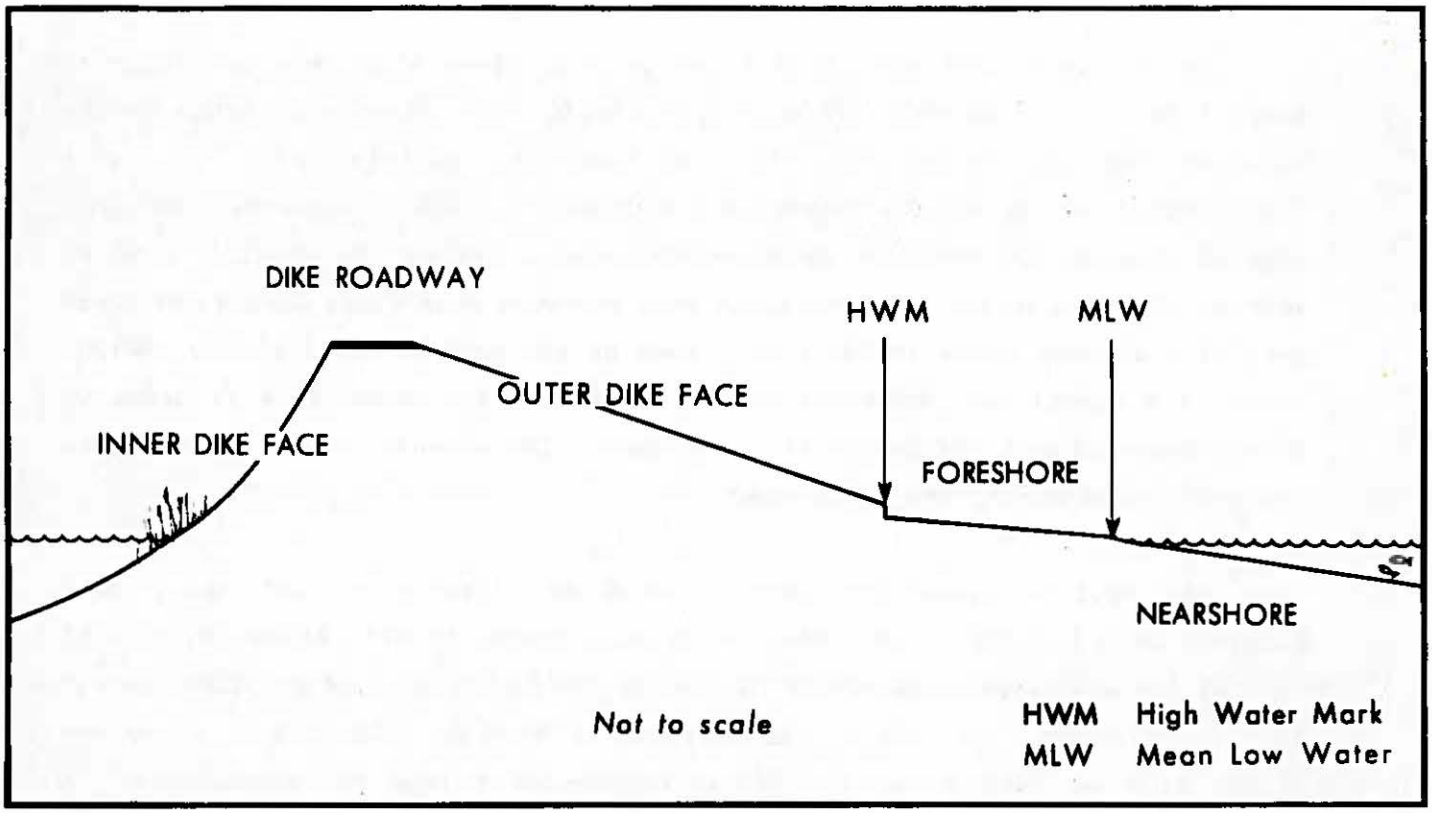


Figure 2-1: **Schematic cross-section of the dike illustrating the three geomorphic regions of the beach.**

This report covers the period between May 27, 1987 and May 12, 1988, the time interval between beach regrades. A reporting period that begins shortly after the May regrade and ends the following year, just before the next regrade, facilitates distinguishing the effects of natural versus anthropogenic processes.

METHODOLOGY

FIELD METHODS

In May 1984, MGS established ten profile lines along the recreational beach (Fig. 2-2). These lines roughly coincide with those established by the Waterway Improvement Division of the Tidewater Administration during a hydrographic survey of the beach in the summer of 1983. Construction of a comfort station in May/June 1988 necessitated shifting the profile line at station 22+00 to 21+75. The ten lines were surveyed four times during the fifth year of the beach study (Table 2-1). Four of the profile lines (22+00, 30+00, 40+00, and 49+00) were extended 300 ft bayward of the water line in order to detect depositional changes in the nearshore. The extended profile lines were surveyed twice during the study year.

All profile elevations were transferred directly or indirectly from Maryland Port Administration (MPA) bench mark number 281614 (elevation = 14.57 ft MLW), located approximately 22 ft east of the center line of the dike roadway at station 30+00. Initially, the location of each profile station along the center line of the dike roadway was referenced to the MPA bench mark. A baseline was established from the bench mark to the Craighill Channel Northern Range Light using a theodolite (Fig. 2-3). The angle between each profile station and the baseline was recorded. To ensure that the same profile line down the face of the beach was surveyed on successive occasions, an azimuth was chosen approximately perpendicular to the center line of the dike roadway. The point at which the profile line crossed the chain link fence that separates the beach and the dike roadway was painted orange. The angles between the baseline and the profile stations as well as the azimuths of the profile lines are reported in the Seventh Year Data Report.The construction of an elevated inner

dike made the MPA bench mark inaccessible. Prior to the raising of the dike, in May 1988, elevations were transferred from the bench mark to cemented pipes located next to the chain link fence at stations 25+36.45 (18.37 ft), 28+55.39 (18.29 ft), and 34+91.04 (18.00 ft) using a self-leveling level.

Standard surveying techniques, using a self-leveling level, stadia rod, and fiberglass measuring tape, were followed in surveying the profiles. Profiles were measured from the center line of the dike roadway downslope in 50-ft increments and at distinct changes in elevation. The water line and elevations below mean low water were also recorded, as was the time at which the water line station was surveyed. Distance and elevation data from all six surveys are tabulated in the Seventh Year Data Report.

Sediment gains and losses were calculated directly from the distance/elevation pairs using a computer program, ISRP (Birkemeier, 1986). Also, the amount of sediment lost by gully erosion was approximated by measuring the length, width, and depth of each gully. The length was measured from the head of the gully downslope to the vicinity of the wave-cut escarpment. Width and depth were measured at the gully mouth. The following formula was used to estimate the volume of sediment eroded from each gully:

$$\text{Volume} = 2/3L^3 \; (\tfrac{1}{2}W/L) \; (D/L)$$

where W = width,
L = length, and
D = depth.

Ground truth photographs were taken to substantiate profile measurements and to document erosional and depositional features present on the beach. The photographs were taken at each profile, facing upslope from beyond the water line. They were also taken facing north and south from selected sites along the beach.. Aerial photographs were taken after each profiling period to record overall changes in shoreline configuration, escarpment and gully development, and vegetation patterns.

Table 2-1: Beach profile survey dates.

Pro-file	1	2	3	4	Extended survey 1	Extended survey 2
22+00	6/16/87	9/23/87	12/7/87	5/11/88	7/8/87	6/7/88
24+00	6/16/87	9/23/87	12/7/87	5/11/88		
28+00	6/16/87	9/23/87	12/7/87	5/11/88		
30+00	6/16/87	9/23/87	12/7/87	5/11/88	7/8/87	6/7/88
32+00	6/16/87	9/23/87	12/7/87	5/12/88		
36+00	6/16/87	9/23/87	12/7/87	5/12/88		
40+00	6/17/87	9/23/87	12/7/87	5/12/88	7/10/87	6/10/88
44+00	6/17/87	9/25/87	12/8/87	5/12/88		
48+00	6/17/87	9/25/87	12/8/87	5/12/88		
49+00	6/17/87	9/25/87	12/8/87	5/12/88	7/10/87	6/10/88

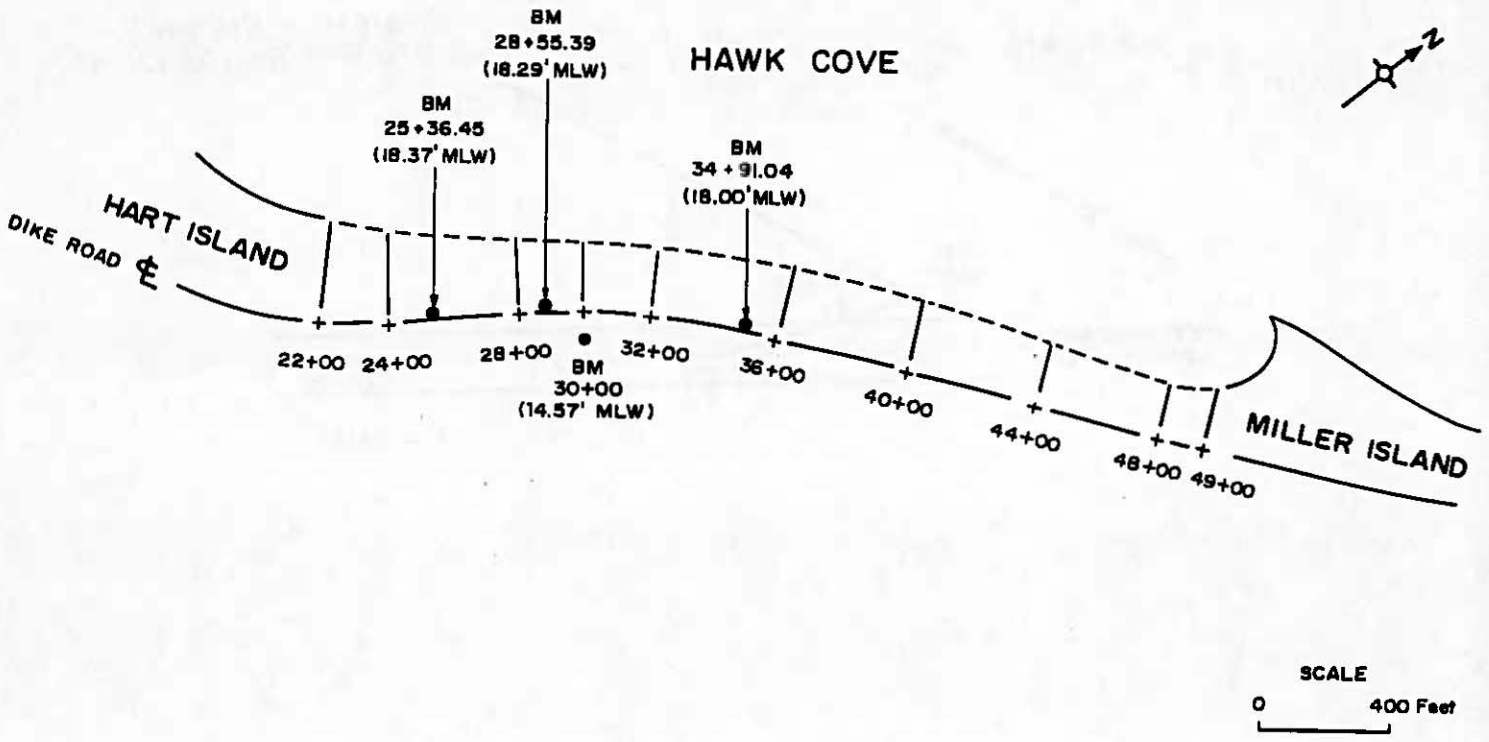


Figure 2-2: Locations of profile lines along the recreational beach between Hart and Miller Islands.

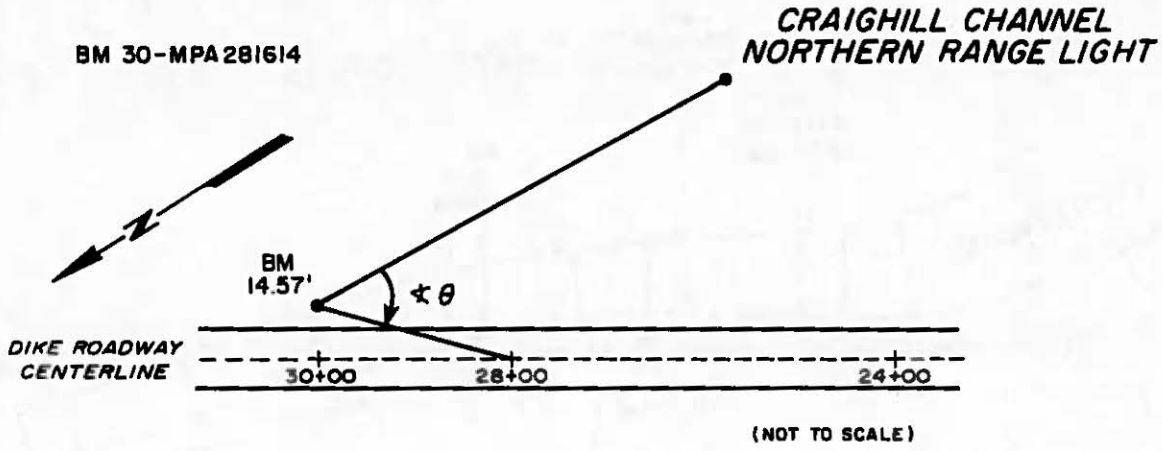


Figure 2-3: Established baseline.

Beach sediments were sampled during the June 1987 and May 1988 surveys in order to determine their natural size distribution. Samples were collected with a plastic scoop at stadia stations along each profile. They were stored at ambient temperatures in "Whirl-Pak" bags and brought back to the MGS laboratory for analysis.

LABORATORY PROCEDURES

Beach sediment samples were processed using methods similar to those described in Part 1 of this report (see Laboratory Procedures - Textural Analysis). The Seventh Year Data Report lists the calculated percentages of gravel, sand, and mud (silt and clay). Silt and clay were combined and presented as a single percentage because of their negligible contribution to beach sediment composition.

RESULTS AND DISCUSSION

To determine the overall changes in beach configuration and beach and nearshore topography, contour maps (Appendix C) and three sets of cross-sectional profiles (Appendix D) were constructed from the acquired survey data. The first set of cross-sectional profiles, depicting the beach during the surveys included in this report, represents the elevational changes between regrades brought about by natural processes. The second set compares the first beach survey (June 1984) with the last reported one (May 1988). The third set illustrates the differences in nearshore elevations at stations 22+00, 30+00, 40+00, and 49+00 for the period June 1987 to July 1988.

The overall shape of the recreational beach, delineated by the 0' contour, was curvilinear throughout the study period, convex near the end of profile 36+00 and concave to either side, at profiles 30+00 and 48+00 (Figs. C-1 through C-4). The 0' contour shifted both laterally and normally to the beach during the year.

Erosion and deposition along the foreshore was inferred from the migration of the 0' contour. Between June and September 1987, the 0' contour remained stationary from profile 44+00 through 49+00. The contour's bayward shift from profile 22+00 through 44+00 is indicative of slight deposition in the foreshore. The deposited sediments were probably reworked sediments from the nearshore zone. Sheet wash erosion of the outer dike face may also have contributed to the shift. Or, the shift may represent an initial adjustment to regrading of the beach.

Between December 1987 and May 1988, the 0' contour moved slightly bayward between 22+00 and 34+50, slightly shoreward between 34+50 and 36+00, bayward from 36+00 to 44+00, and slightly bayward between 48+00 and 49+00. The position of the shoreline remained unchanged between 44+00 and 48+00. The net effect indicated by the change in shoreline configuration was deposition, possibly due to the tremendous amount of material eroded from the lower dike face and foreshore by sheet wash and wave attack.

Comparing the June 1987 and May 1988 contour maps (Figs. C-1 and C-4), the 0' contour shifted bayward between 22+00 and 31+50. Net deposition of sediments in the foreshore is attributed to longshore currents transporting sediments southward along the beach. The stretches of beach between 31+50 through 40+00 and 43+50 through 48+00 underwent erosion. The shoreline retreated, shifting a maximum of about 20 ft. Wave action removed sediments from the lower dike face and foreshore. Of particular interest are waves generated by winds blowing from the northwest. Such waves, striking perpendicular to the beach, would result in erosion of the shoreline with deposition along the flanks by longshore currents. The process may explain the concave shape of the beach here. The shoreline position north of 48+00 remained about the same for the entire year. This section of the beach is protected from the most damaging waves by Miller Pt., a spit off Miller Island.

The set of cross-sectional profiles constructed for the monitoring year (Figs. D-1 through D-10) indicate that the lower dike face and foreshore were the zones most susceptible to erosion and/or deposition. Sediment was deposited on the lower dike face and foreshore of profile 22+00. Erosion of the lower dike face and slight deposition on the bayward side of the foreshore

characterized profiles 24+00 through 30+00. The erosion is attributed to waves assaulting the beach at high tide. Deposition along the outer foreshore resulted from the redistribution of sediments from the lower dike face and the accumulation of other eroded sediments carried by longshore currents. The lower dike face and foreshore of profiles 32+00 through 49+00 were eroded by sheet wash and wave activity. The eroded sediments were reworked and redistributed in the nearshore. Some were transported down the beach to the profiles south of 32+00.

The second set of cross-sectional profiles (Figs. D-11 through D-20) was constructed to show the changes experienced by the beach since the inception of monitoring in May 1984. Along the lower dike face and foreshore, there was net deposition from profile 22+00 north to 24+00, and net erosion from 28+00 north to 49+00. Erosion is due primarily to wave attack and secondarily to sheet wash.

In order to determine the fate of sediments eroded from the lower dike face, profiles 22+00, 30+00, 40+00, and 49+00 were extended 300 ft offshore in July 1987 and June 1988. Cross-sectional profiles based on data accumulated during the extended profile surveys (Figs. D-21 through D-24) show net erosion in the nearshore area. Approximately 773 yd^3 (591 m^3) of sediment were eroded below 0' MLW. Although some sediment was deposited near the water line on profiles 22+00, 30+00, and 40+00, the remainder of each profile showed erosion out to 300 ft. The sediments lost from the nearshore were carried away by longshore currents.

ESCARPMENT FORMATION

Escarpments are erosional features produced when wind-generated waves accompanying high tides assault the beach. The most damaging waves to the recreational beach are those from northerly directions, due to the large generating area or fetch. A small escarpment (less than 6 in.) was evident during the first profile survey of the monitoring year (June 1987) from 32+00 north to 48+00. By September 1987, the small escarpment was present along the entire length of the beach. In December 1987, the escarpment was more prominent

from stations 28+00 to 32+00 and from 40+00 to 49+00. By the last profile survey in May 1988, the wave-cut escarpment extended from station 28+00 to well beyond station 49+00. The height of the escarpment rose steadily from several inches at station 28+00 to approximately 2 ft at 49+00.

Wind data recorded by the Maryland Environmental Service (MES) at a weather station located 1.6 km east of the recreational beach were used to construct wind roses for each survey period (Fig. 2-4). An increase in the frequency and velocity of northerly and northwesterly winds from September through December probably accounts for the increased prominence of the escarpment during that period. (No tidal data were available for the area to determine when high tide and wind-generated waves coincided.)

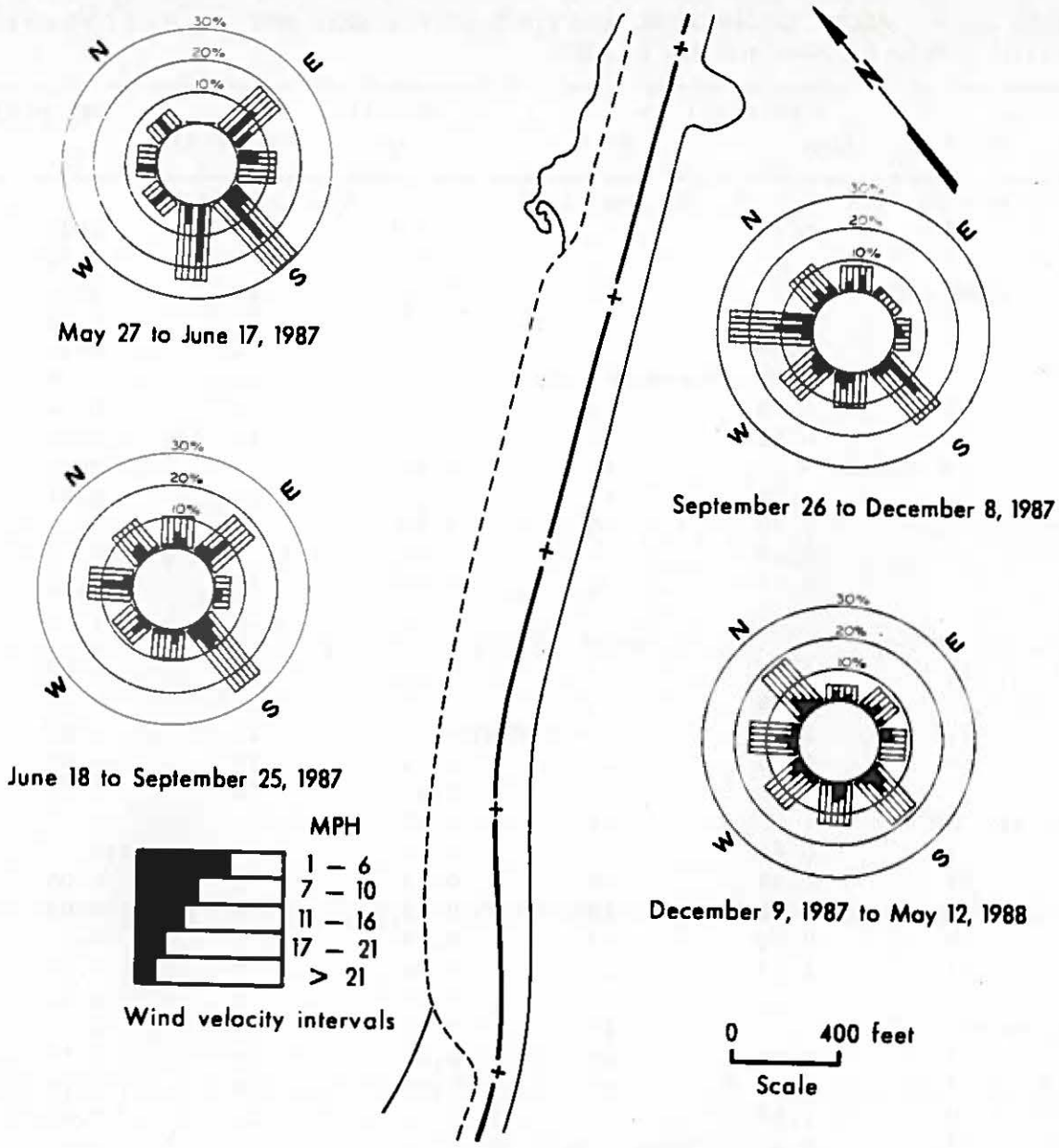
GULLY DEVELOPMENT

Gully development along the recreational beach is controlled primarily by rainfall intensity and gradient or slope. Rainfall intensity, the criterion used to define a "storm" (at least half an inch of rain in half an hour (Barnett and Hendrickson (1960)), could not be determined from the weather data collected at the containment facility. Only the amount of rain falling in a 24-hr period is recorded. Based solely on the amount of precipitation however, there were 30 storm events during the monitoring year (Table 2-2). A total of 37.65 in. of rain was reported. Storms accounted for 27.08 in. of that total, or 72 percent.

A minimum average slope of 4.1-4.2° is prerequisite to gully formation on the recreational beach (Wells et al., 1986, 1987). Throughout this reporting period, average slope equalled or

Table 2-2: PRECIPITATION DATA COLLECTED BY THE MARYLAND ENVIRONMENTAL SERVICE (MES) AT HART-MILLER ISLAND.

Date	Rainfall (in)	Date	Rainfall (in)	Date	Rainfall (in)
May 1987		October 1987		February 1988	
31	0.32	3	0.34	3	0.10
		7	0.54	4	0.40
June 1987		11	0.02	12	0.86
3	0.15	27	0.80	13	0.92
4	0.90			15	0.35
9	0.02	November 1987		16	0.09
12	0.25	10	0.70	19	0.66
13	0.02	11	0.25	23	0.07
--SURVEY--		12	0.20	27	0.03
21	0.15	18	0.05	28	0.01
22	0.70	28	0.29		
26	0.28	29	1.45	March 1988	
30	0.75	30	0.05	3	0.02
				4	0.75
July 1987		December 1987	9	0.05	
1	1.25	3	0.10	15	0.11
2	0.15	4	0.10	16	0.02
10	2.00	--SURVEY--		26	1.25
14	0.90	10	0.20	27	0.05
		11	0.31	28	0.05
August 1987		14	0.05		
5	0.40	15	0.60	April 1988	
22	0.42	20	0.32	1	0.03
26	0.01	22	0.15	6	0.03
28	0.01	23	0.05	7	0.60
31	1.05	25	0.36	8	0.22
		26	0.10	9	0.04
September 1987		28	0.20	15	0.10
6	0.50	29	0.05	18	0.30
7	0.60	31	0.05	19	0.03
8	1.50			23	0.03
12	0.80	January 1988		27	1.10
13	0.50	1	0.04	28	0.05
15	0.54	3	0.10	29	0.05
16	0.11	4	0.07		
17	0.37	7	0.20	May 1988	
18	2.10	8	0.55	3	0.03
19	0.11	14	0.20	4	0.03
20	0.04	17	0.46	5	1.00
22	0.15	25	0.42	6	0.55
25	0.10			9	0.04
--SURVEY--		February 1988			
				10	0.20
30	0.20	2	0.66	11	0.05



WIND CLIMATE: HART-MILLER ISLAND VICINITY

Figure 2-4: Wind roses for the Hart-Miller Island vicinity, based on data collected by the Maryland Environmental Service (MES) for the period between May 27, 1987 and May 12, 1988.

exceeded that critical value along all profiles except 22+00 and 24+00 (Table 2-3). Along the lower dike face, from the break in slope to the water line, slopes were so steep (range = 4.9° to 8.3°) that given sufficiently intense rainfall, gullying was inevitable.

During the monitoring period, incipient gullies were first observed in June 1987 in the vicinity of profiles 30+00, 44+00, 48+00, and 49+00. The gullies forming near profile 30+00 were shallow (< 2 in.); those forming around profiles 48+00 and 49+00 were considerably deeper (about 6-8 in.). Of the six rainfall events between the May 27, 1987 regrade and the first survey of the monitoring year, only one (0.90 in. of rain on June 4, 1987) contributed significantly to gully development. The steeper slope of the beach at 48+00 and 49+00 permitted deeper incision of the dike face by storm runoff.

The period between the first and second surveys marked the beginning of deeply incised gullies on profiles 28+00, 30+00, 32+00, 48+00, and 49+00. Gullies in the area of 48+00 and 49+00 were deepest (up to 1.8 ft). Between surveys, the average slopes of the affected profiles changed very little, if at all. None however, fell below the critical minimum slope of 4.1°. Thirteen storm events produced a total rainfall of 13.19 in. The maximum rainfall on a single day was 2.10 in. Although vegetation was abundant on the beach during this period, it was spotty in the areas of gully development.

By the December 1987 survey, gullies were observed on all profiles except 24+00 and 40+00. A small gully was beginning to form on profile 22+00. At the northern end of the beach, gullies were very deep (up to 2 ft). Some of the gullies extended to within 11 ft of the dike roadway. The average slope rose on all profiles except 32+00, 36+00, and 48+00, where it decreased slightly. Vegetation, which was abundant earlier in the year, was either dead or being washed away. Between the September and December surveys, four storms produced 3.49 in. of rain. Although less rain fell during this period than the preceding one, gully erosion accelerated because of the increase in slope, the lack of vegetation, and the presence of established gullies.

A greater number of gullies was observed during the May 1988 survey than had ever been noted before. Aerial photographs of the beach showed gullying along

the entire beach except in the vicinity of profiles 24+00 and 28+00. Gullies along profile 22+00 were very shallow (< 3 in. deep). However, in the vicinity of profiles 48+00 and 49+00, gullies reached a maximum depth of 2.4 ft. The headward extent of some of the gullies along the northern profiles was within 10 ft of the dike roadway. One small gully near profile 48+00 actually began at the edge of the roadway. Twelve storm events during the period produced a total rainfall of 9.5 in. The lack of vegetation caused much of the lower dike face to erode more quickly than it had during the previous profiling periods.

Gully erosion has accelerated since the beginning of beach monitoring. Although annual regrading temporarily erases the gullies, it increases the slope of the beach. As shown in Table 2-3, the average slopes of all of the profiles were higher in June 1987 than in June 1984. Without reducing the beach slope by replenishing the lost sand, each successive regrade increases the likelihood of gully development.

BEACH SEDIMENT DISTRIBUTION

To assess the natural distribution of sediment size, samples were collected in June 1987, after beach regrading, and in May 1988, before regrading. Summarizing the results of grain size analysis of the samples, Figures 2-7 through 2-10 depict the distribution patterns of silt and clay and of

Table 2-3: Average slope, in degrees, of beach profiles, from the roadway to the water line, by survey date.

	Survey date					
Profile	6/84	3/87	6/87	9/87	12/87	5/88
22+00	3.1	3.2	3.3	3.2	3.5	3.2
24+00	3.3	3.5	3.6	3.5	3.7	3.6
28+00	3.7	4.4	4.3	4.2	4.5	4.4
30+00	4.2	4.8	4.7	4.7	4.8	4.8
32+00	3.4	5.0	4.8	5.0	4.9	5.0
36+00	3.0	4.2	4.2	4.3	4.2	4.4
40+00	3.2	4.3	4.2	4.1	4.2	4.3
44+00	3.3	4.8	4.8	5.0	5.0	5.2
48+00	4.2	5.8	5.9	6.0	5.9	6.0
49+00	3.7	5.0	5.0	5.1	5.2	5.2

gravel. To illustrate the effects of beach regrading on grain size distribution, similar figures for the March 1987 sampling period are also included (Figs. 2-5 and 2-6).

The effects of beach regrading can be seen by comparing sediment distribution patterns in March 1987 and June 1987. Regrading resulted in a general decrease in the percentage of silt and clay over the entire beach, except for a small area around profile 30+00. Gravel percentages also changed, decreasing slightly for the beach south of profile 48+00.Between June 1987 and May 1988, natural processes were responsible for changes in sediment distribution patterns. The silt and clay content of samples collected from the central part of the beach, between profiles 30+00 and 44+00, increased. Vegetation growing on the beach had trapped fine, wind-blown sediment.

The distribution of gravel on the beach is controlled primarily by the use of poorly sorted material in beach construction and secondarily by annual bulldozing. Fluctuations in gravel percentages attributable to natural processes are due largely to the addition or removal of finer sediments. During the monitoring year, the relative proportion of gravel increased over the entire beach. The greatest increase, up to 64 percent, was seen along the foreshore north of profile 40+00. The removal of fine sediments by sheet wash and perhaps some transportation of gravel from upper elevations were responsible for the higher gravel percentages.

NET EROSION AND DEPOSITION

The volume of sediment lost from the beach this past monitoring year totalled 3,996 yd^3 (3,057 m^3), including an estimated 94 yd^3 (72 m^3) removed by gully erosion and 773 yd^3 (591 m^3) eroded from the nearshore. Since the inception of the beach erosion study (June 1984), approximately 11,244 yd^3 (8,602 m^3) of sediment have been lost from the beach. This is a conservative estimate, excluding gully and nearshore erosion.

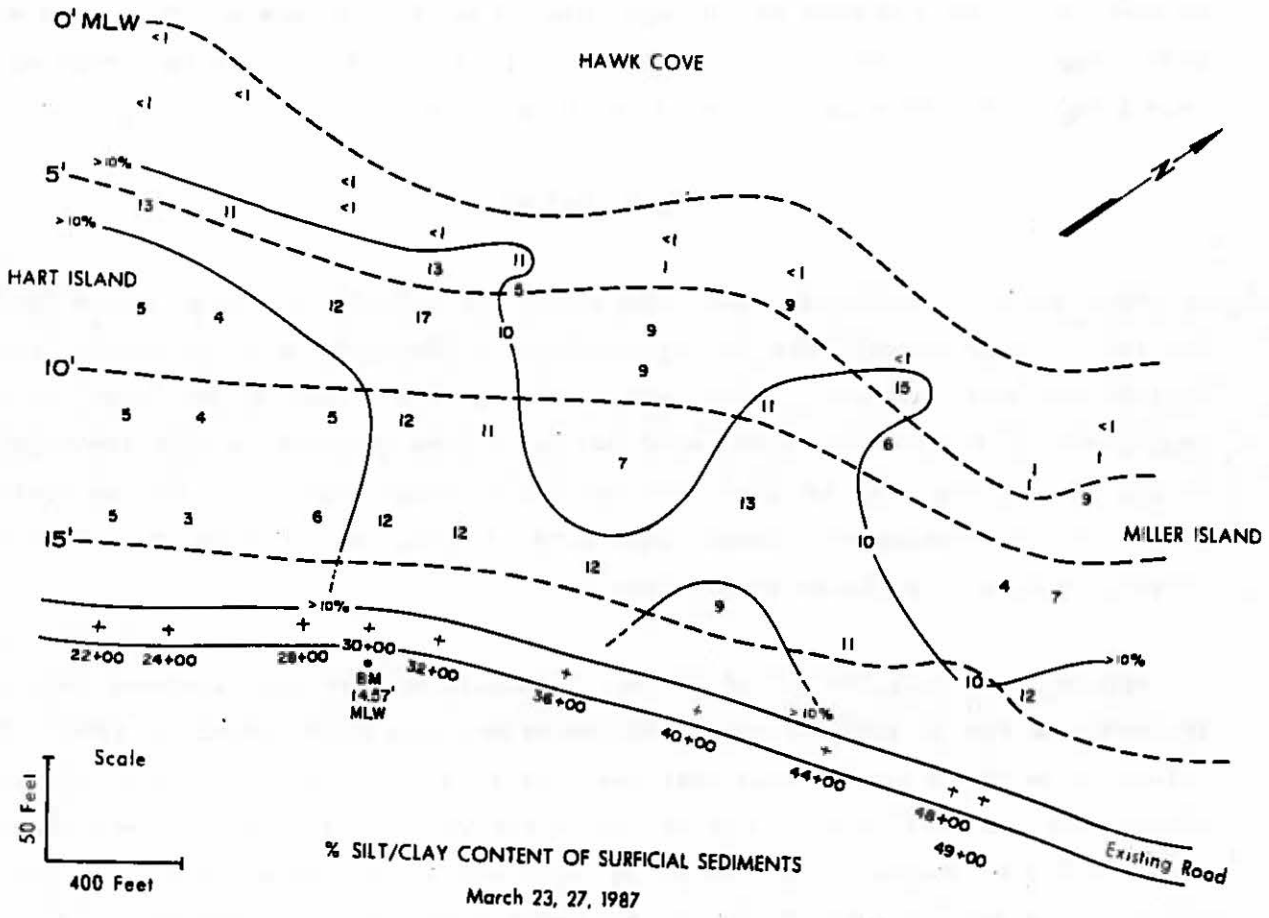
Net sediment loss was computed for the four monitoring periods between regrades (Table 2-4). Erosion escalated for the first three years of the beach erosion study, then subsided slightly. The increase in erosion rate during the

first three periods was attributed to steepening of the lower dike face by bulldozing. Sheet wash removed greater quantities of material from the steeper slopes. Also, waves were able to carve off larger sections of the lower dike face by undercutting. The amount of sediment lost during the past monitoring year is about the same as that eroded during the previous year. Average beach slopes were about the same at the beginning of both study years. Other elements affecting beach erosion (e.g., waves, tides, rainfall) were comparable, resulting in nearly equal volumes of sediment lost.

CONCLUSIONS

Wave activity and sheet wash, the two major natural processes operating on the beach, were responsible for the erosional features observed on the beach during the study period. Wave action during high tides eroded most of the sediment from the beach. Sheet wash during storms resulted in the development of gullies, which grew in depth and headward extent throughout the monitoring year. By steepening the lower dike face, bulldozing greatly amplified the effects of these two geomorphic processes.

Approximately 11,244 yd^3 (8,602 m^3) of sediment have been removed from the beach above the 0' contour since the beach erosion study began in 1984. The volume of sediment eroded this year was just slightly less than the amount lost during the previous year (3,129 yd^3 vs. 3,472 yd^3). Gully erosion was slight, 94 yd^3 (72 m^3), compared to erosion by wave action and sheet wash. Longshore currents removed 773 yd^3 (591 m^3) of material from the nearshore zone.



F-3

Figure 2-5: Map showing the distribution of silt and clay on the beach in March 1987 (before regrading).

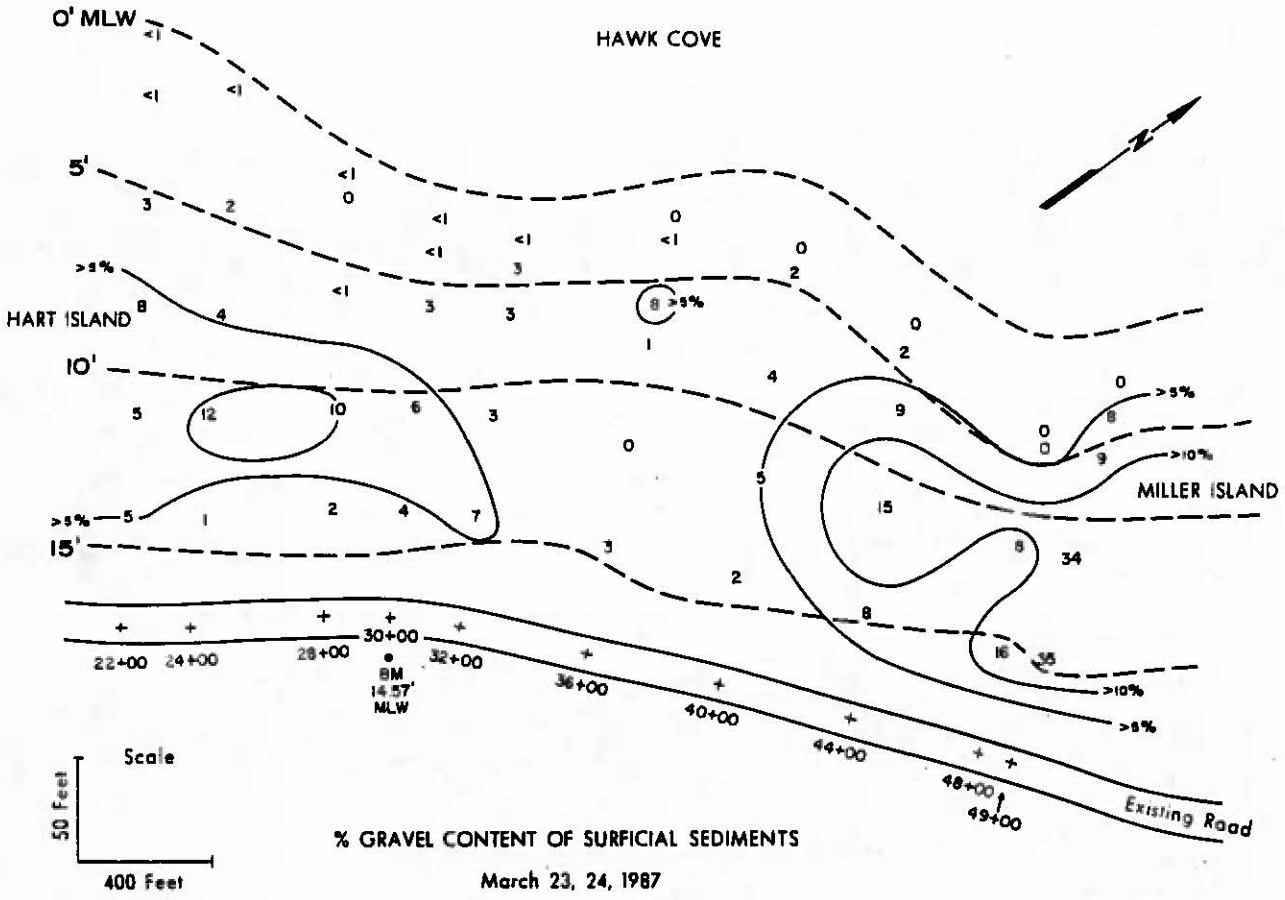


Figure 2-6: Map showing the distribution of gravel on the beach in March 1987 (before regrading).

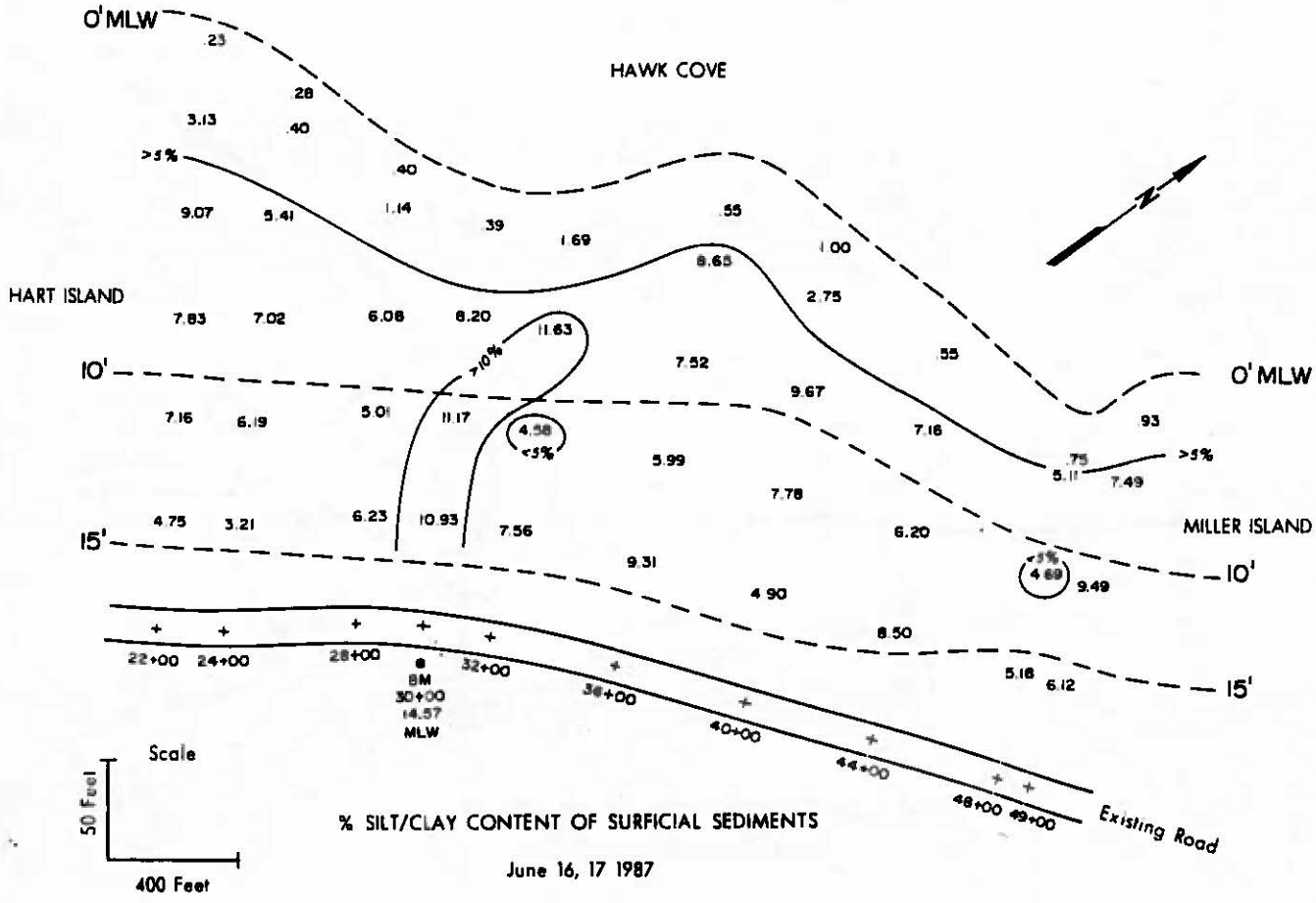


Figure 2-7: Map showing the distribution of silt and clay on the beach in June 1987 (after regrading).

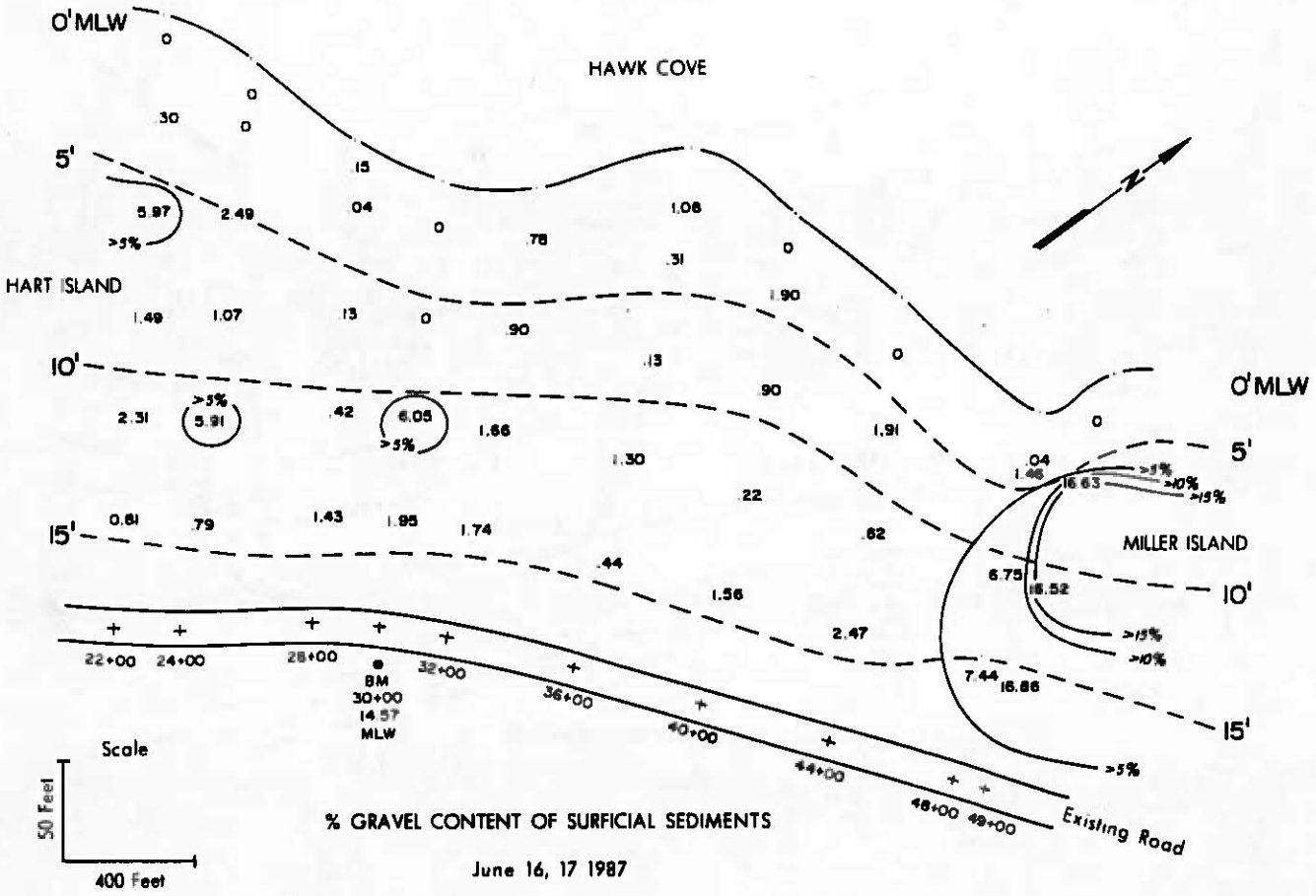


Figure 2-8: Map showing the distribution of gravel on the beach in June 1987 (after regrading).

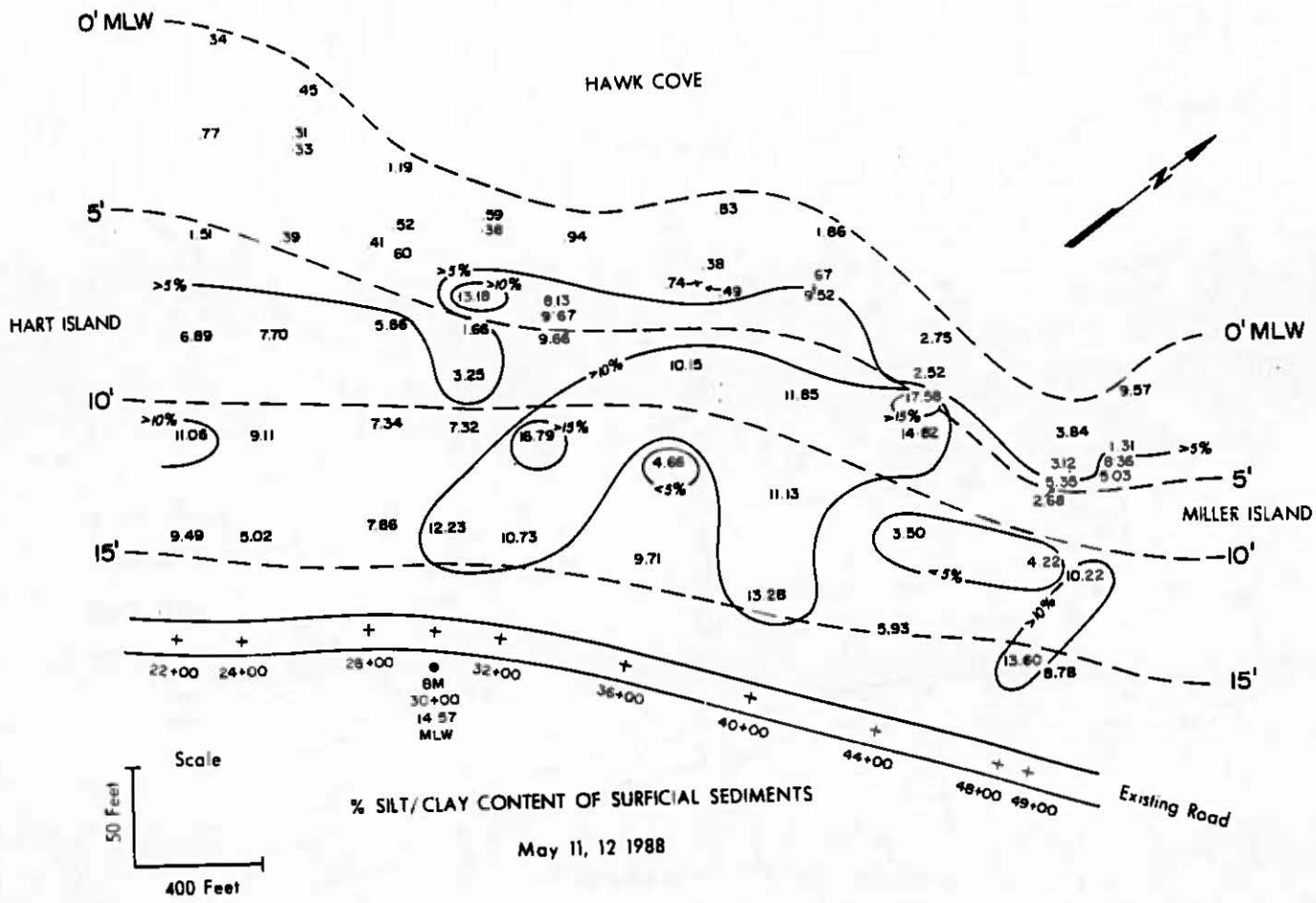


Figure 2-9: Map showing the distribution of silt and clay on the beach in May 1988 (before regrading).

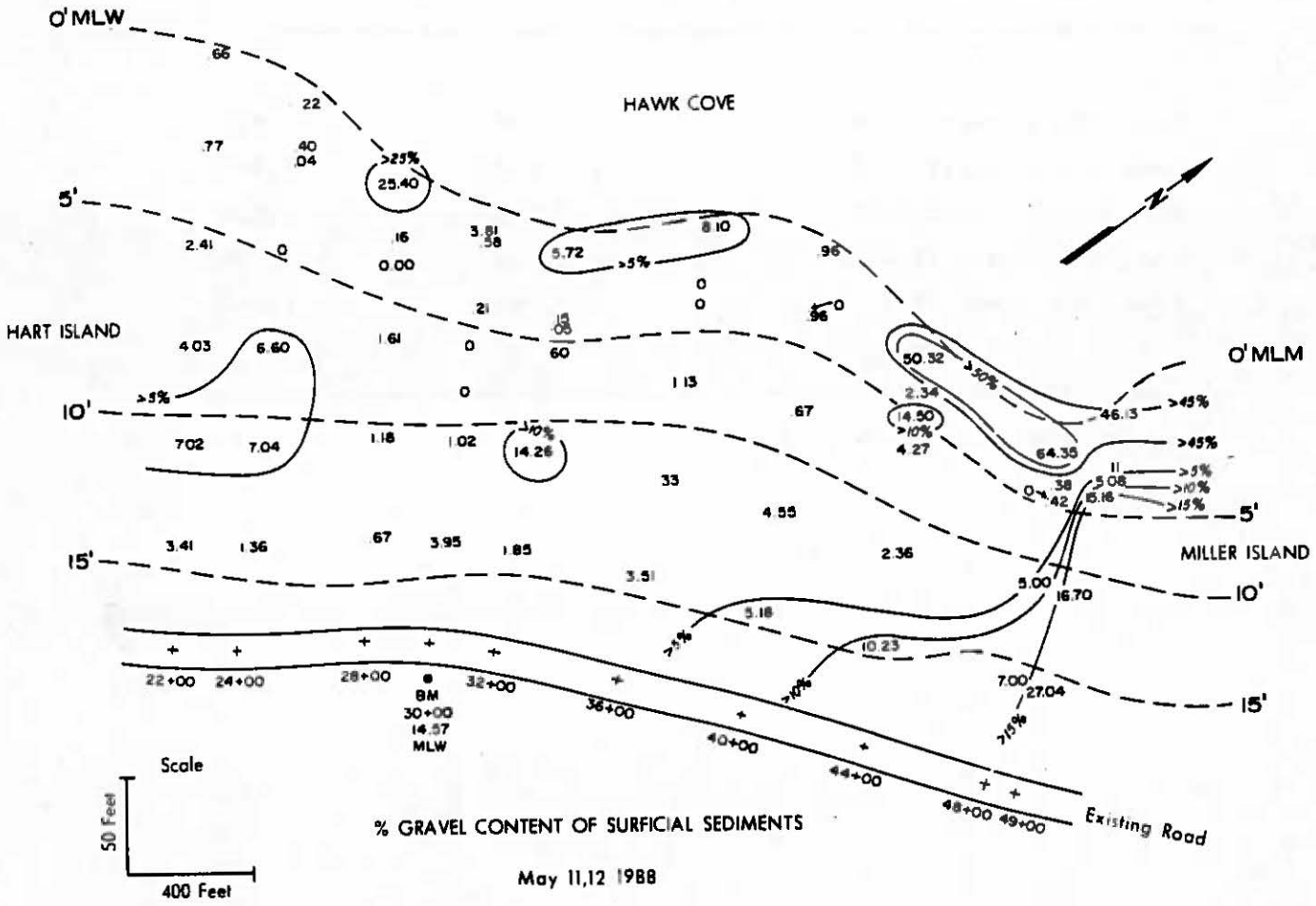


Figure 2-10: Map showing the distribution of gravel on the beach in May 1988 (before regrading).

Table 2-4: Volume of sediment eroded between regrades since the inception of the beach erosion study.

Time period	Sediment volume lost* (yd^3)	(m^3)
June 1984 - March 1985	1,190	910
June 1985 - April 1986	2,083	1,593
June 1986 - March 1987	3,472	2,656
June 1987 - May 1988	3,129	2,394
June 1984 - May 1988	11,244	8,602

* based on ISRP (Birkemeier, 1986)

RECOMMENDATIONS

Several of the erosion control measures recommended in previous reports were implemented in September 1988. Construction of two berms parallel to the shoreline will redirect storm runoff. Seeding the beach will stabilize it by reducing sheet wash and gully erosion. However, erosion of the 50-75 ft wide sand beach by wave attack will continue. Sand replenishment and/or the construction of an offshore breakwater may still be necessary to deter erosion.

ACKNOWLEDGMENTS

The following people were part of the crew that collected survey data: William Panageotou, Marguerite Toscano, Darlene Wells, Robert Conkwright, and Sally Jones. The climatological data supplied by the Maryland Environment Service and used in the diagnosis of erosional problems found on the beach was greatly appreciated.

APPENDICES

Appendix A: Xeroradiographs of the gravity cores.

Appendix B: Shepard's diagrams and component (sand-silt-clay) plots of selected stations.

Appendix C: Contour maps of the recreational beach.

Appendix D: Cross-sectional profiles of the recreational beach.

APPENDIX A

Xeroradiographs of the gravity cores.

HART - MILLER ISLAND

Station BC-1

April 14, 1988

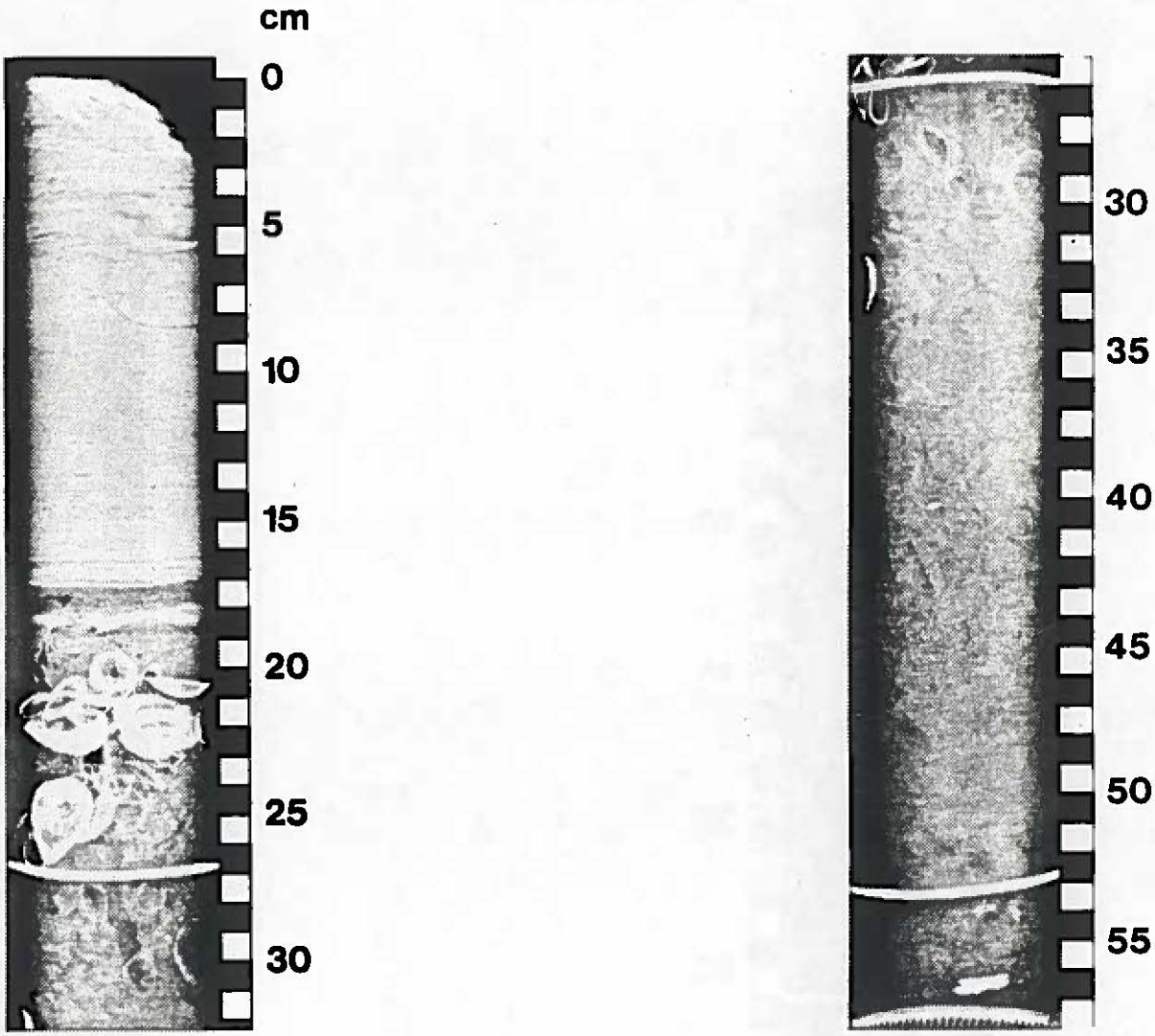


Figure A-1

HART - MILLER ISLAND

Station BC-2

April 14, 1988

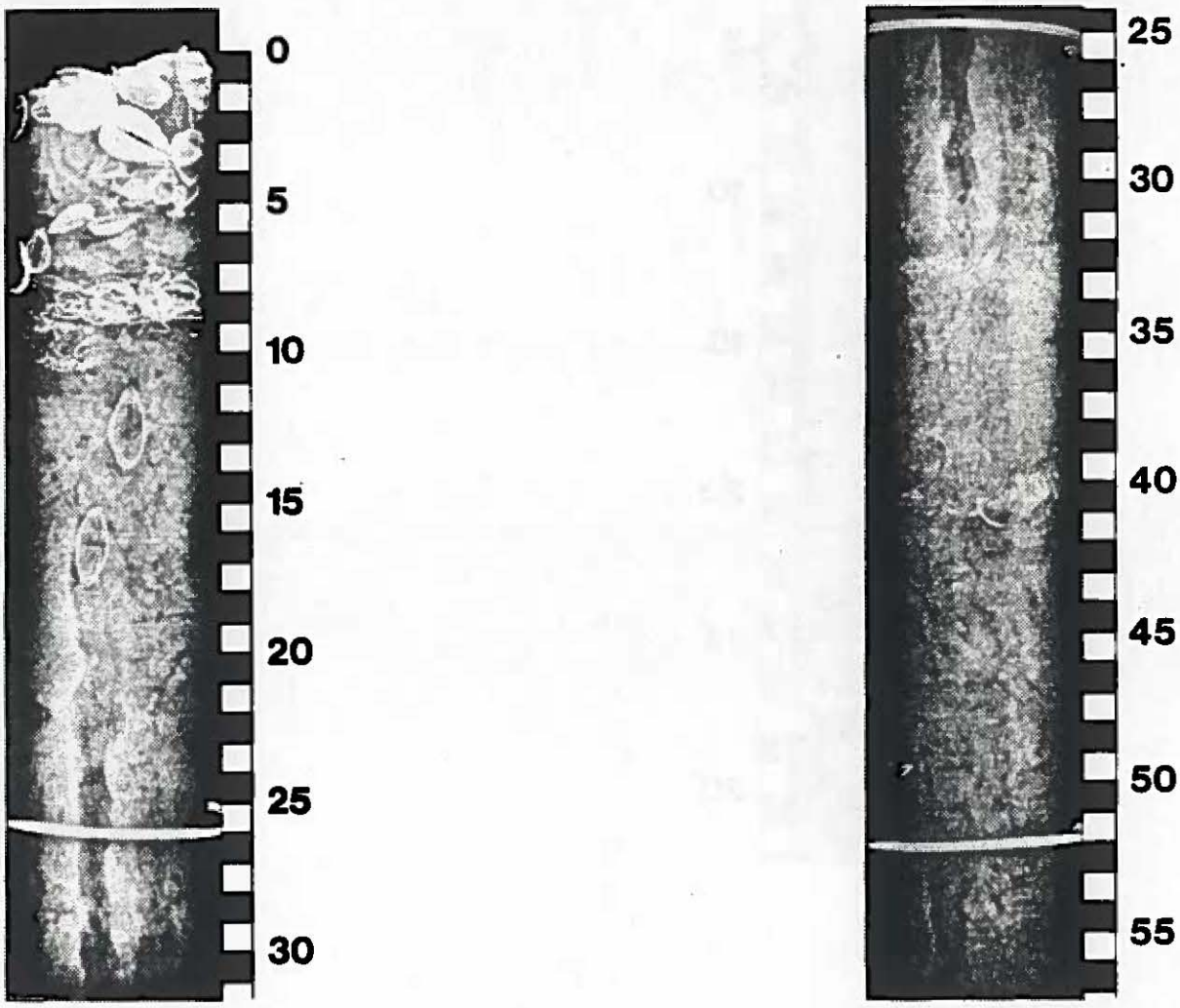


Figure A-2

HART - MILLER ISLAND

Station BC-3

April 14, 1988

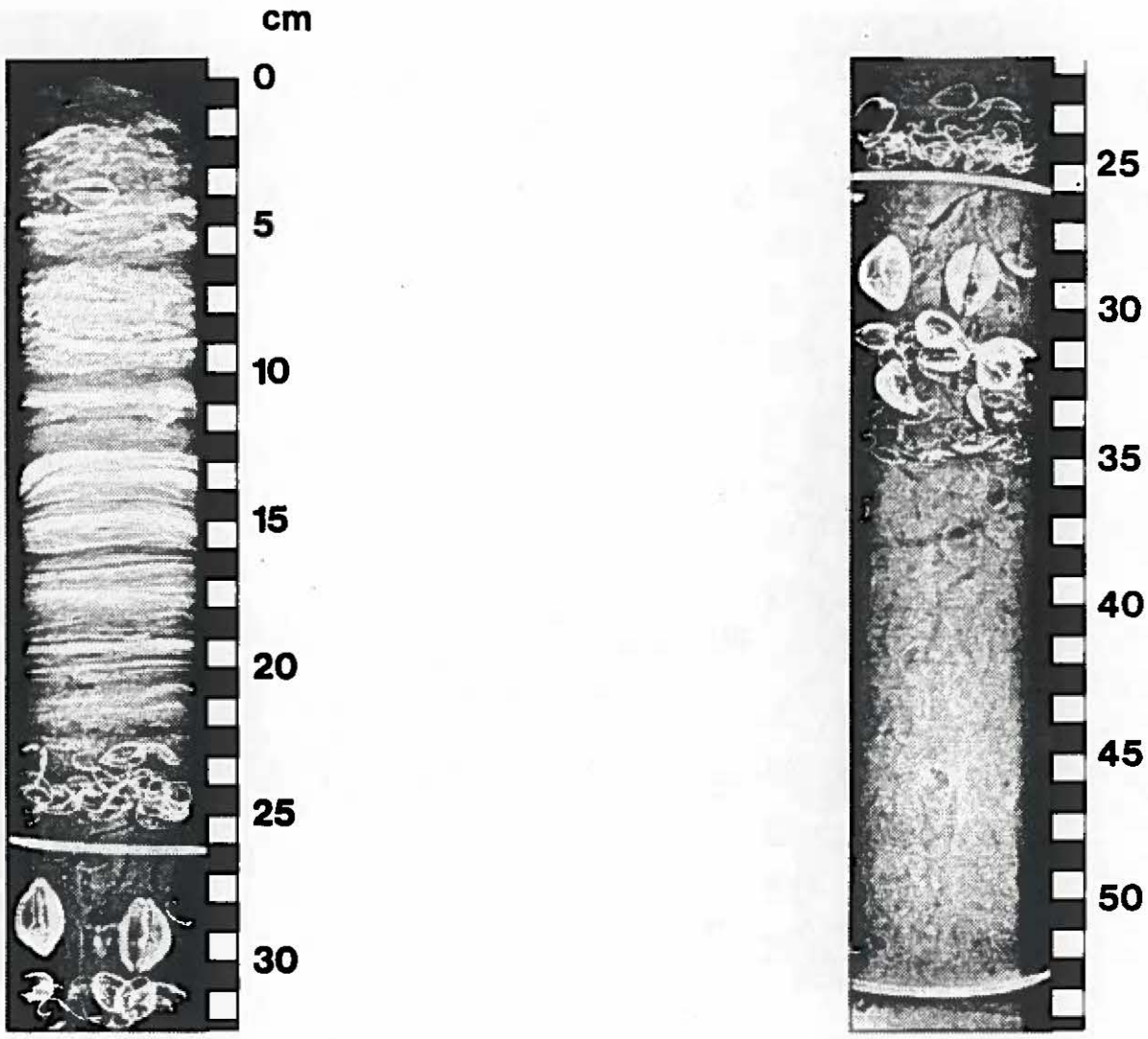


Figure A-3

HART - MILLER ISLAND

Station BC-4

April 14, 1988

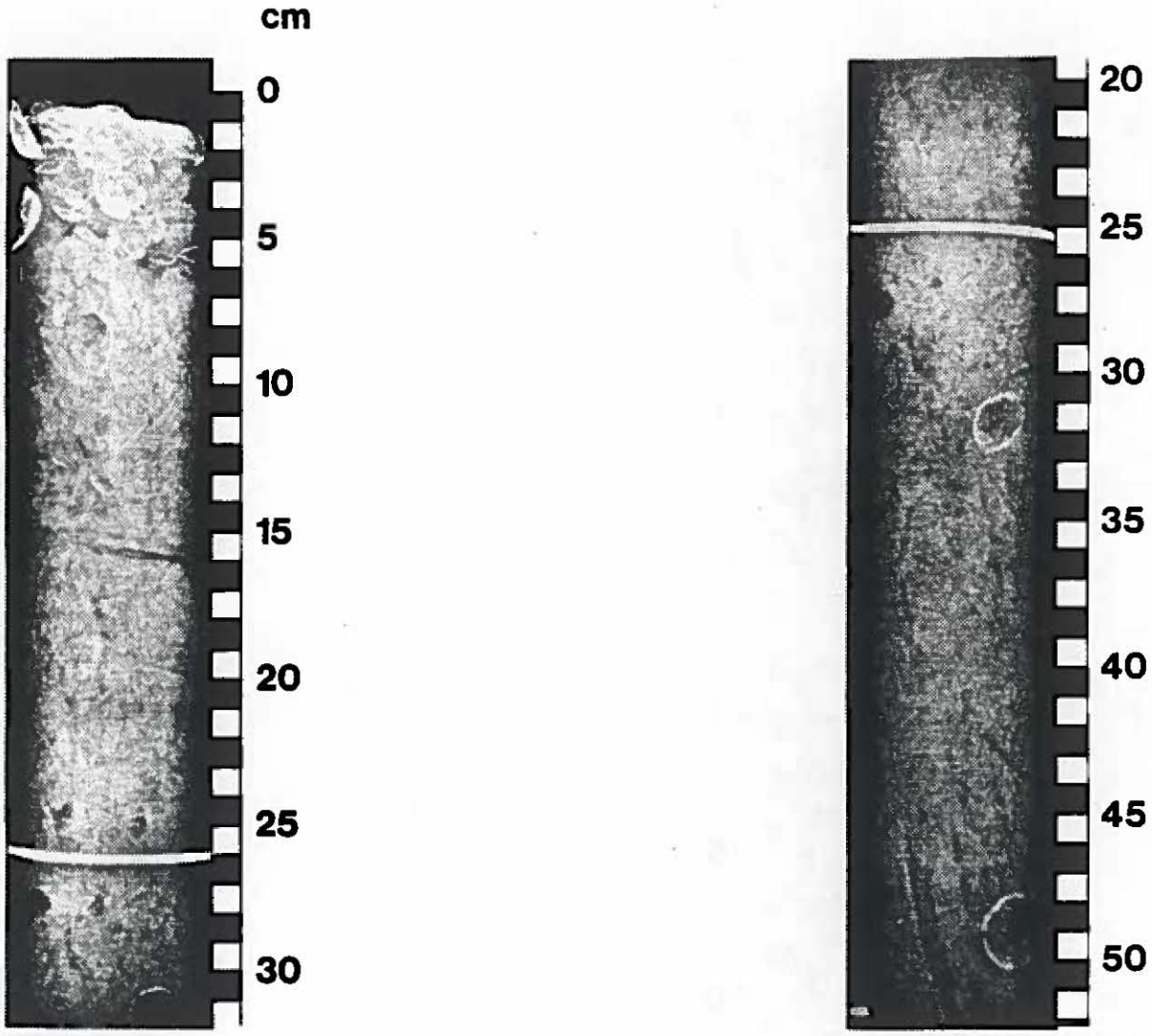


Figure A-4

HART - MILLER ISLAND

Station BC-5

April 14, 1988

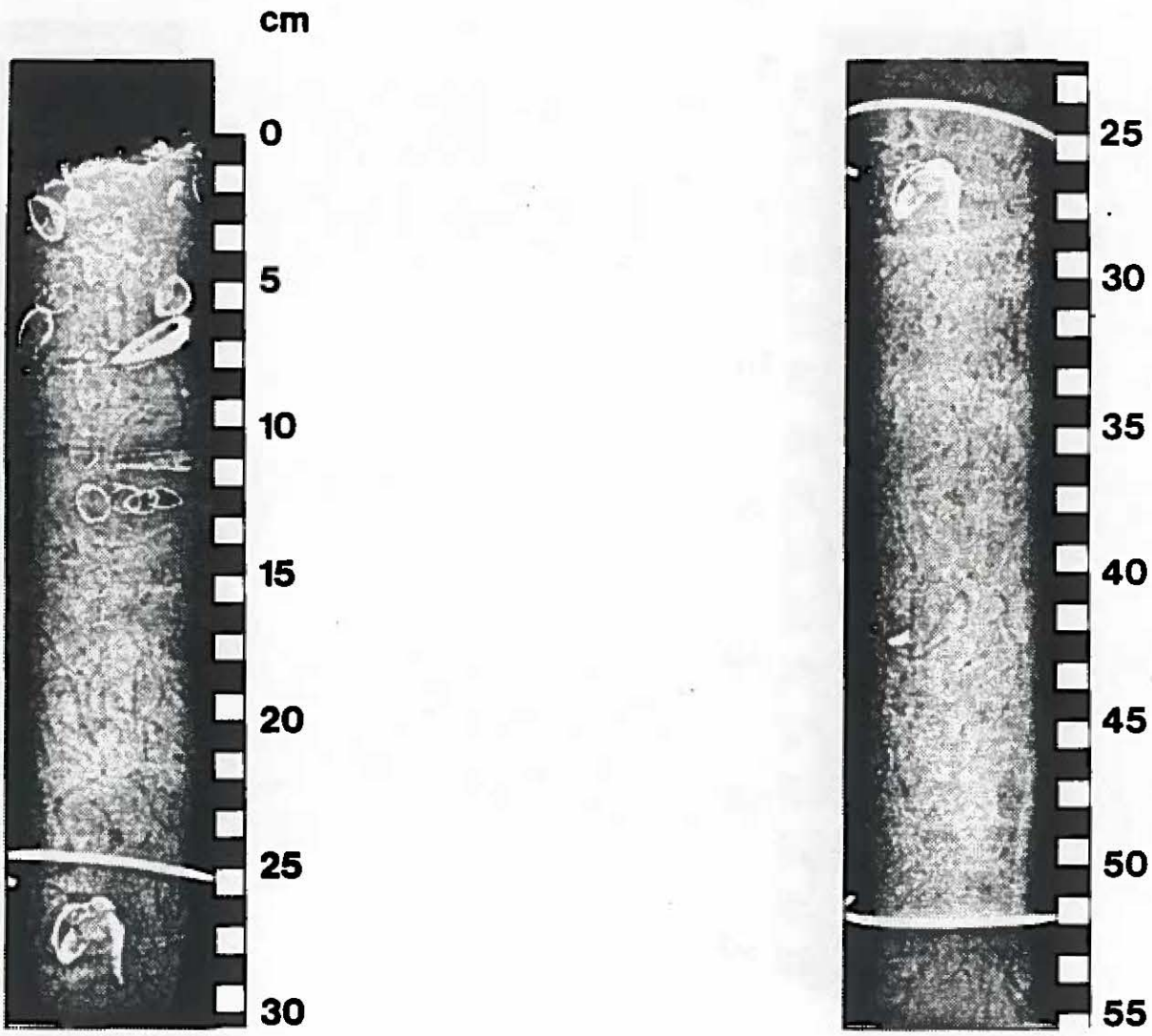


Figure A-5

HART - MILLER ISLAND

Station BC-6

April 14, 1988

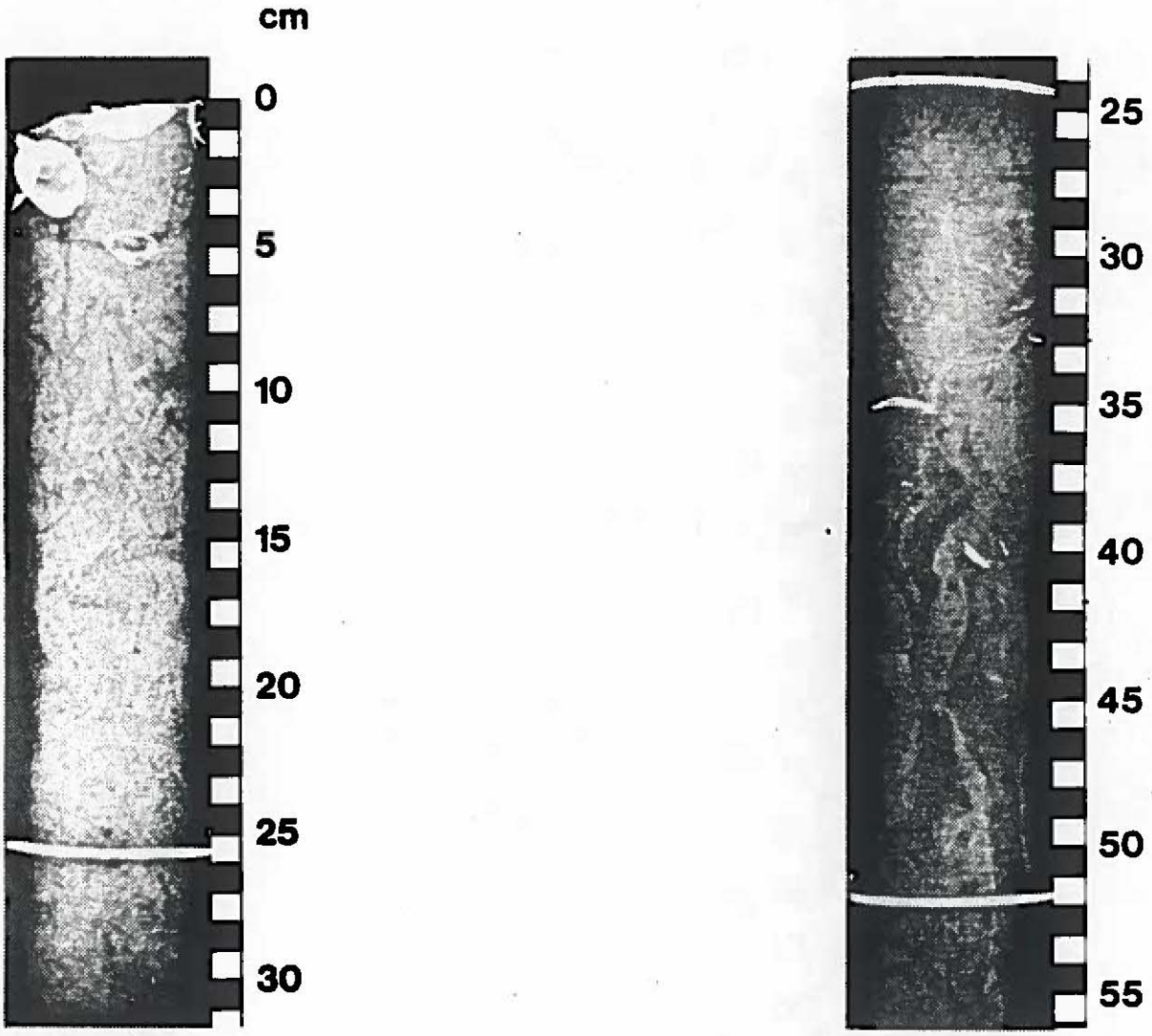


Figure A-6

HART - MILLER ISLAND

Station BC-7

April 14, 1988

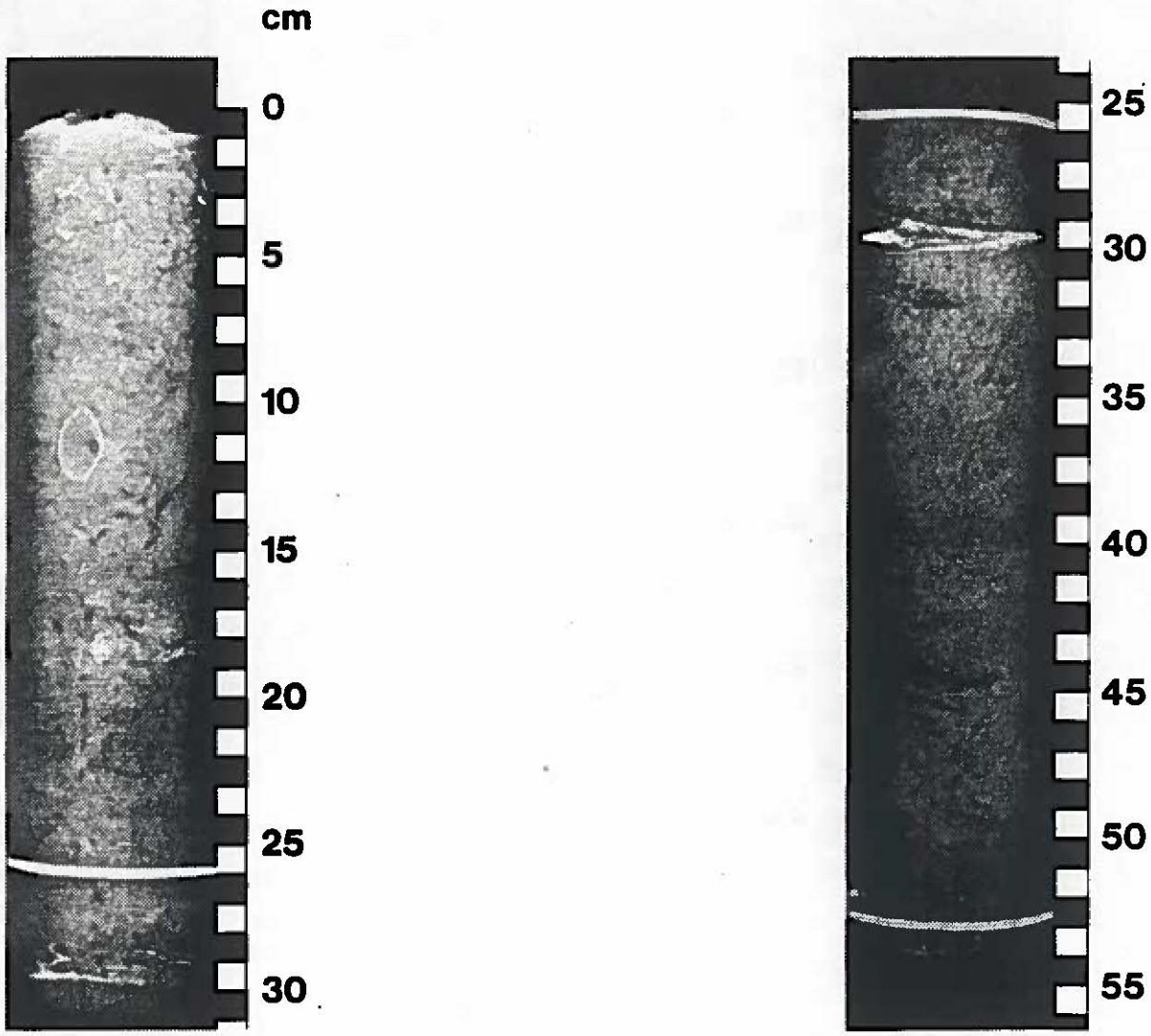


Figure A-7

HART - MILLER ISLAND

Station 12

April 14, 1988

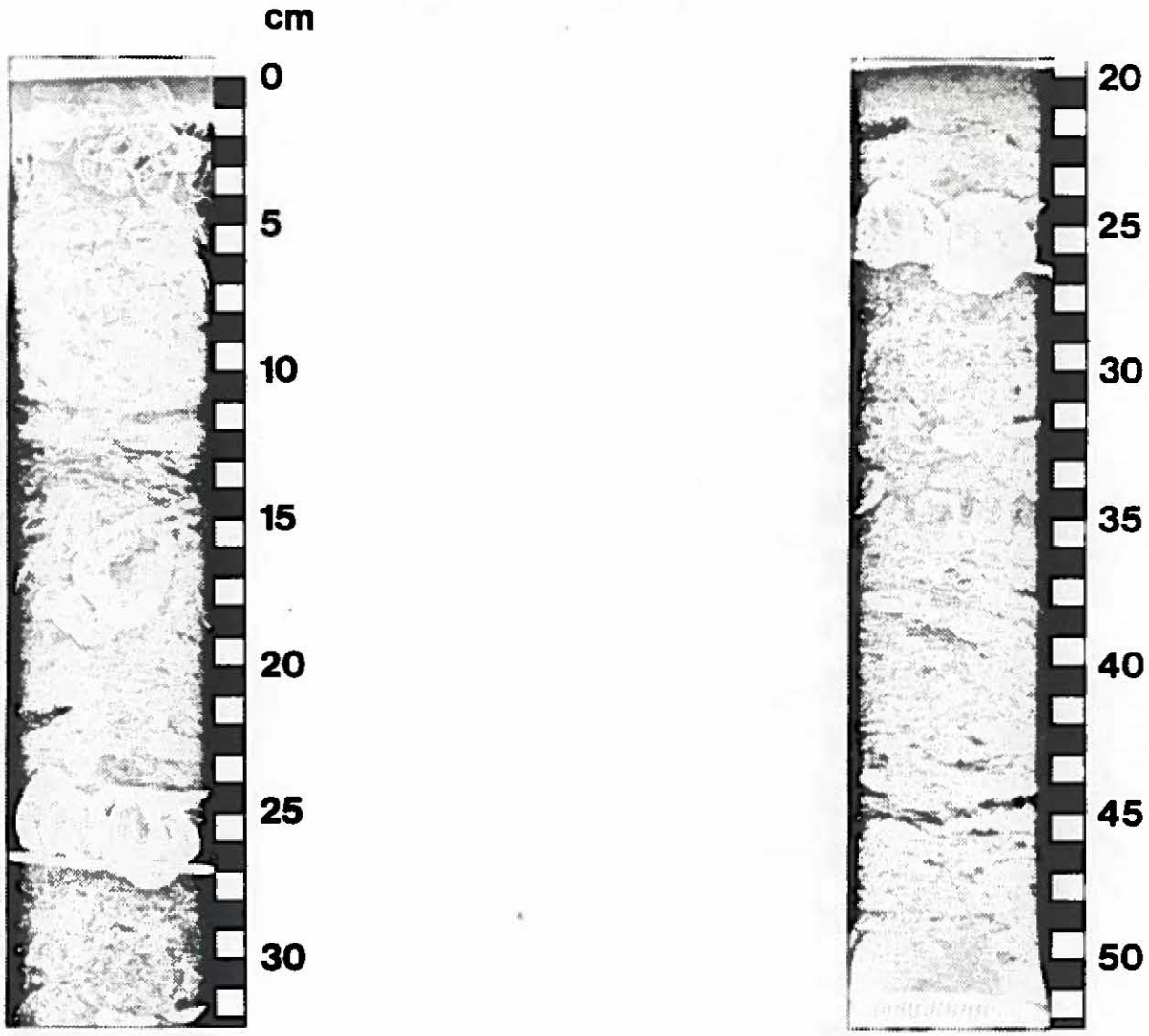


Figure A-8

HART - MILLER ISLAND

Station 21B

April 14, 1988

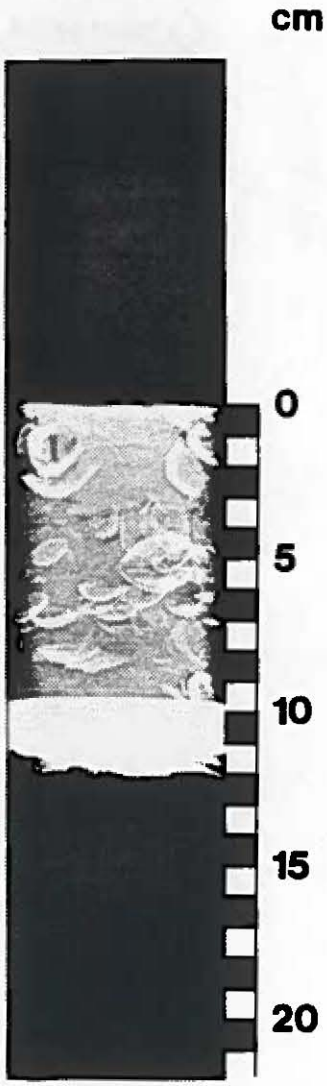


Figure A-9

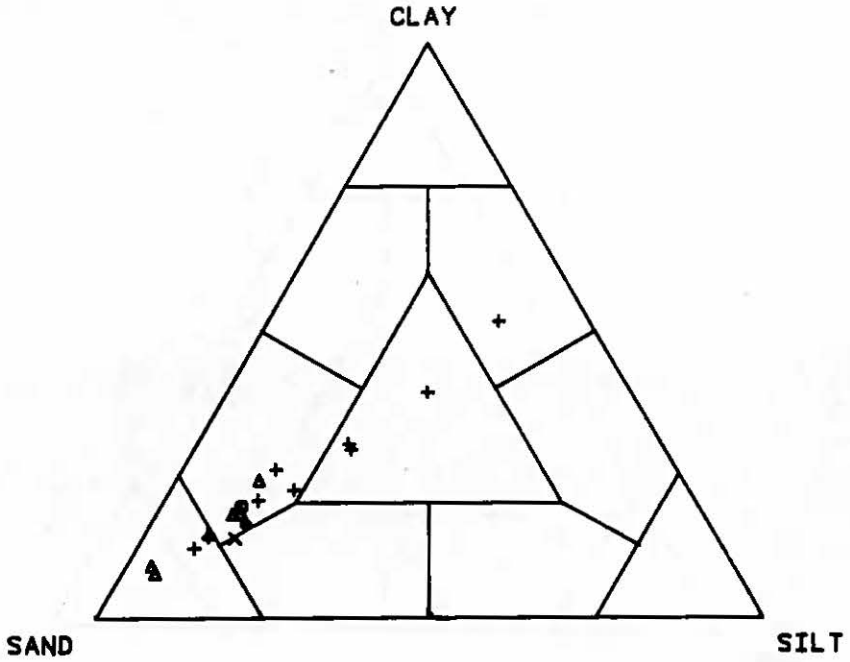
APPENDIX B

Shepard's diagrams and component (sand-silt-clay) plots of selected stations.

LEGEND (Shepard's diagram)

- ○ Cruise 1 (pre-construction)
- △ Cruises 2-7 (during construction)
- ✚ Cruises 8-16 (post-construction)
- X Cruise 17 (seventh monitoring year)
- ◇ Cruise 18 (seventh monitoring year)

STATION 3



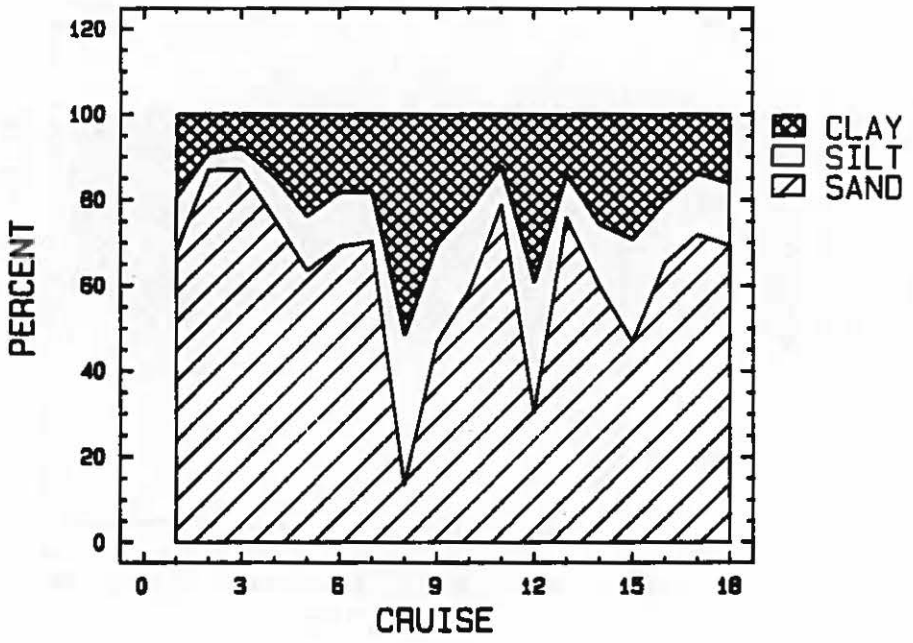
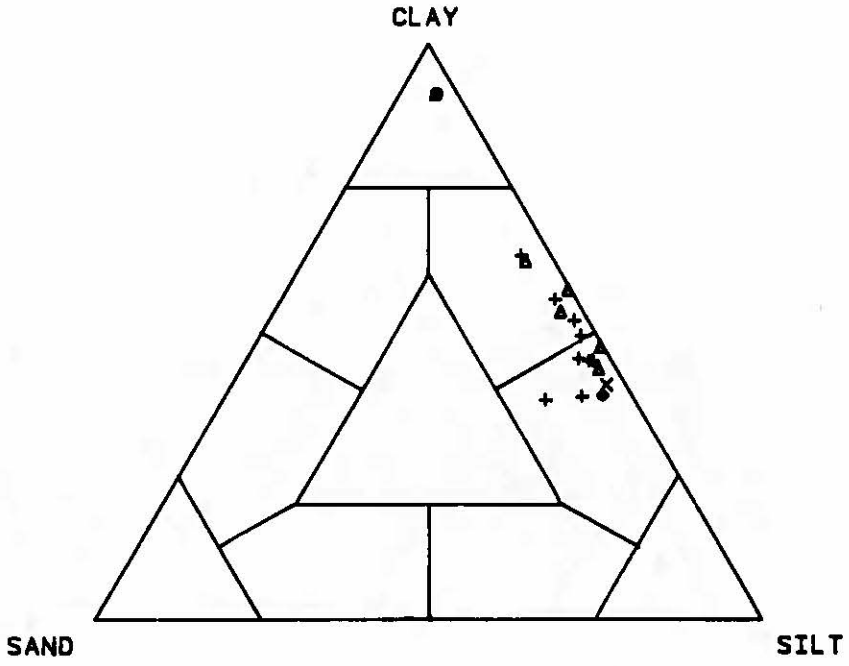


Figure B-1

STATION 5



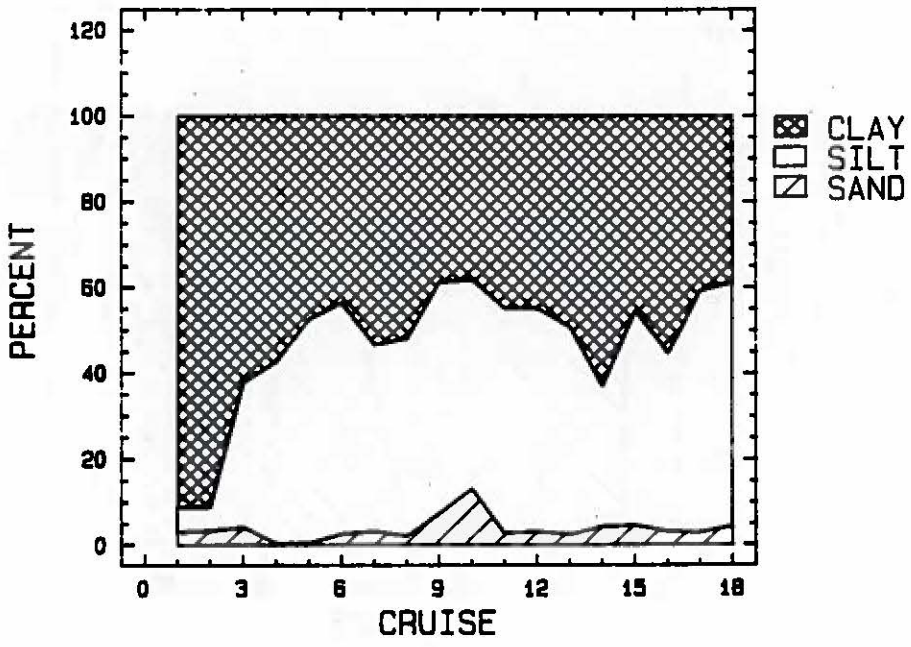
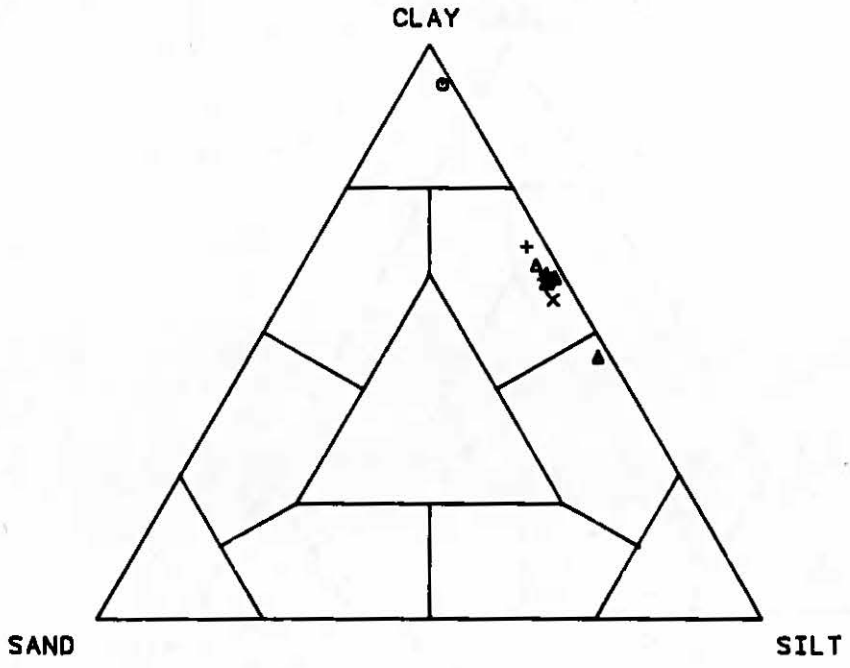


Figure B-2

STATION 9



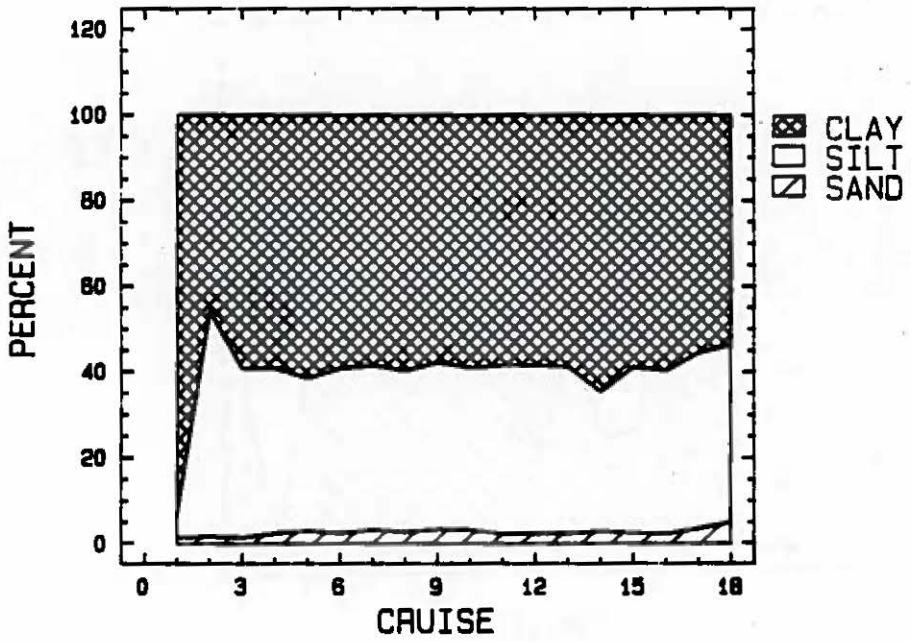
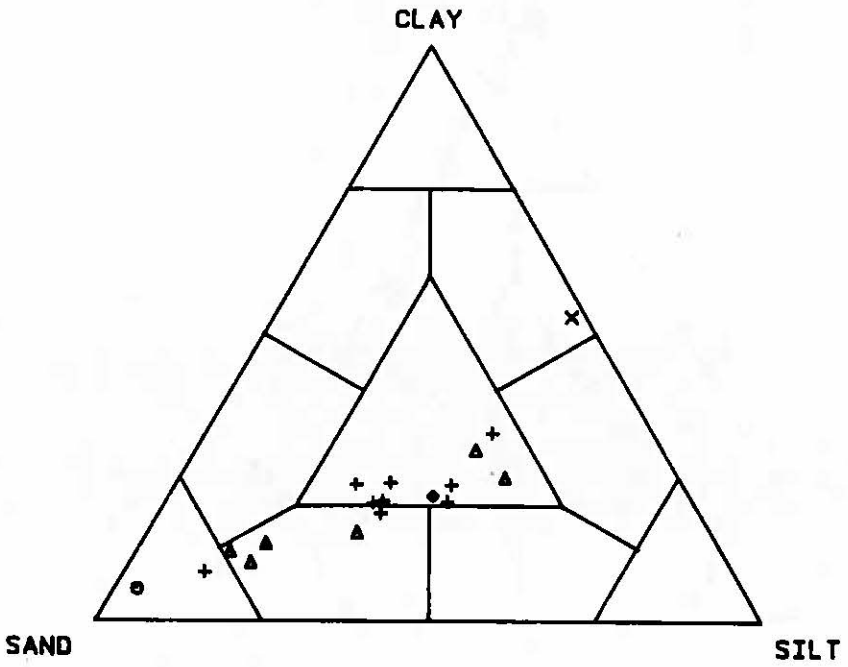


Figure B-3

STATION 12



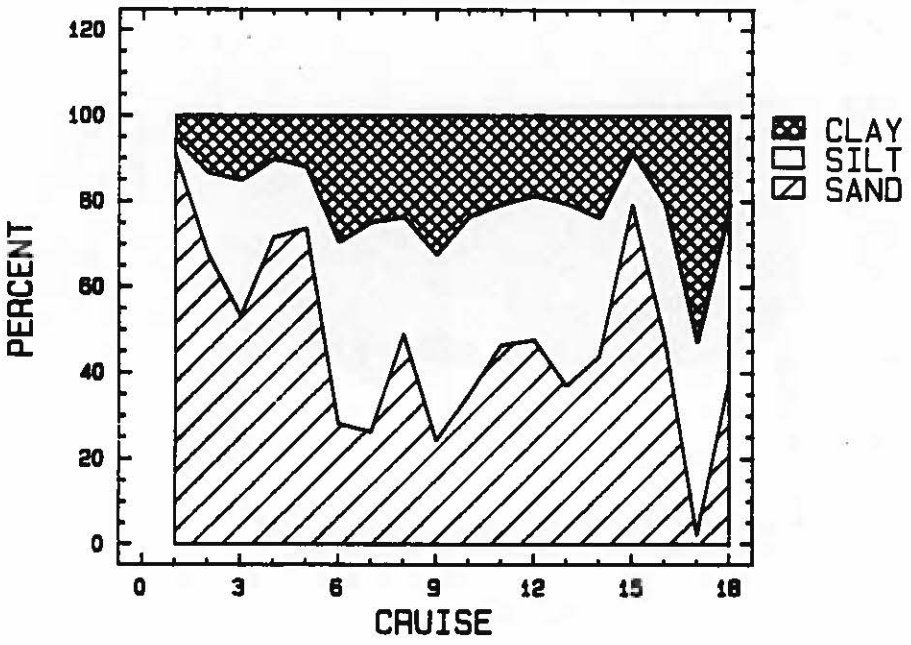
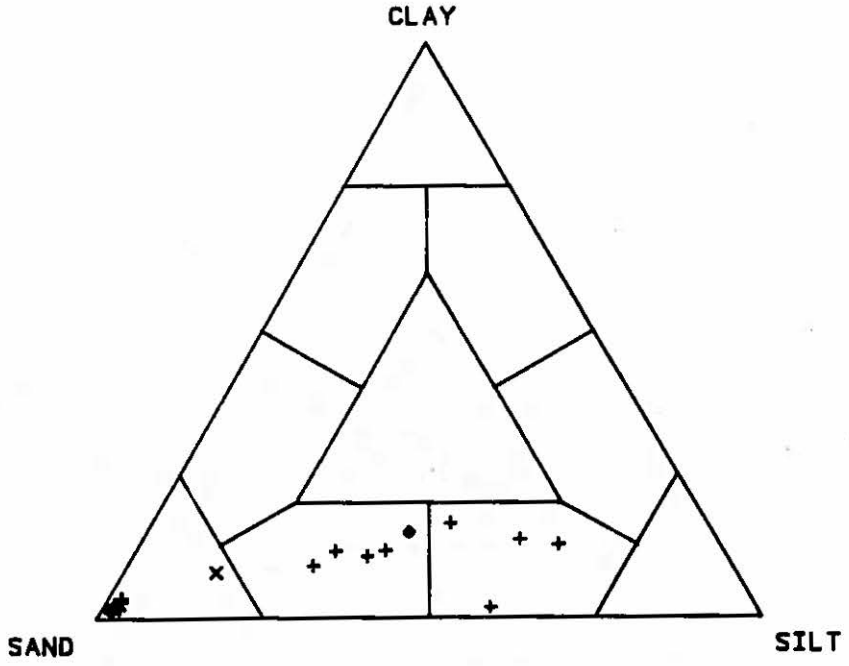


Figure B-4

STATION 21B



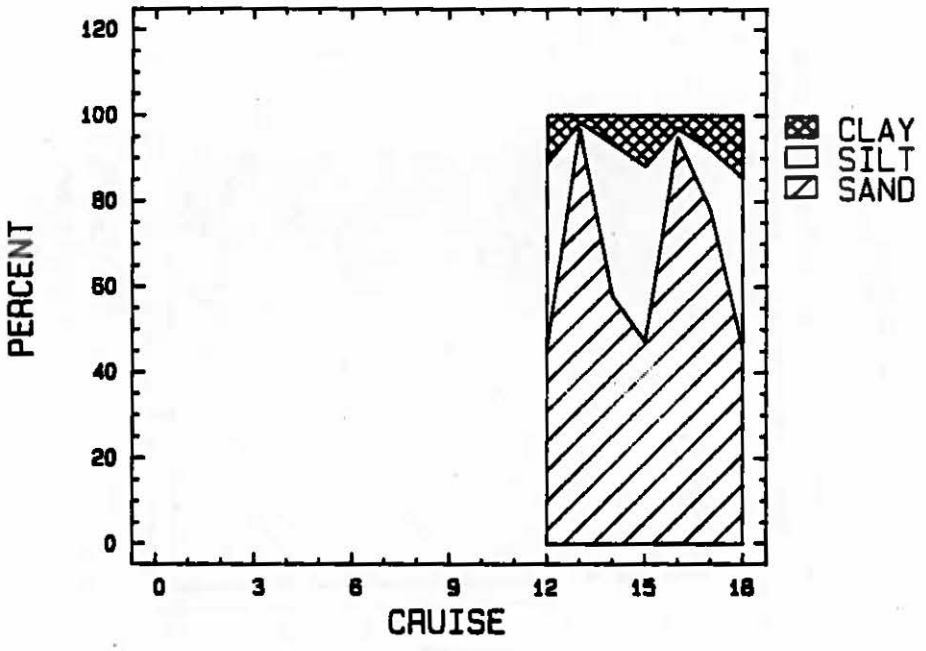
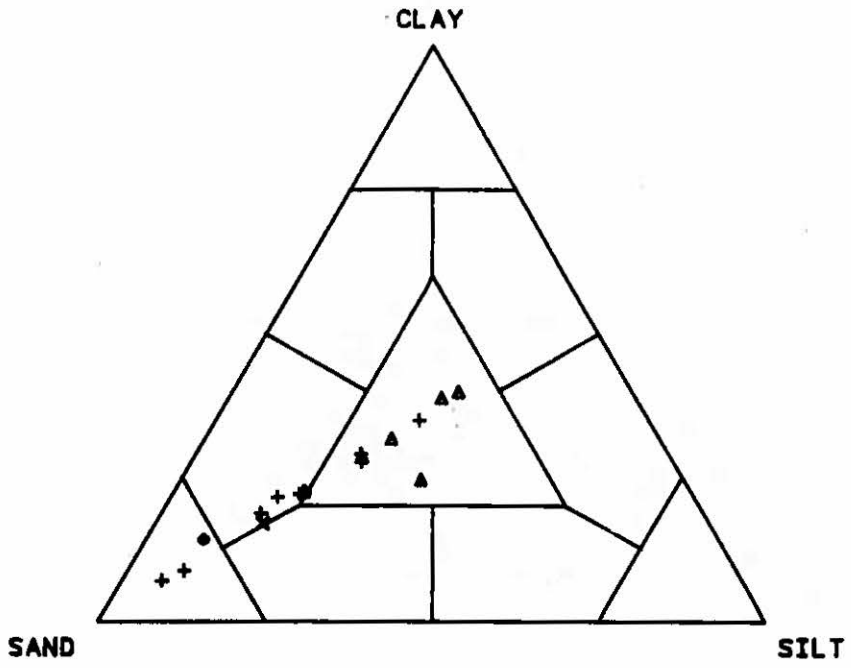


Figure B-5

STATION 22



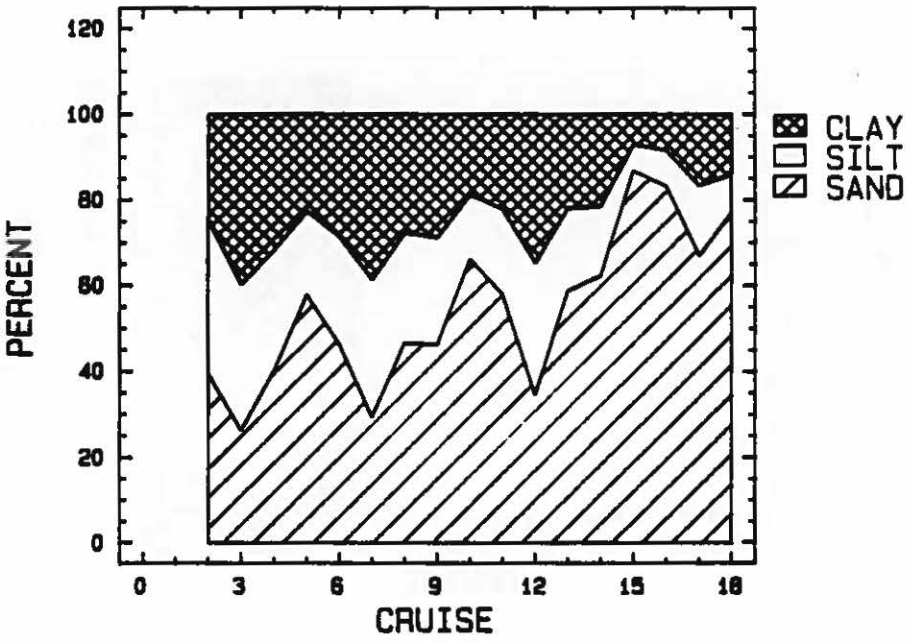
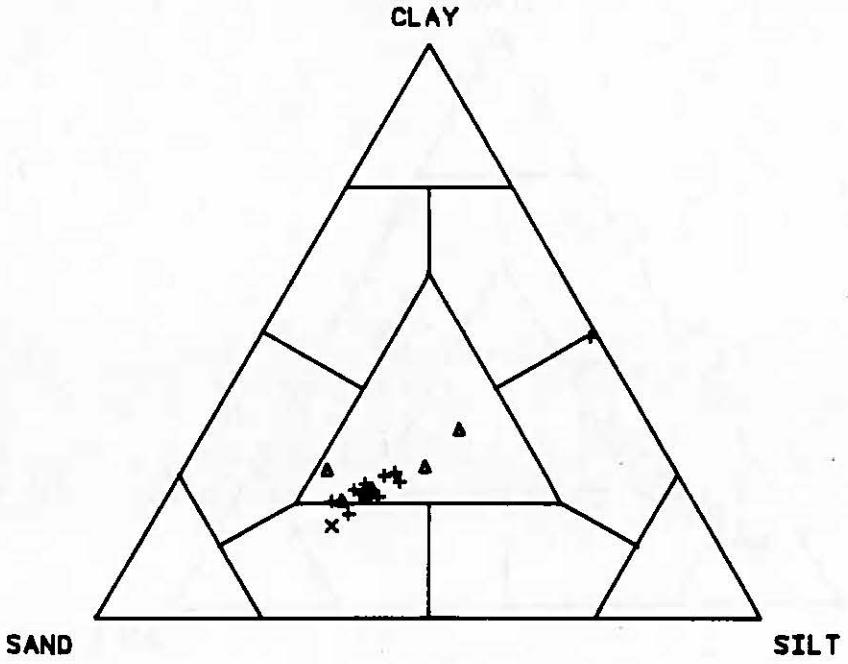


Figure B-6

STATION 23



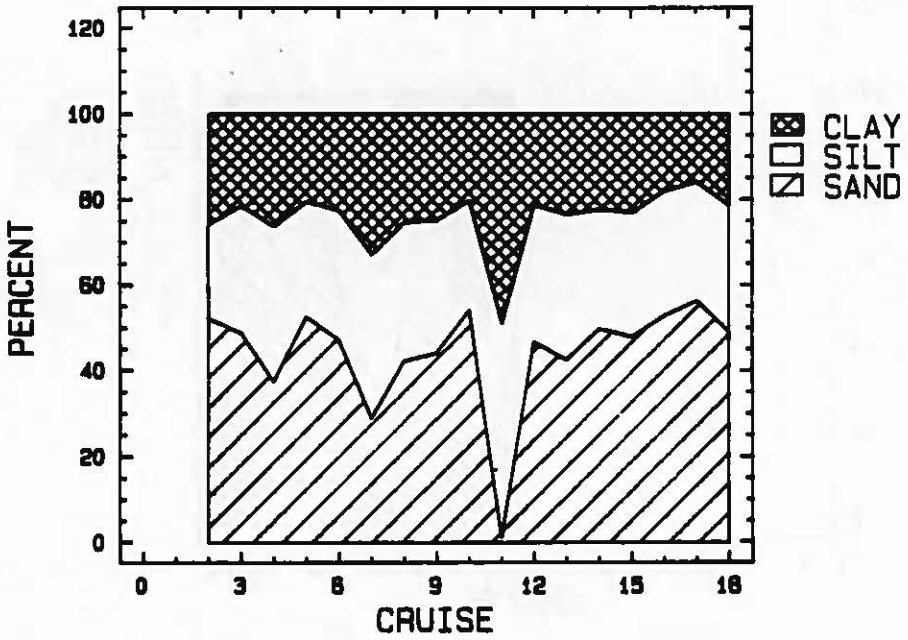
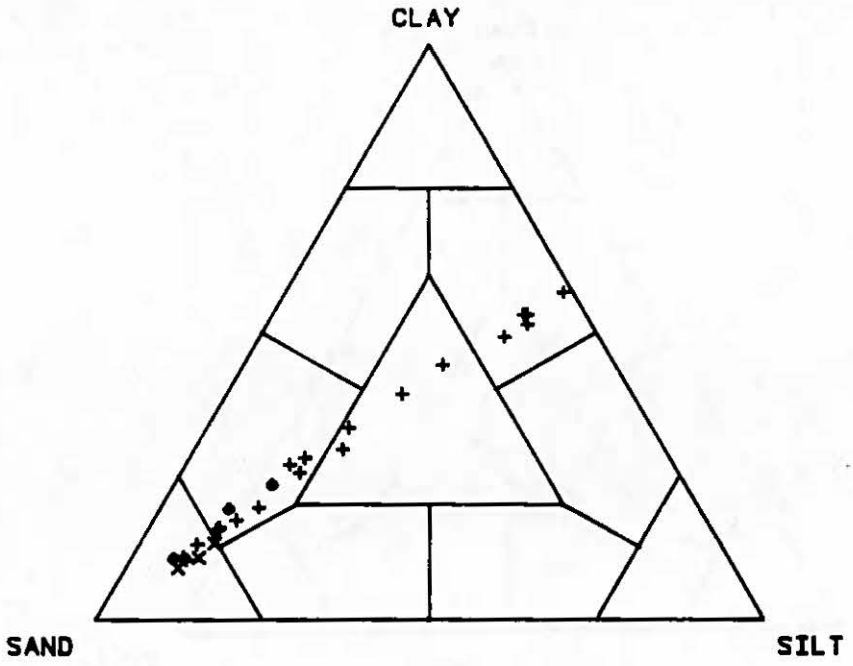


Figure B-7

STATION 24



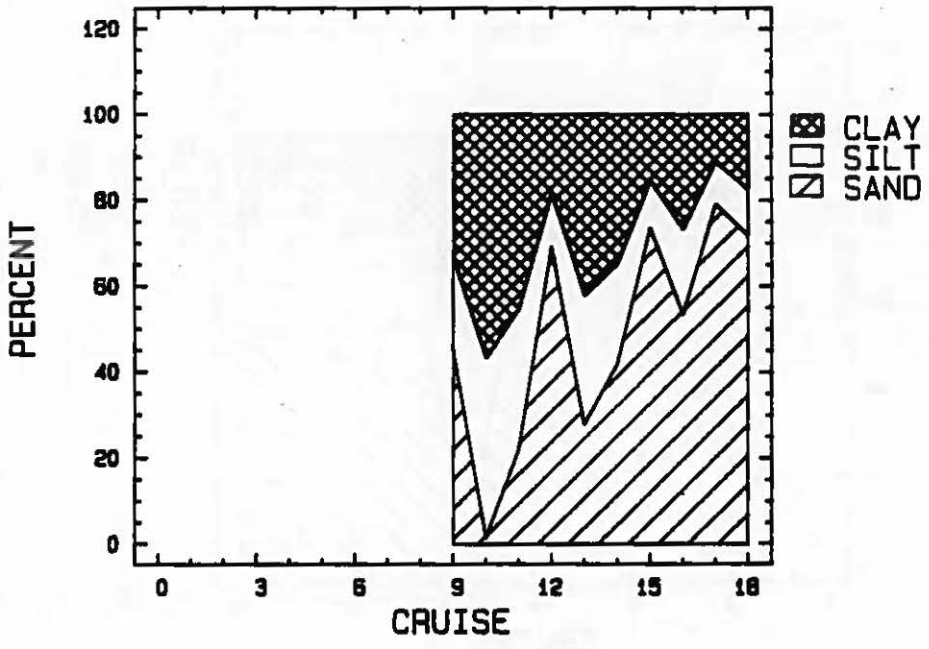
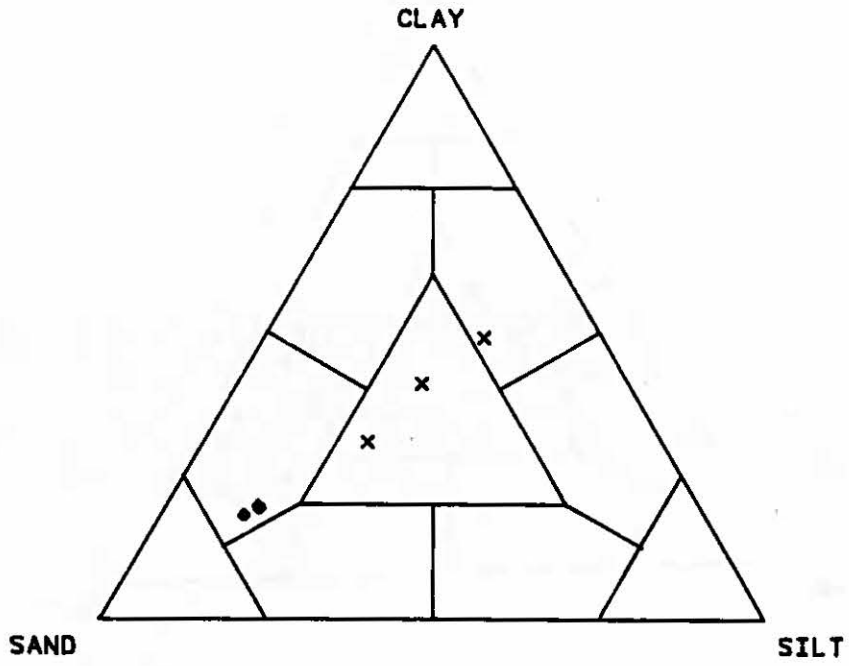


Figure B-8

STATION 28



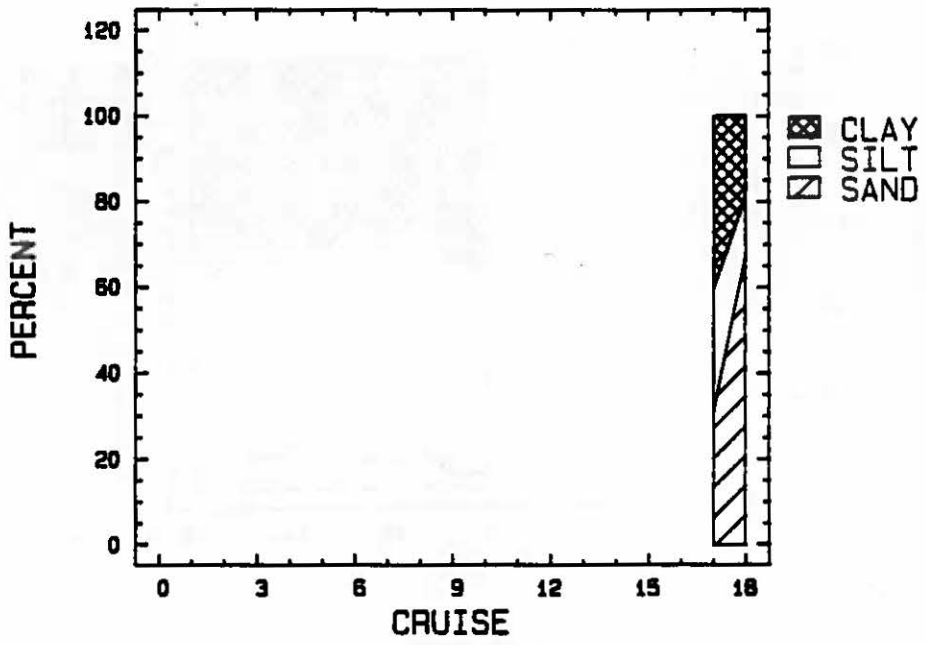
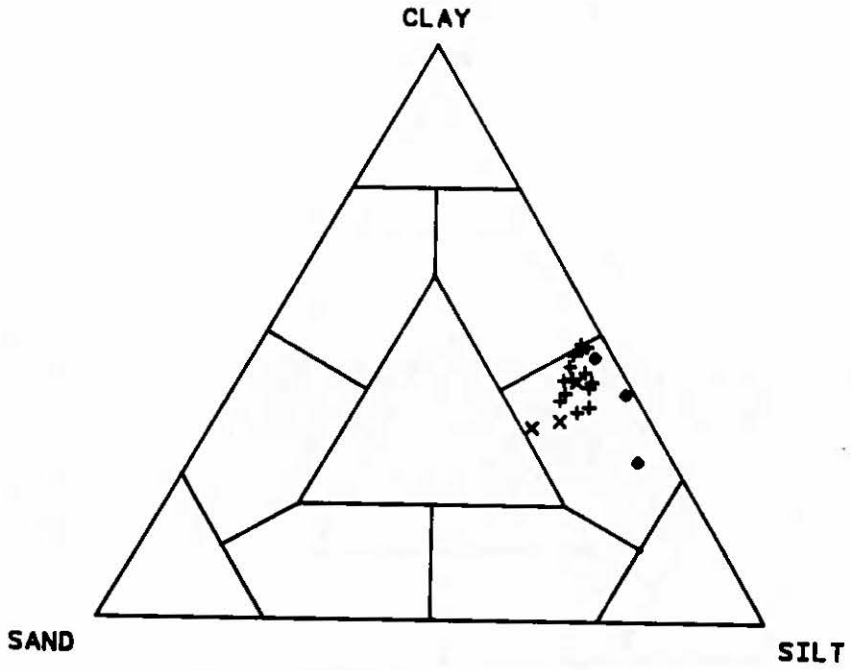


Figure B-9

STATION BC-3



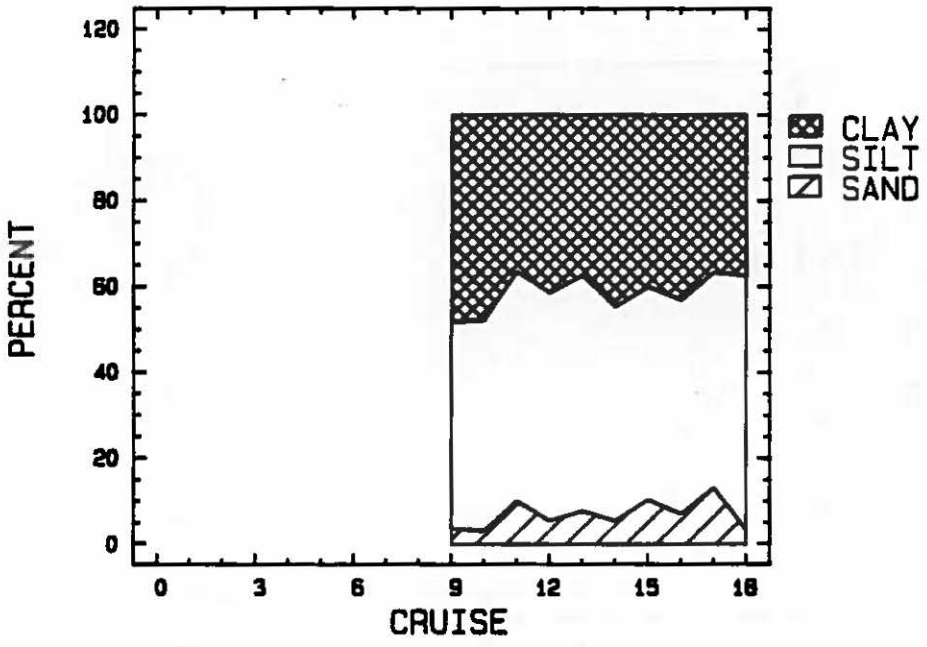
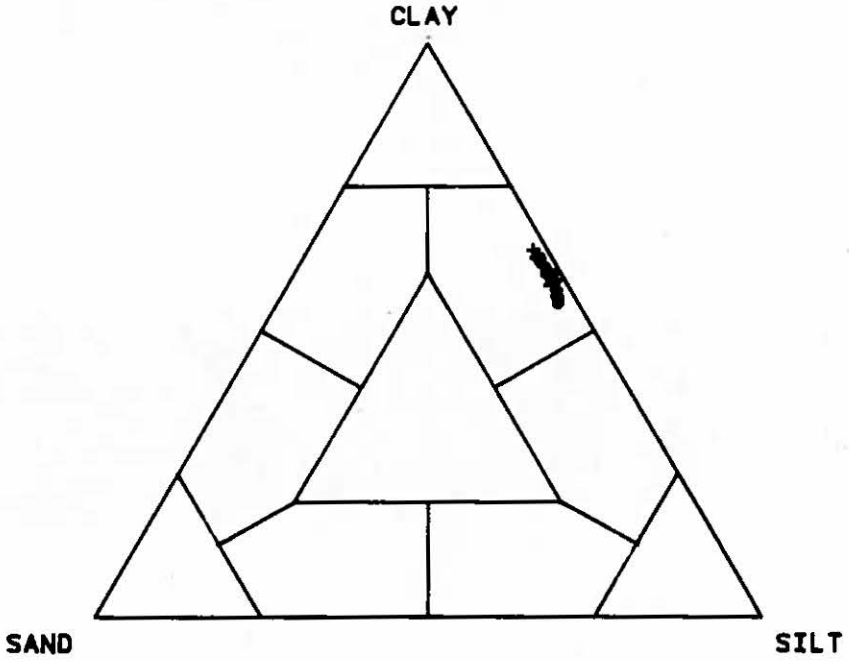


Figure B-10

STATION BC-6



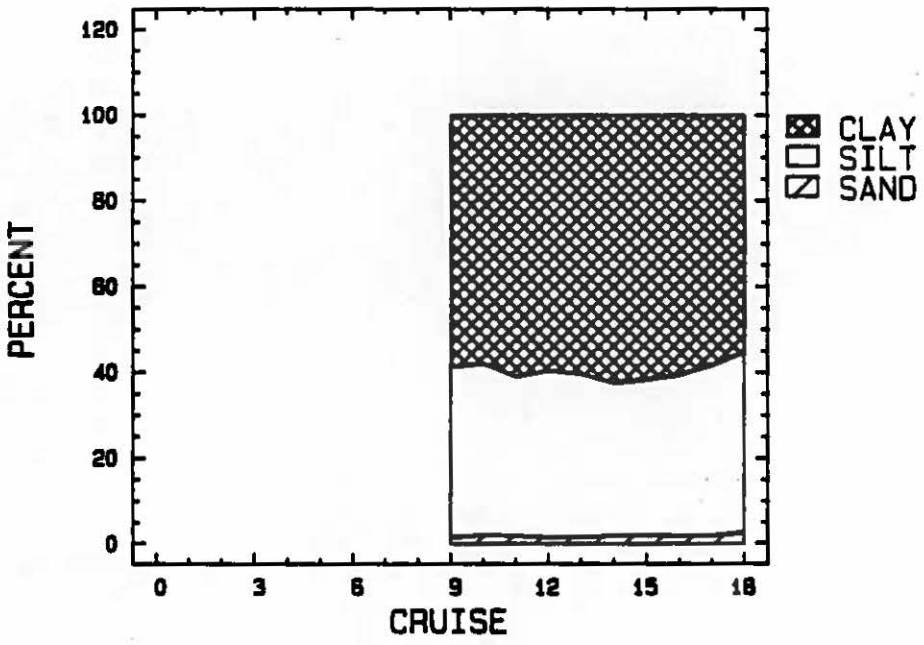


Figure B-11

APPENDIX C

Contour maps of the recreational beach.

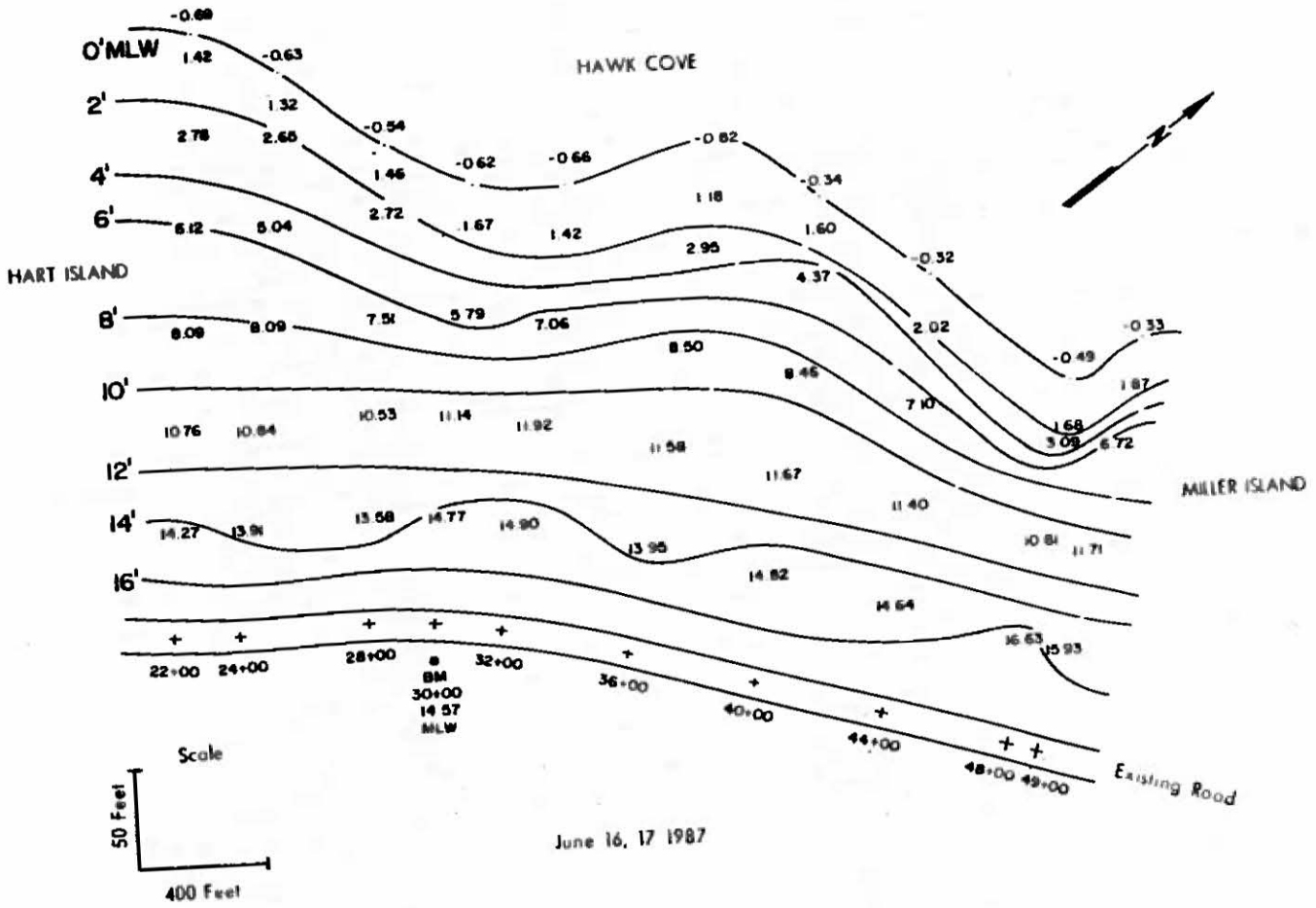

HAWK COVE
HART ISLAND
MILLER ISLAND
0'MLW
2'
4'
6'
8'
10'
12'
14'
16'
22+00
24+00
28+00
BM
30+00
14.57
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
June 16, 17 1987

Figure C-1

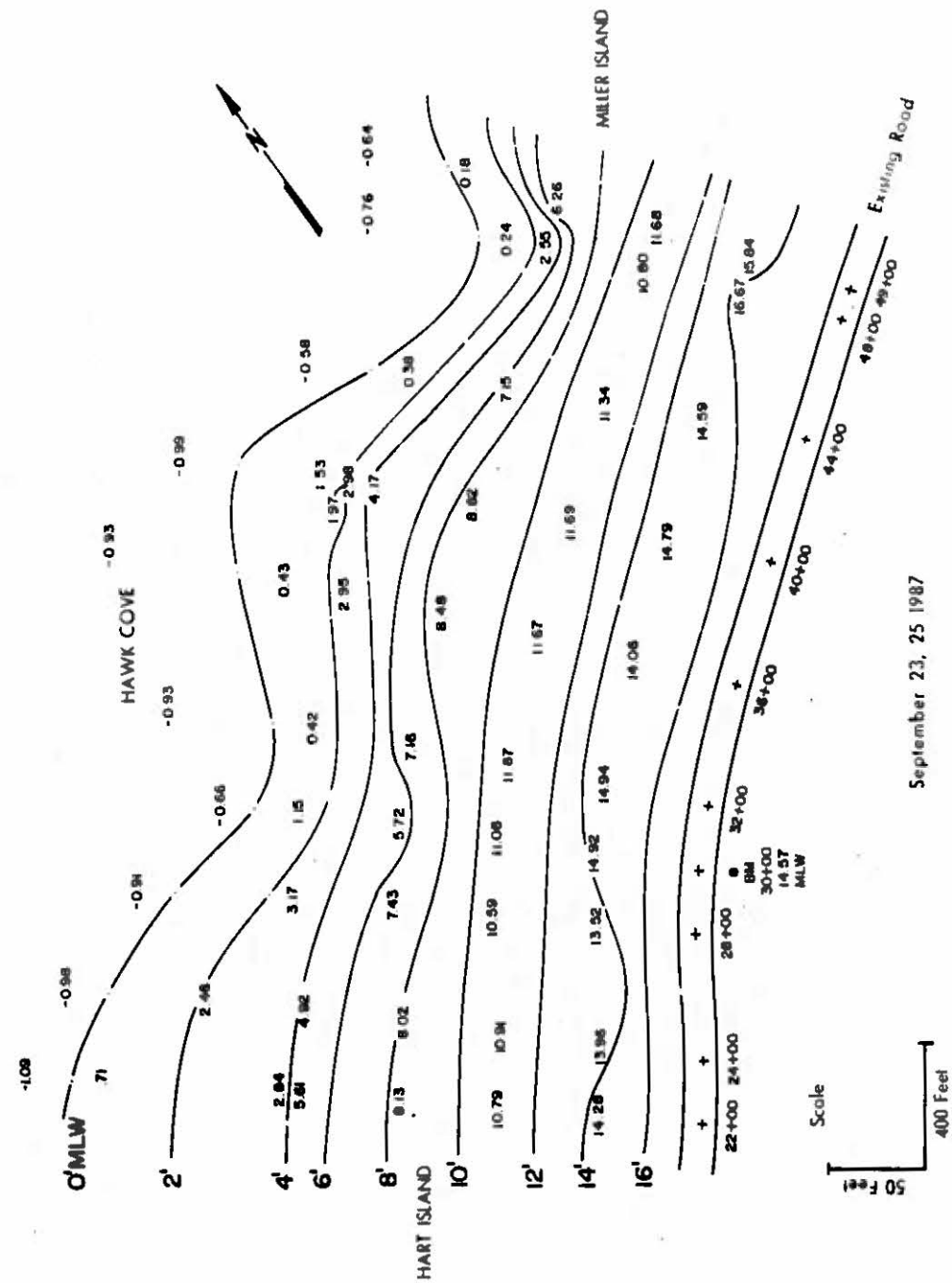

HAWK COVE
MILLER ISLAND
HART ISLAND
Existing Road
September 23, 25 1987
0'MLW
2'
4'
6'
8'
10'
12'
14'
16'
Scale
50 Feet
400 Feet

Figure C-2

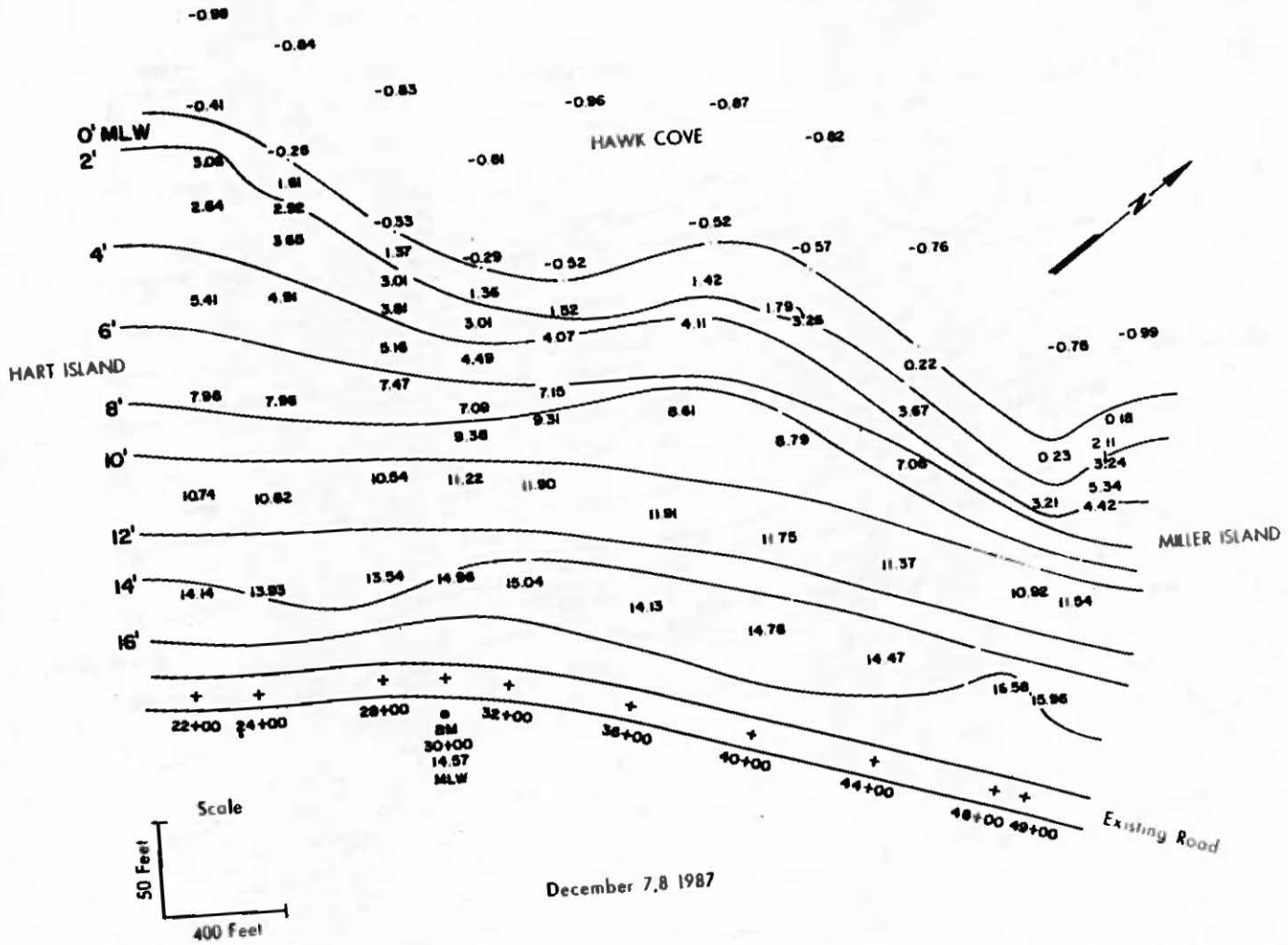

0' MLW
2'
4'
6'
8'
10'
12'
14'
16'
HART ISLAND
HAWK COVE
MILLER ISLAND
22+00
24+00
28+00
BM
30+00
14.57
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
December 7,8 1987

Figure C-3

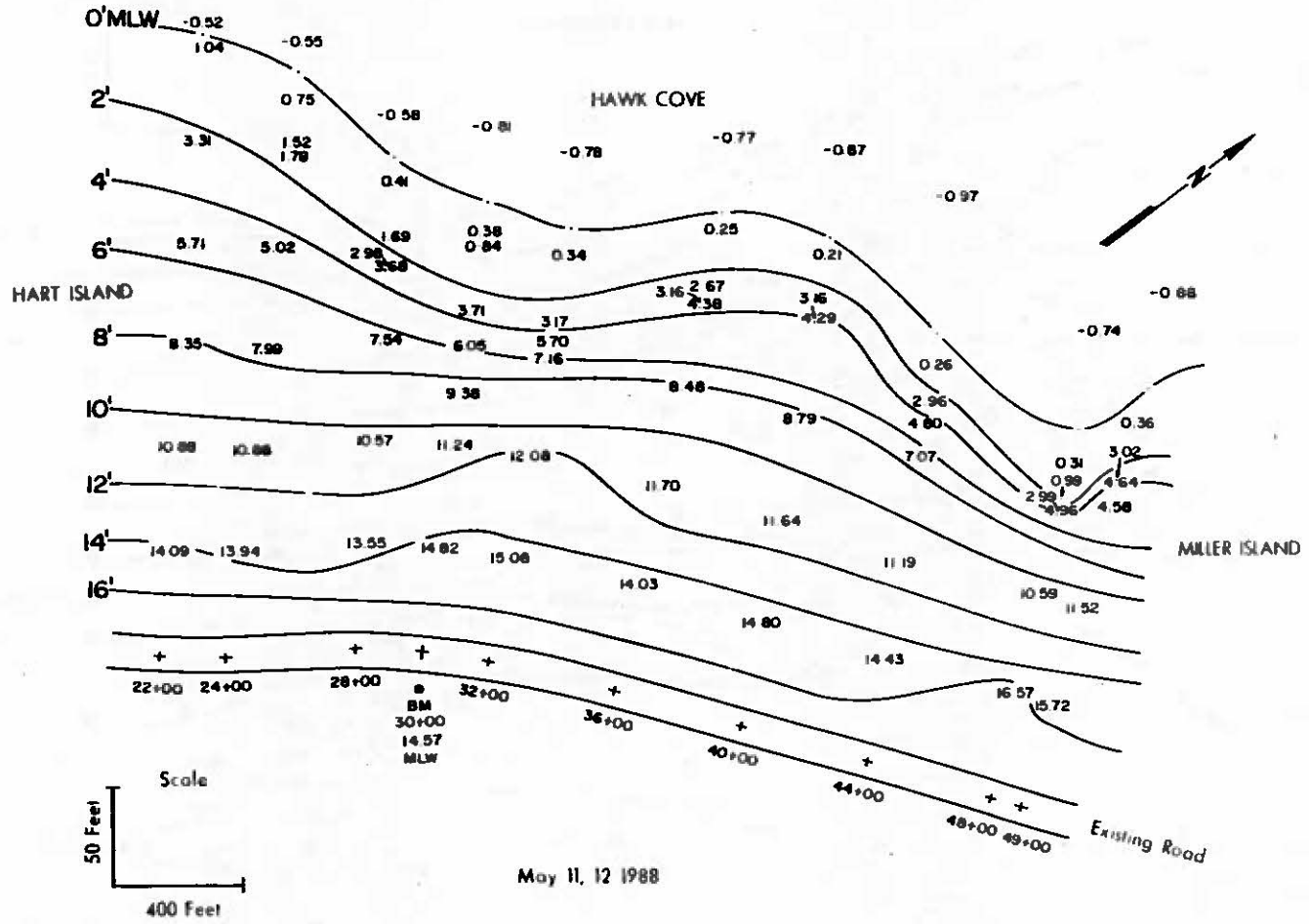

0'MLW
2'
4'
6'
8'
10'
12'
14'
16'
HAWK COVE
HART ISLAND
MILLER ISLAND
22+00
24+00
28+00
BM
30+00
14.57
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
May 11, 12 1988

Figure C-4

APPENDIX D

Cross-sectional profiles of the recreational beach.

Figures D-1 through D-10

Cross-sectional profiles for each of the profile stations, based on surveys conducted in June 1987 and May 1988.

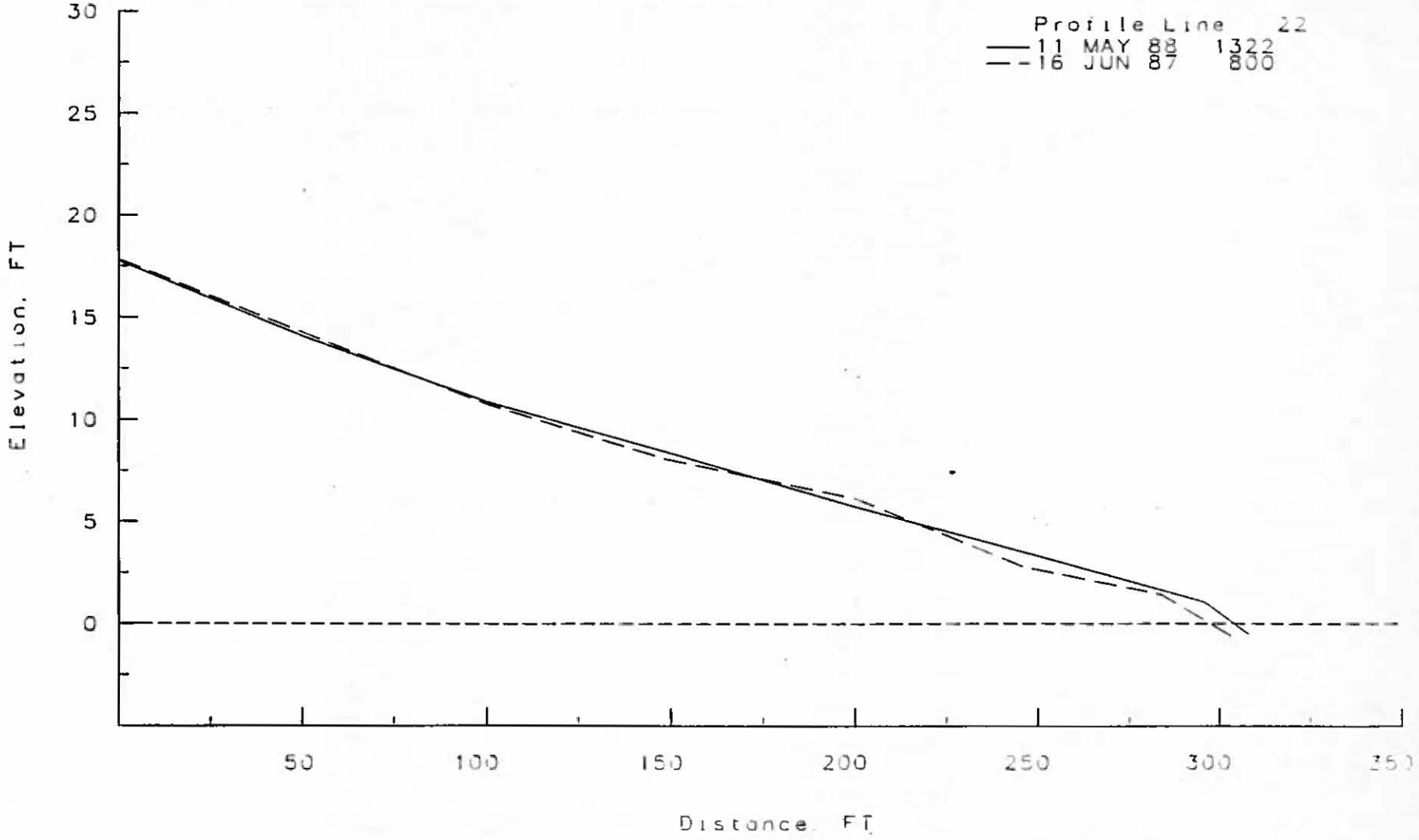

Profile Line 22
11 MAY 88 1322
16 JUN 87 800
30
25
20
15
10
5
0
Elevation, FT
50
100
150
200
250
300
Distance, FT

Figure D-1

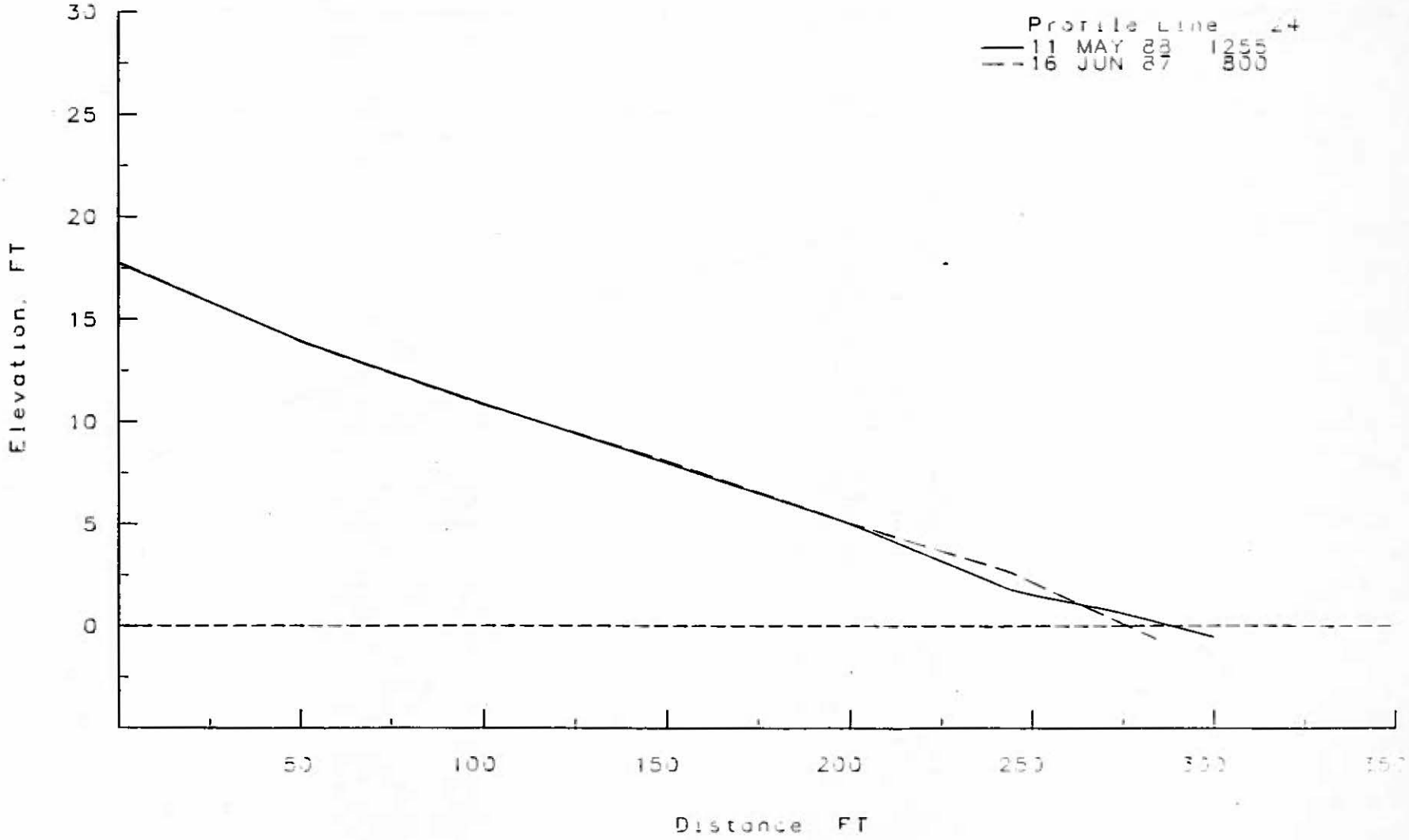

Profile Line 24+
11 MAY 88 1255
16 JUN 87 800
30
25
20
15
10
5
0
Elevation, FT
50
100
150
200
250
Distance FT

Figure D-2

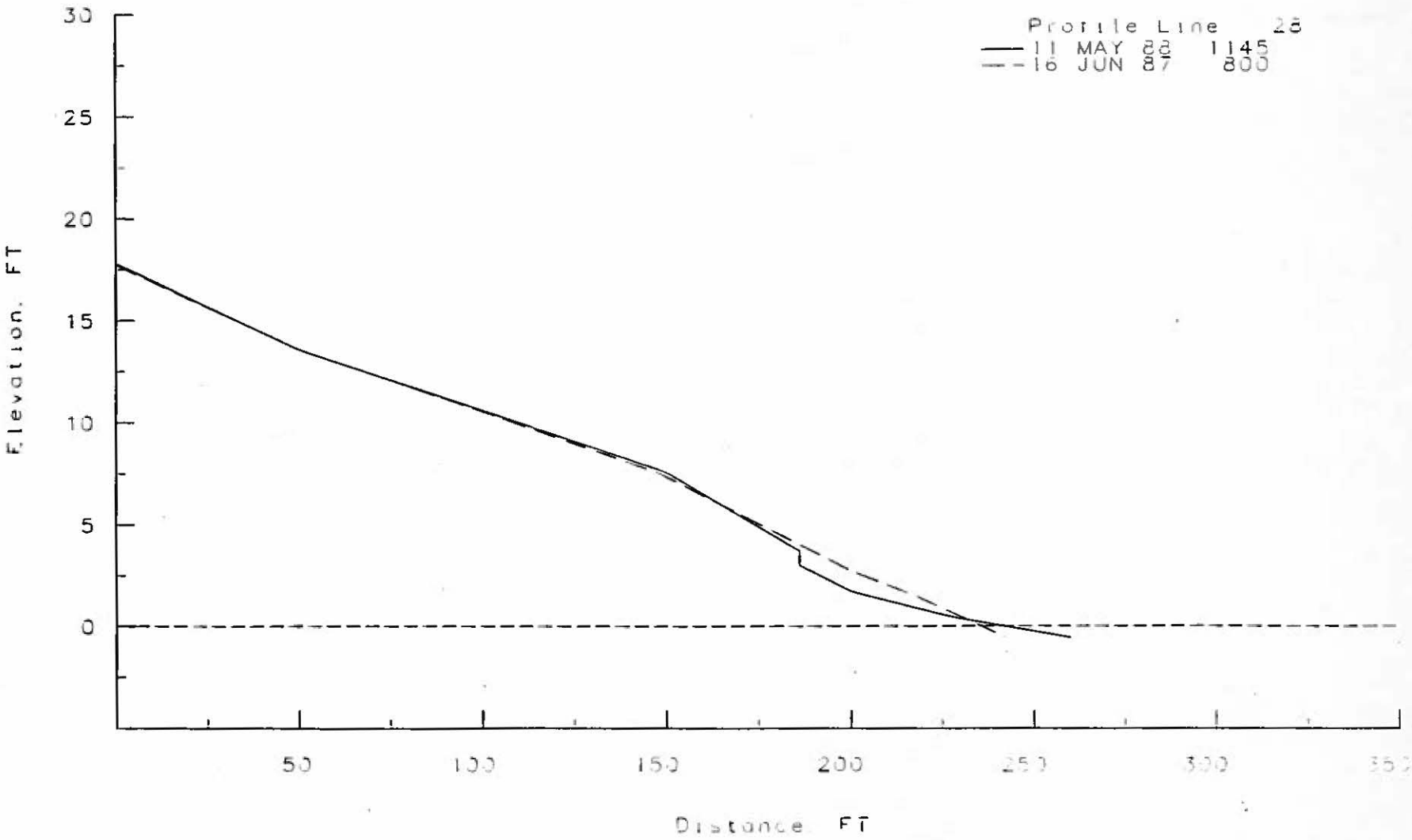
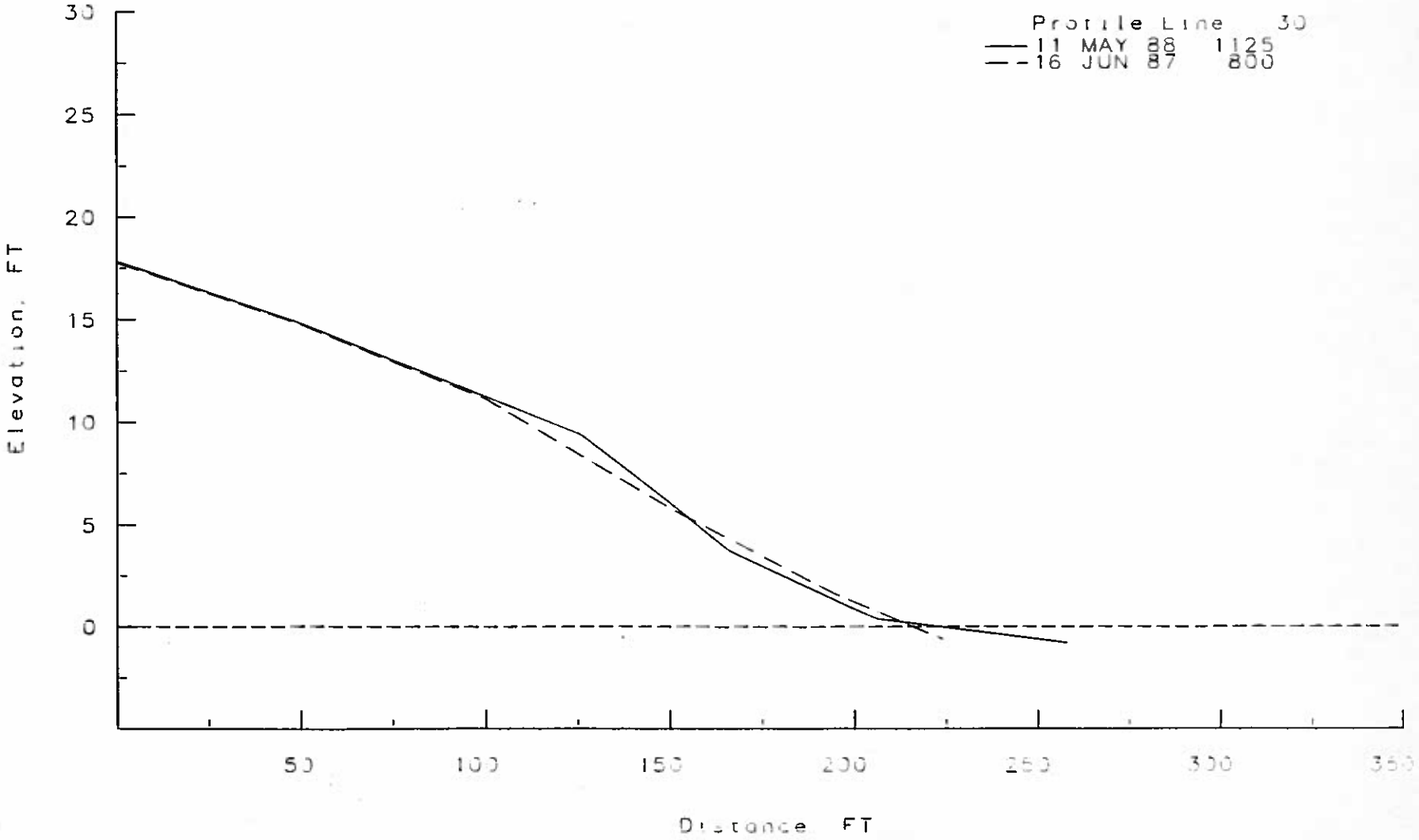

Profile Line 28
11 MAY 88 1145
16 JUN 87 800
30
25
20
15
10
5
0
Elevation, FT
50
100
150
200
250
300
350
Distance FT

Figure D-3


Profile Line 30
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16 JUN 87 800
30
25
20
15
10
5
0
Elevation, FT
50
100
150
200
250
300
350
Distance FT

Figure D-4

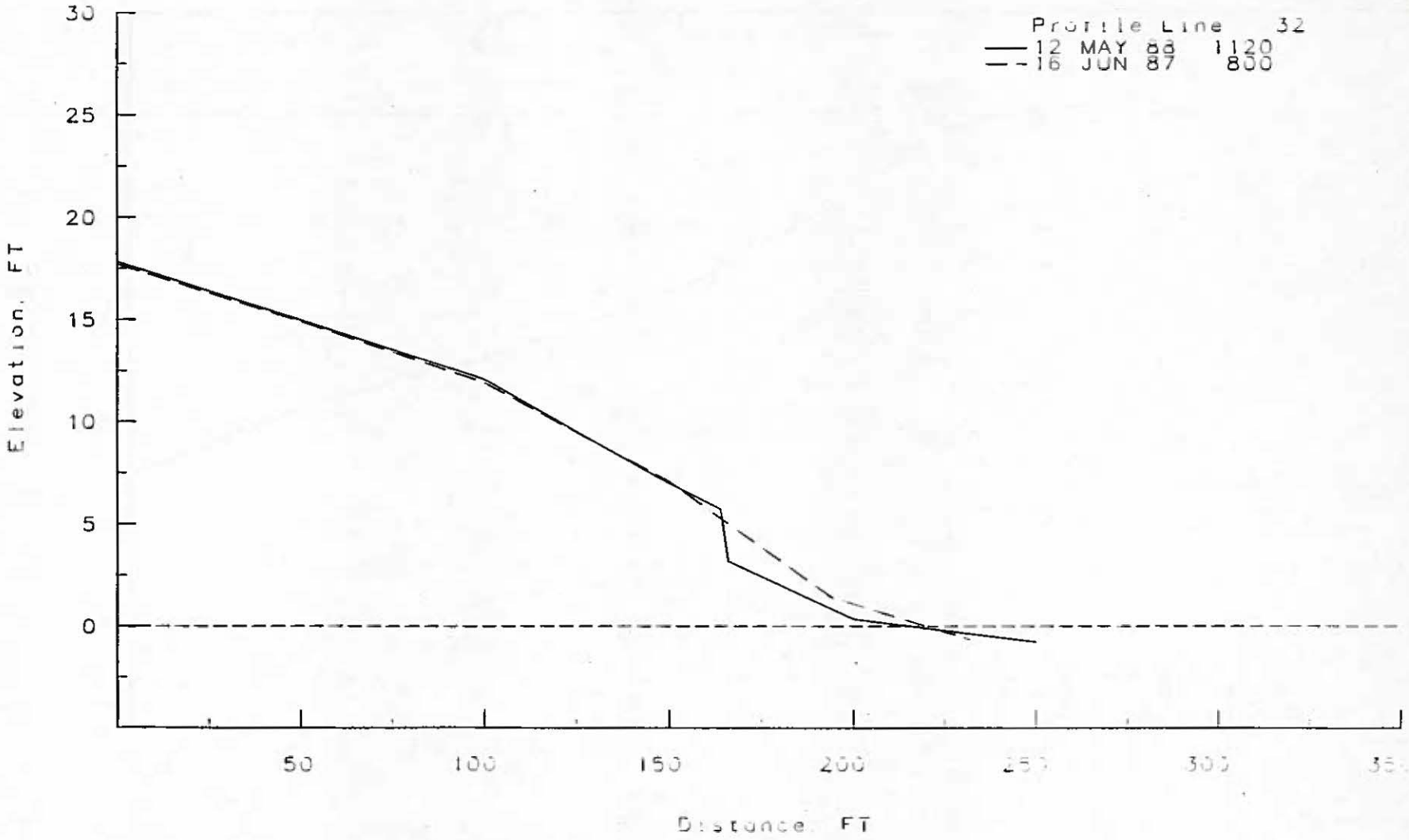

Profile Line 32
12 MAY 88 1120
16 JUN 87 800
30
25
20
15
10
5
0
Elevation, FT
50
100
150
200
Distance, FT

Figure D-5

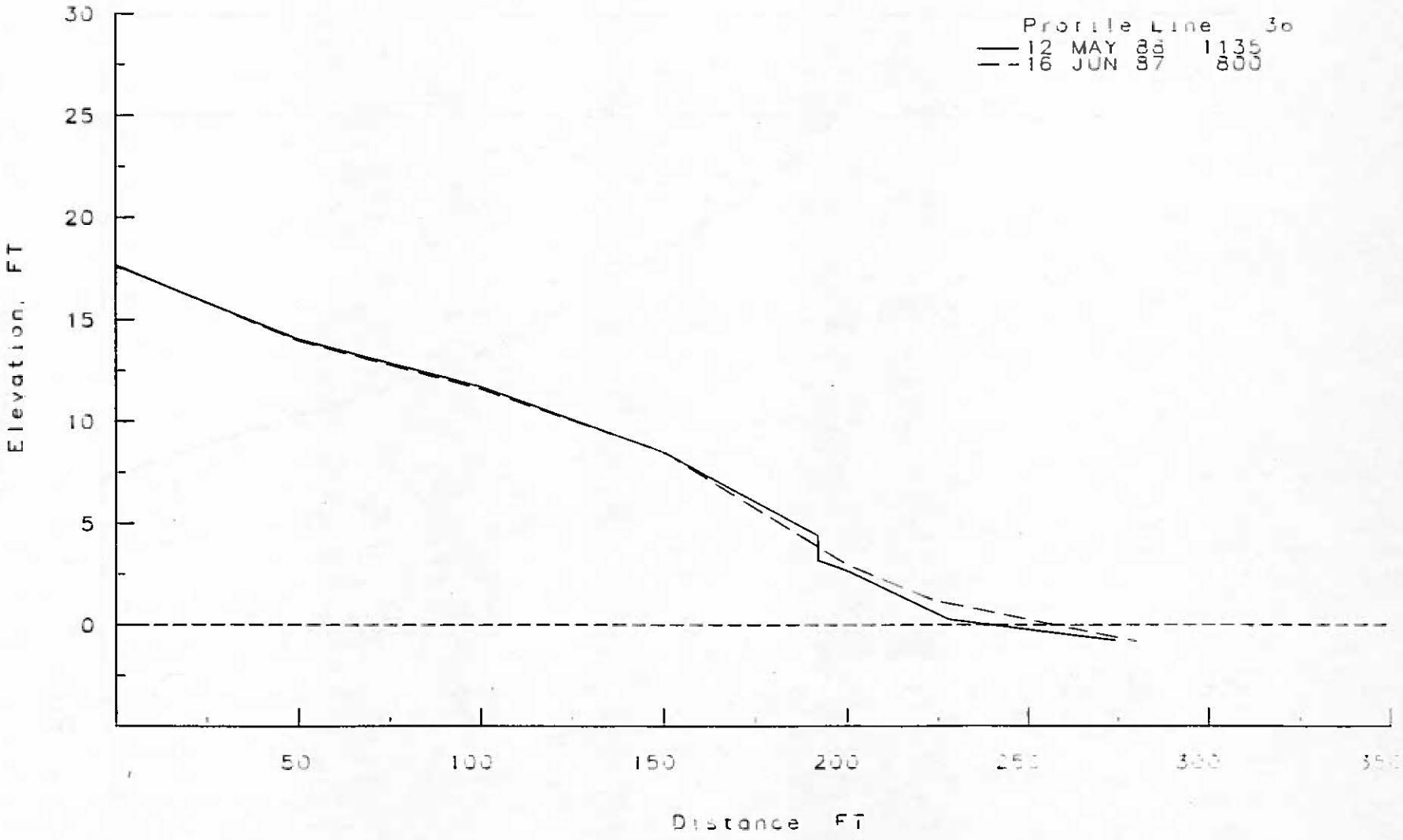
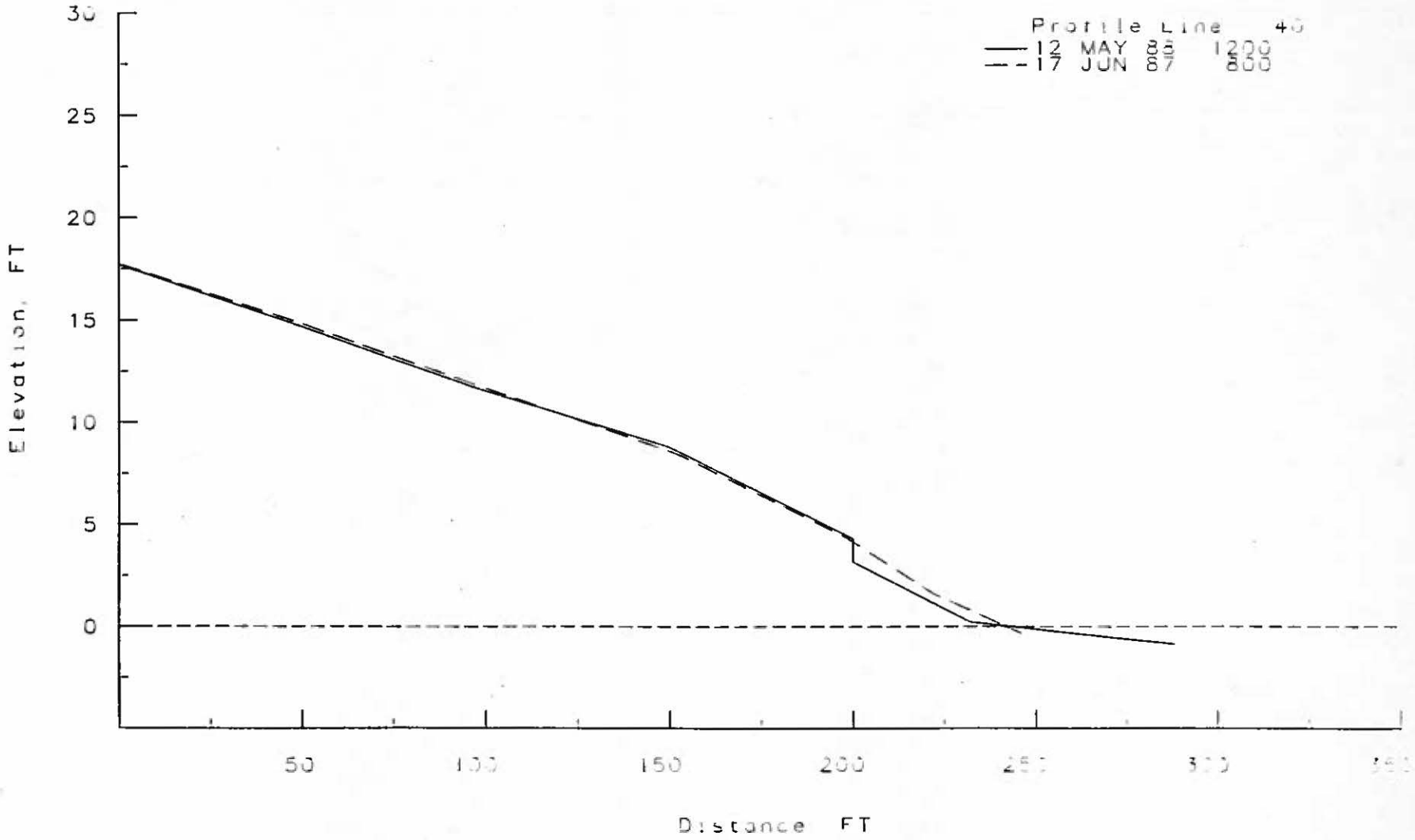

Profile Line 3o
12 MAY 88 1135
16 JUN 87 800
30
25
20
15
10
5
0
Elevation, FT
50
100
150
200
Distance FT

Figure D-6


Profile Line 40
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17 JUN 87 800
30
25
20
15
10
5
0
Elevation, FT
50
150
200
Distance FT

Figure D-7

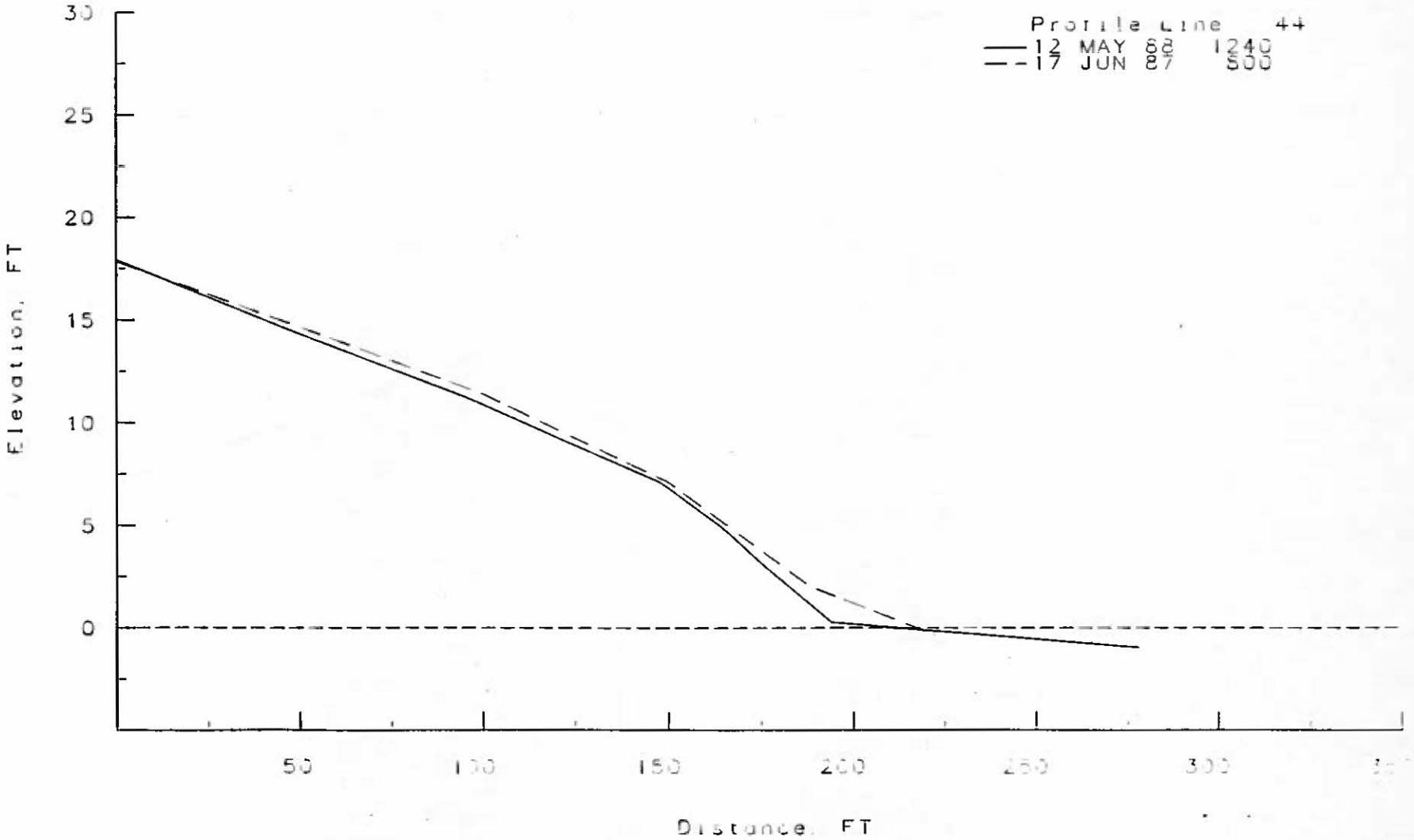
Profile Line 44
12 MAY 88 1240
17 JUN 87 800
30
25
20
15
10
5
0
Elevation, FT
50
100
150
200
250
300
Distance, FT

Figure D-8

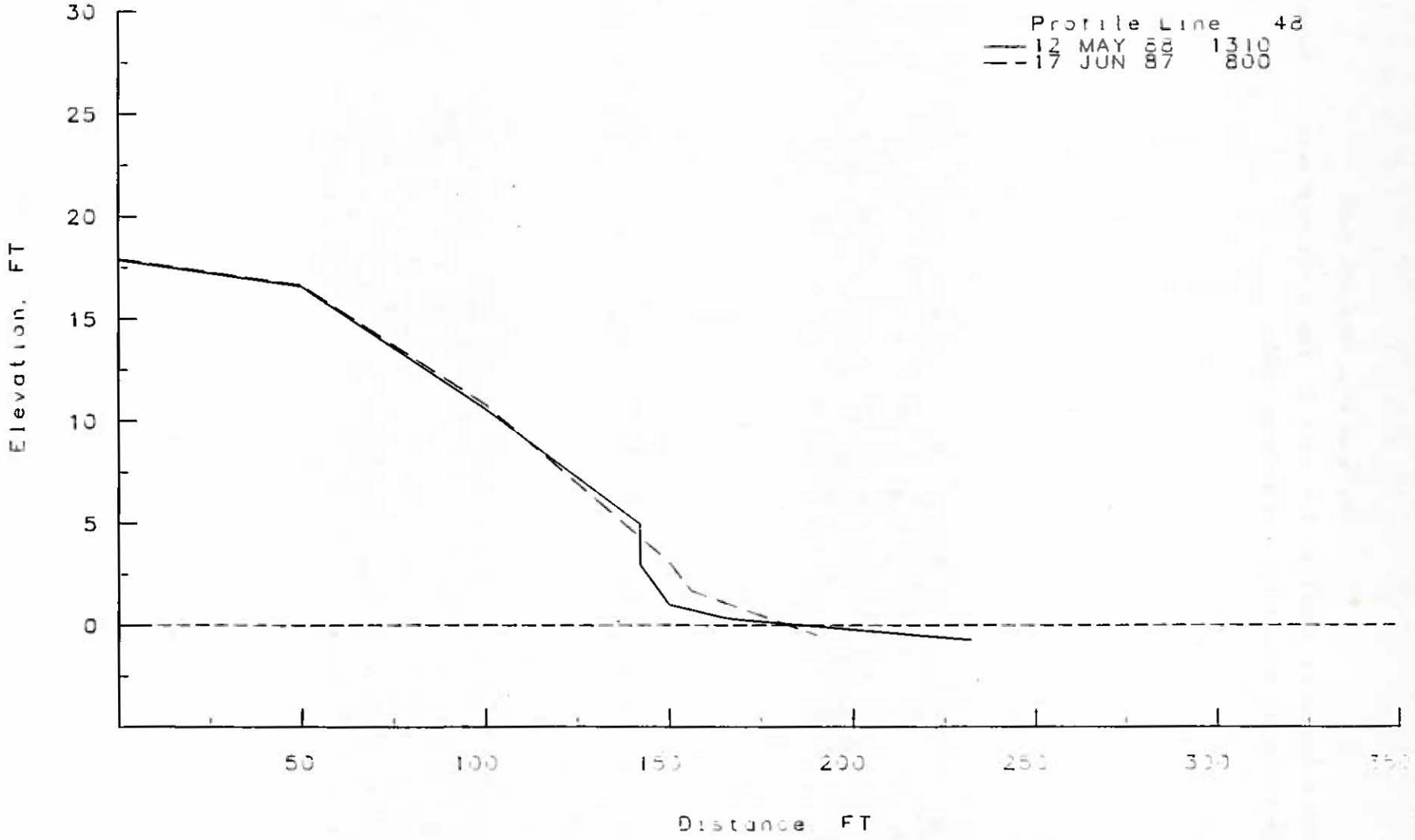
Profile Line 48
12 MAY 88 1310
17 JUN 87 800
30
25
20
15
10
5
0
Elevation, FT
50
100
150
200
250
300
Distance, FT

Figure D-9

Figures D-11 through D-20

Cross-sectional profiles for each of the profile stations, based on surveys conducted in June/July 1984 and May 1988.

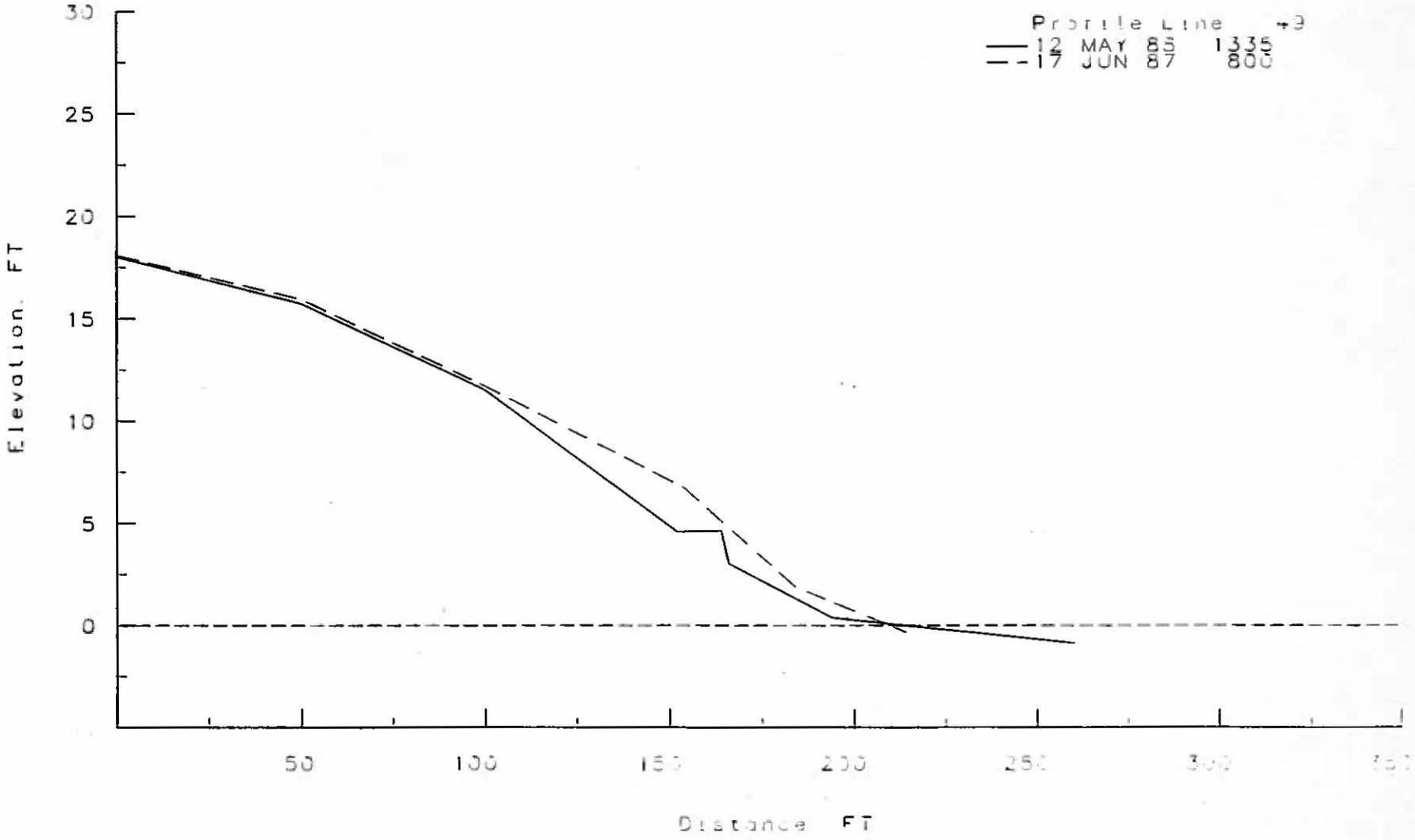
Profile Line +9
12 MAY 85 1335
17 JUN 87 800
30
25
20
15
10
5
0
Elevation, FT
50
100
Distance FT

Figure D-10

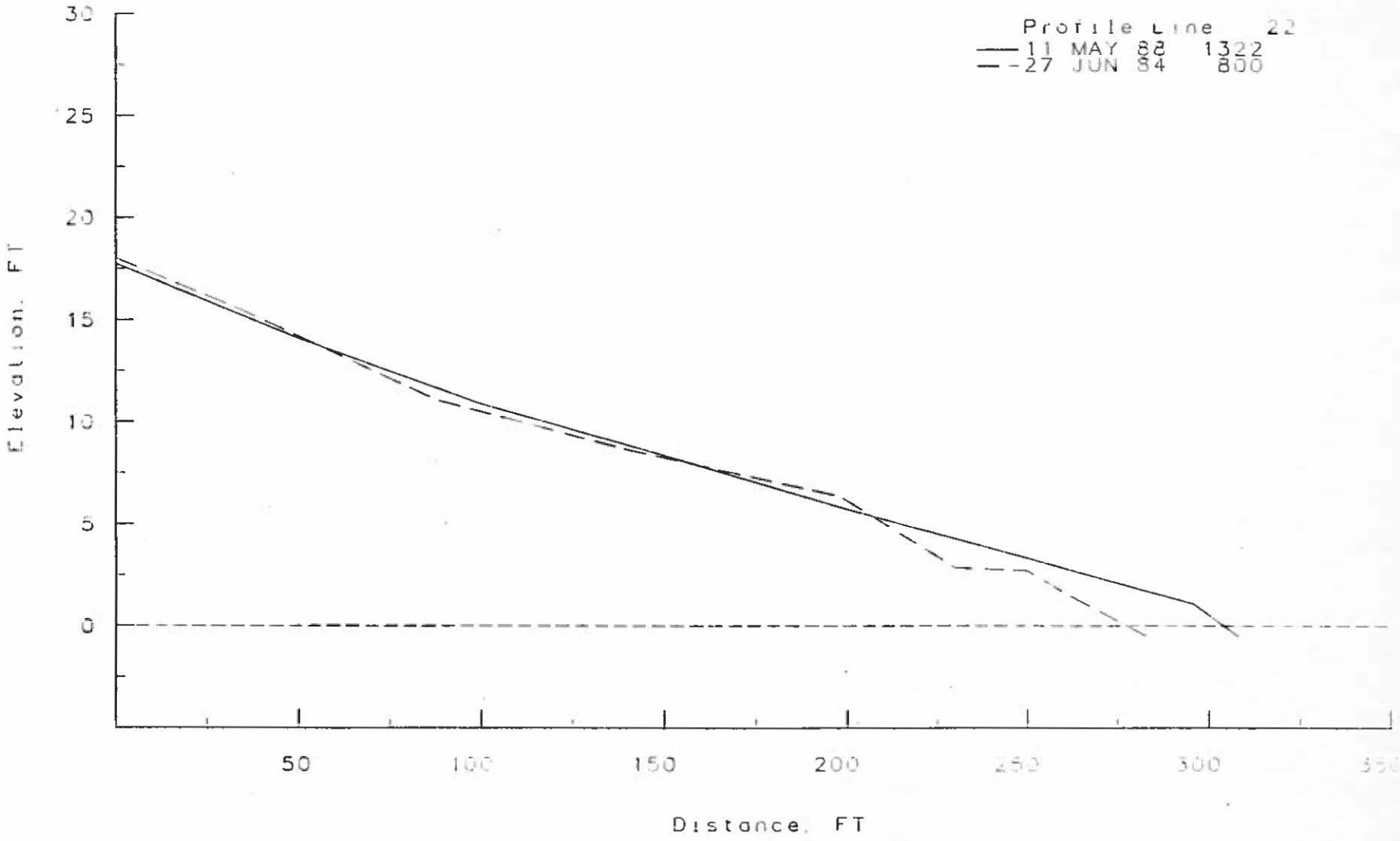
Profile Line 22
11 MAY 82 1322
27 JUN 84 800
30
25
20
15
10
5
0
Elevation, FT
50
100
150
200
250
300
350
Distance, FT

Figure D-11

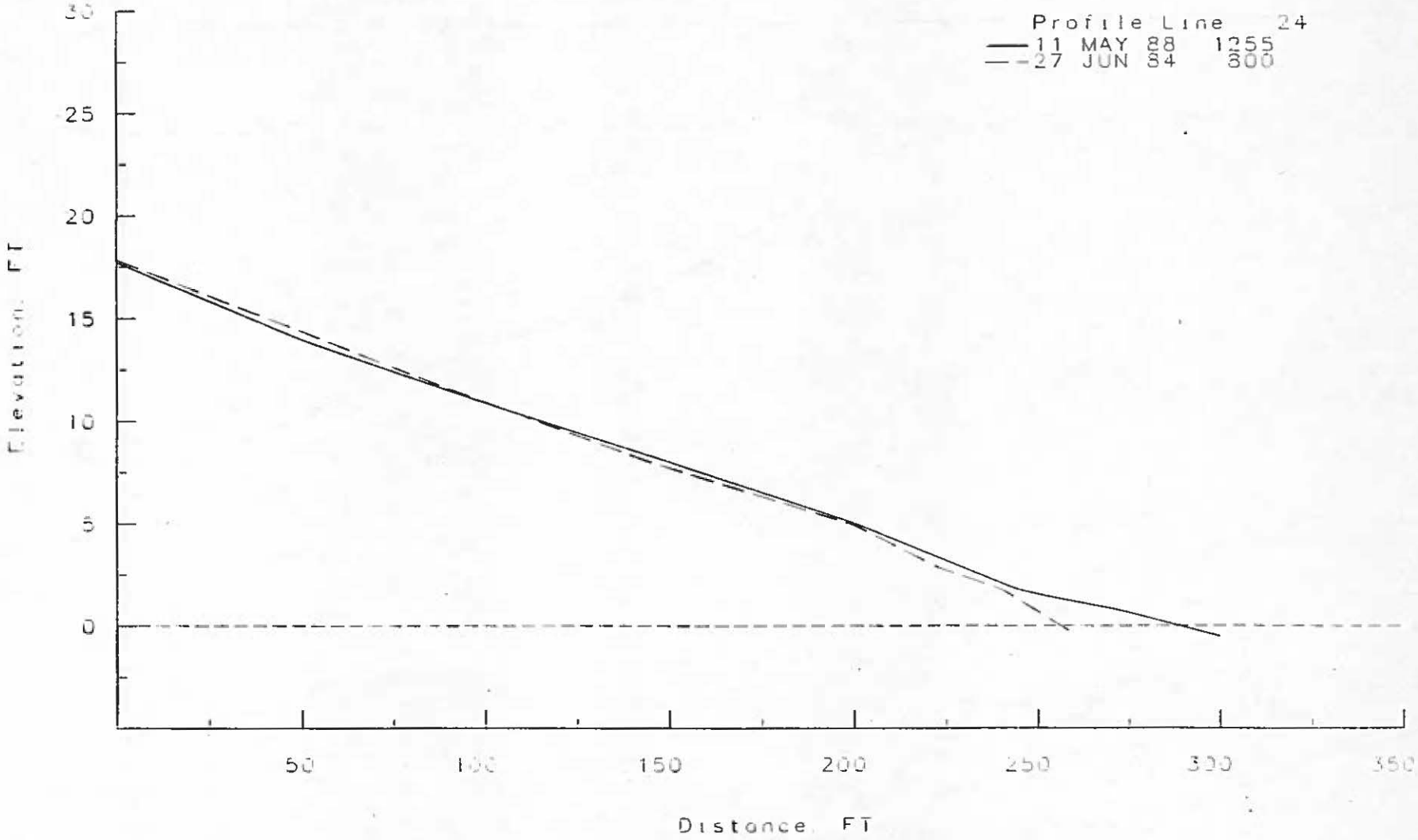
Profile Line 24
11 MAY 88 1255
27 JUN 84 800
30
25
20
15
10
5
0
Elevation, FT
50
100
150
200
250
300
350
Distance, FT

Figure D-12

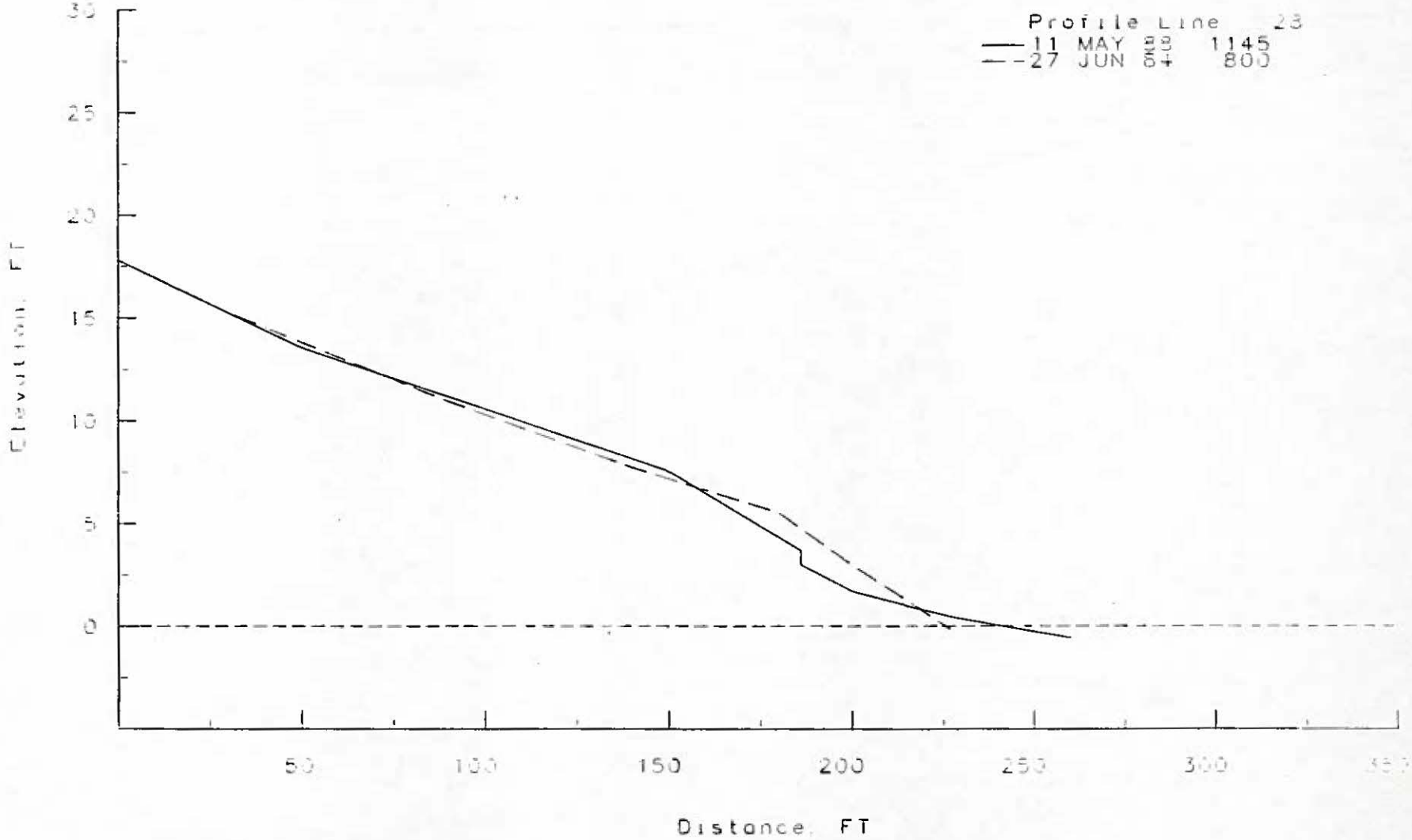
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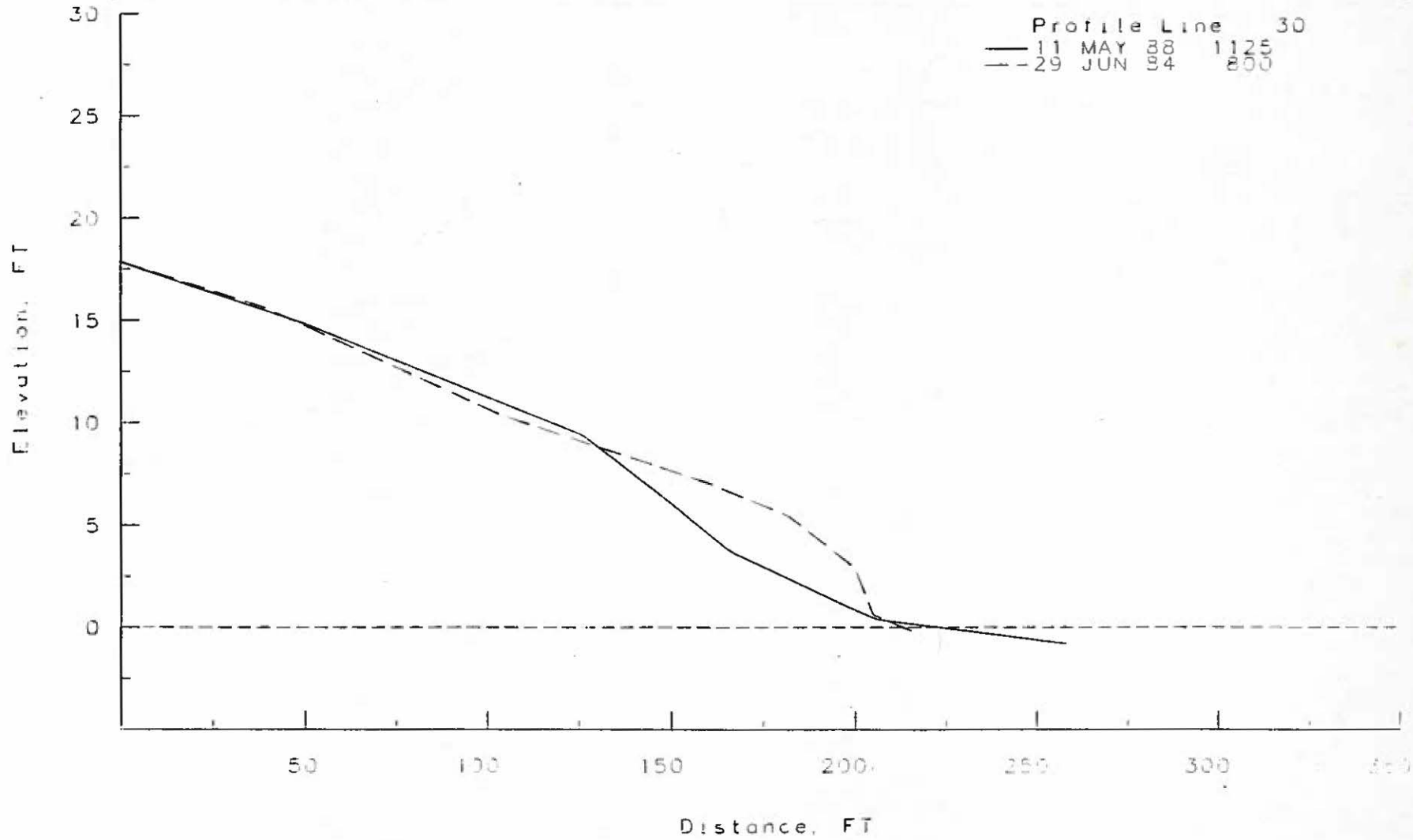
Figure D-13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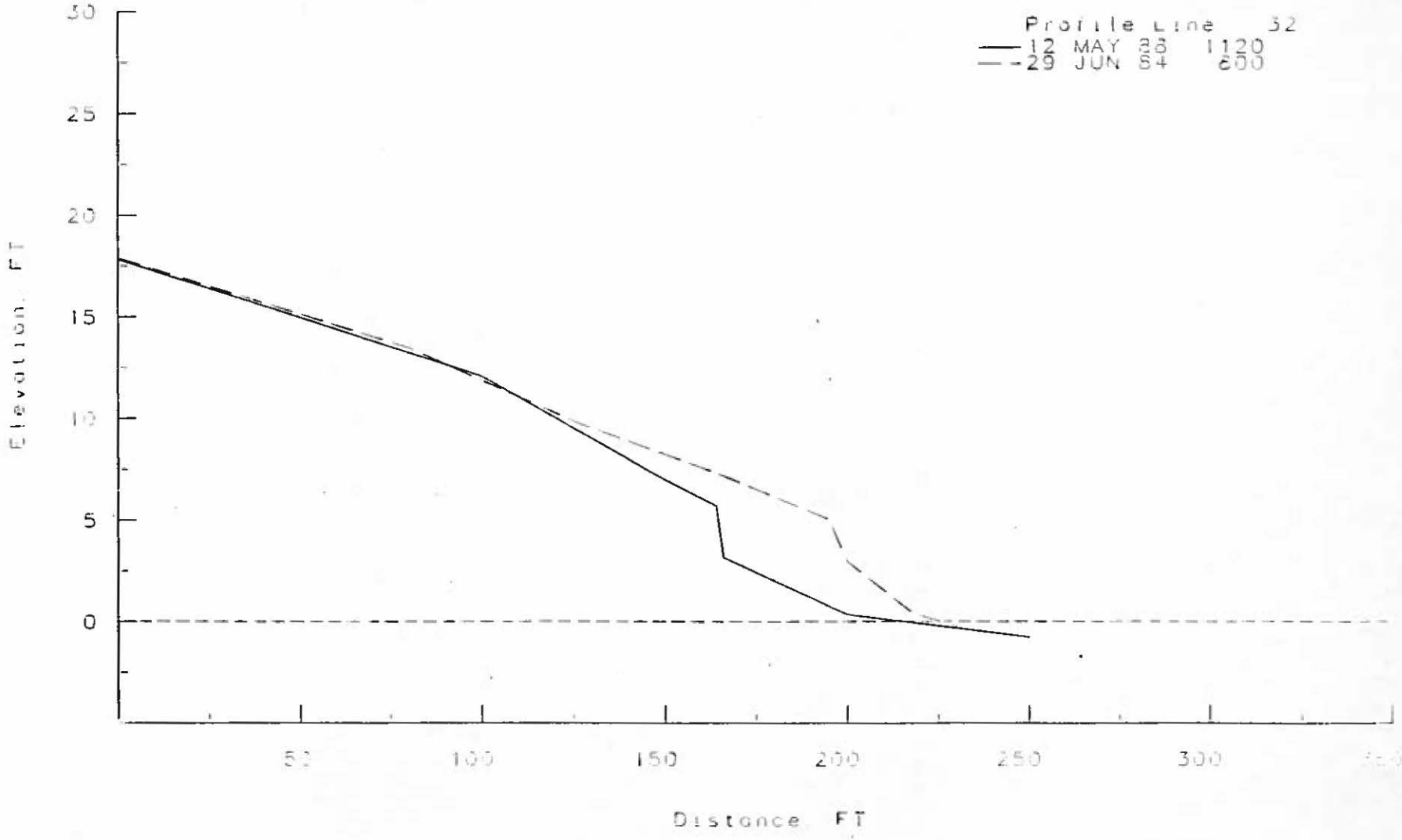
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Figure D-15

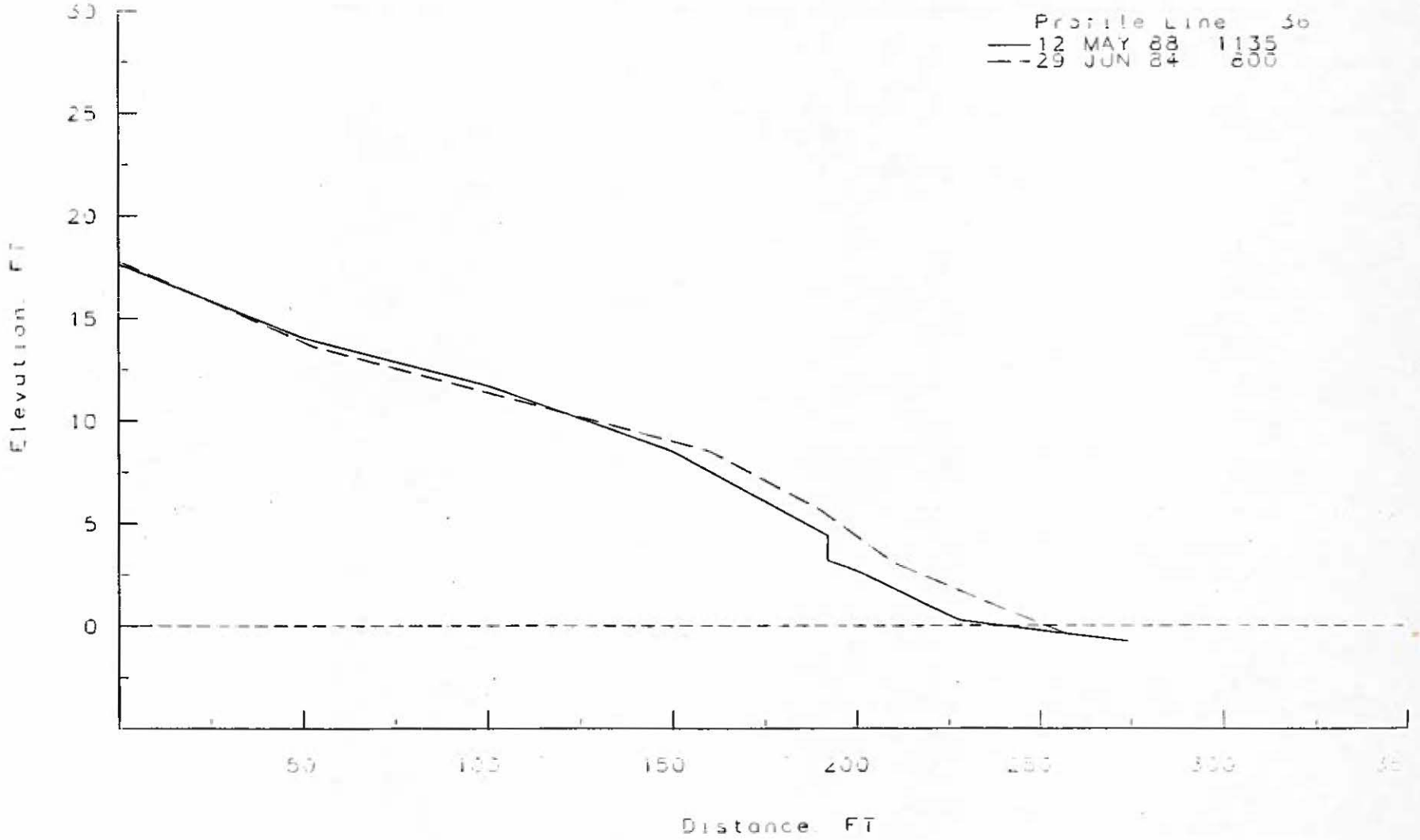
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Figure D-16

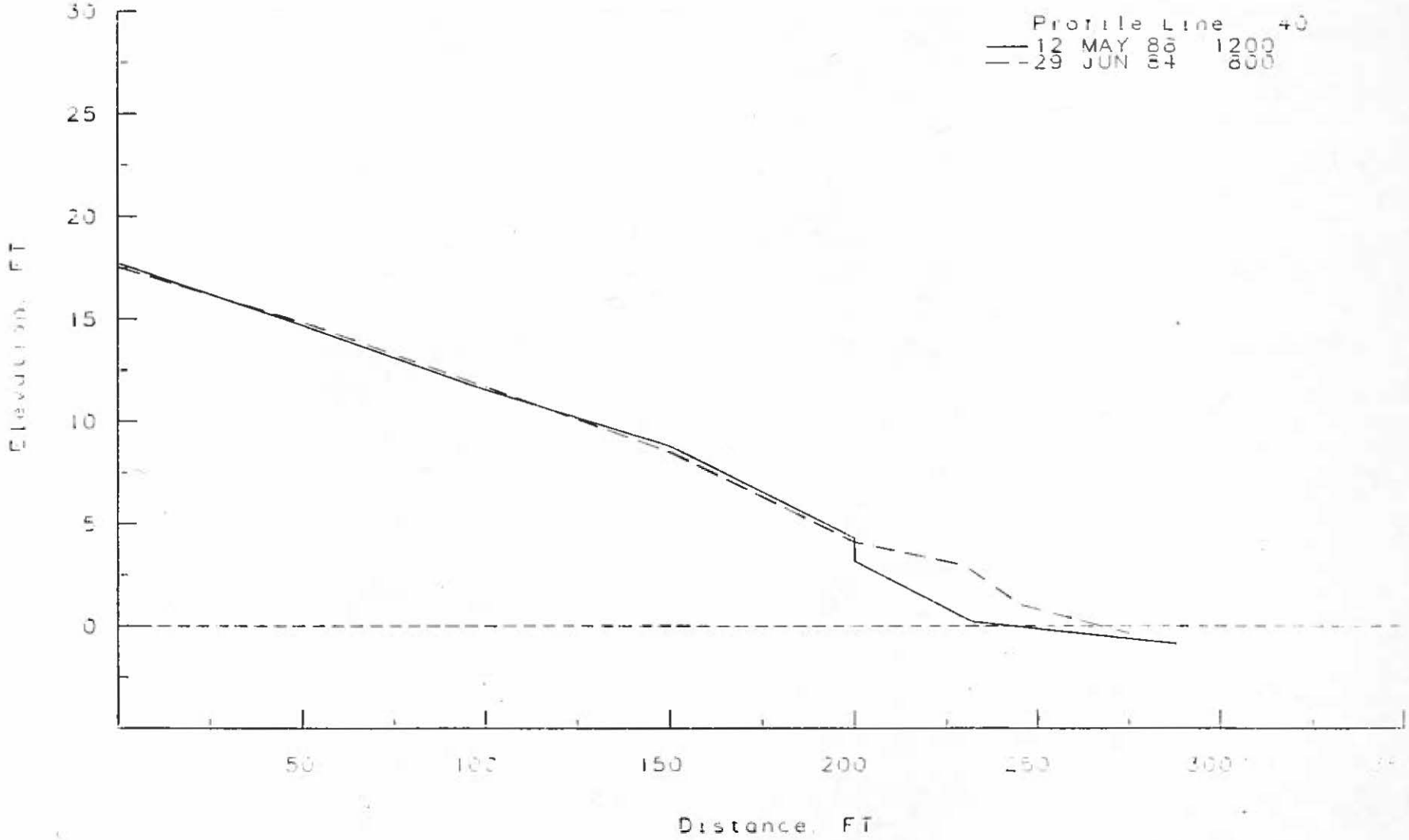
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Figure D-17

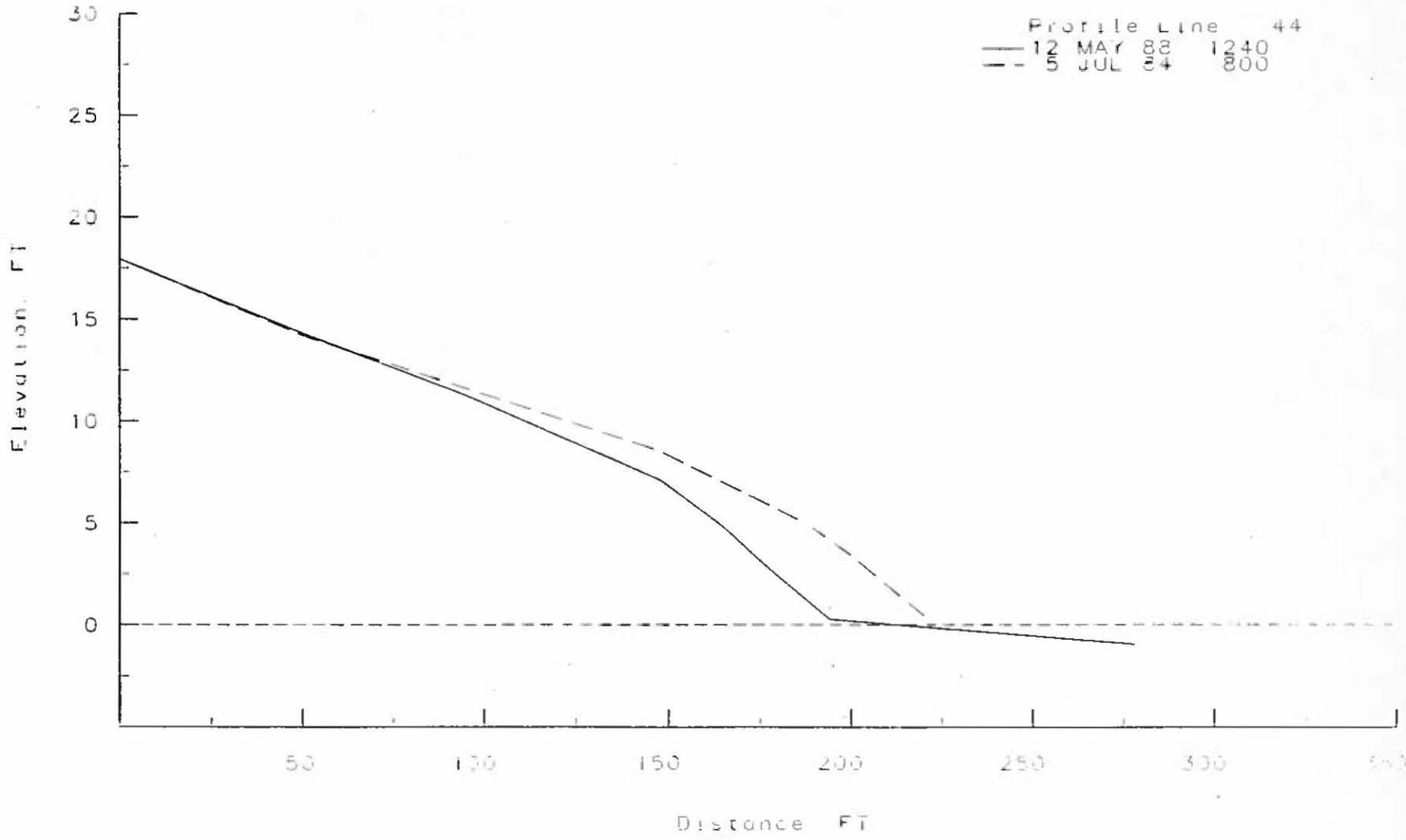
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Figure D-18

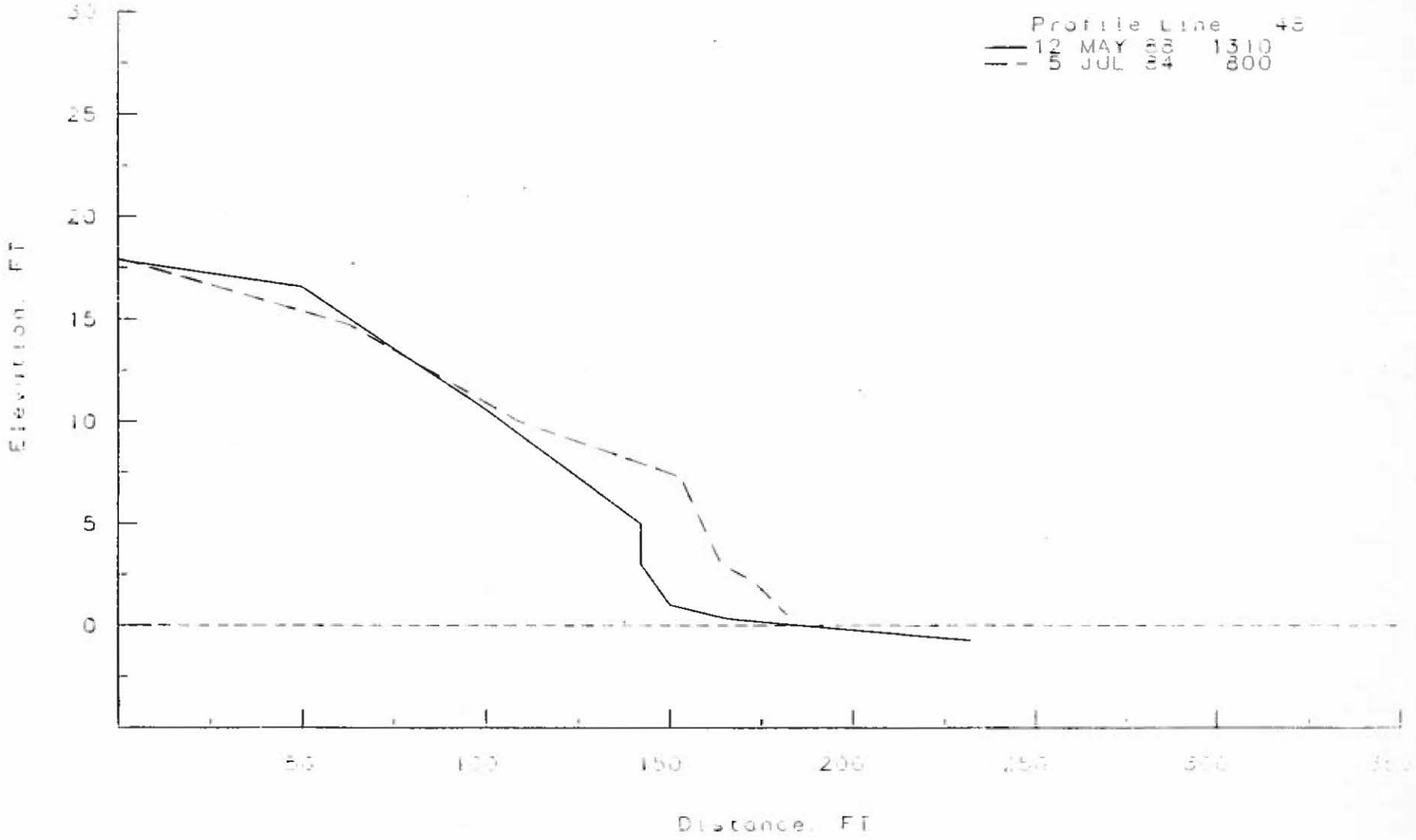
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Figure D-19

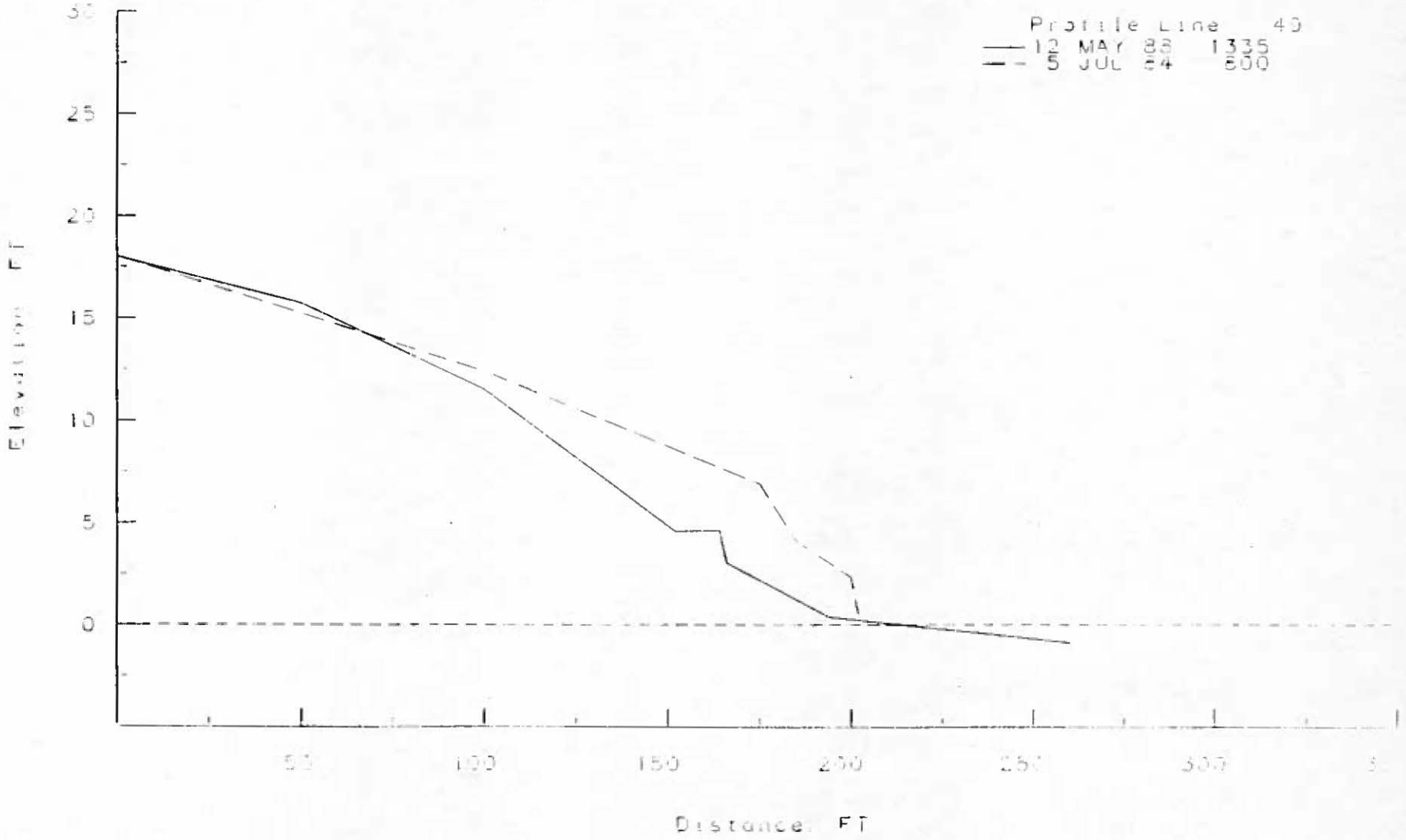
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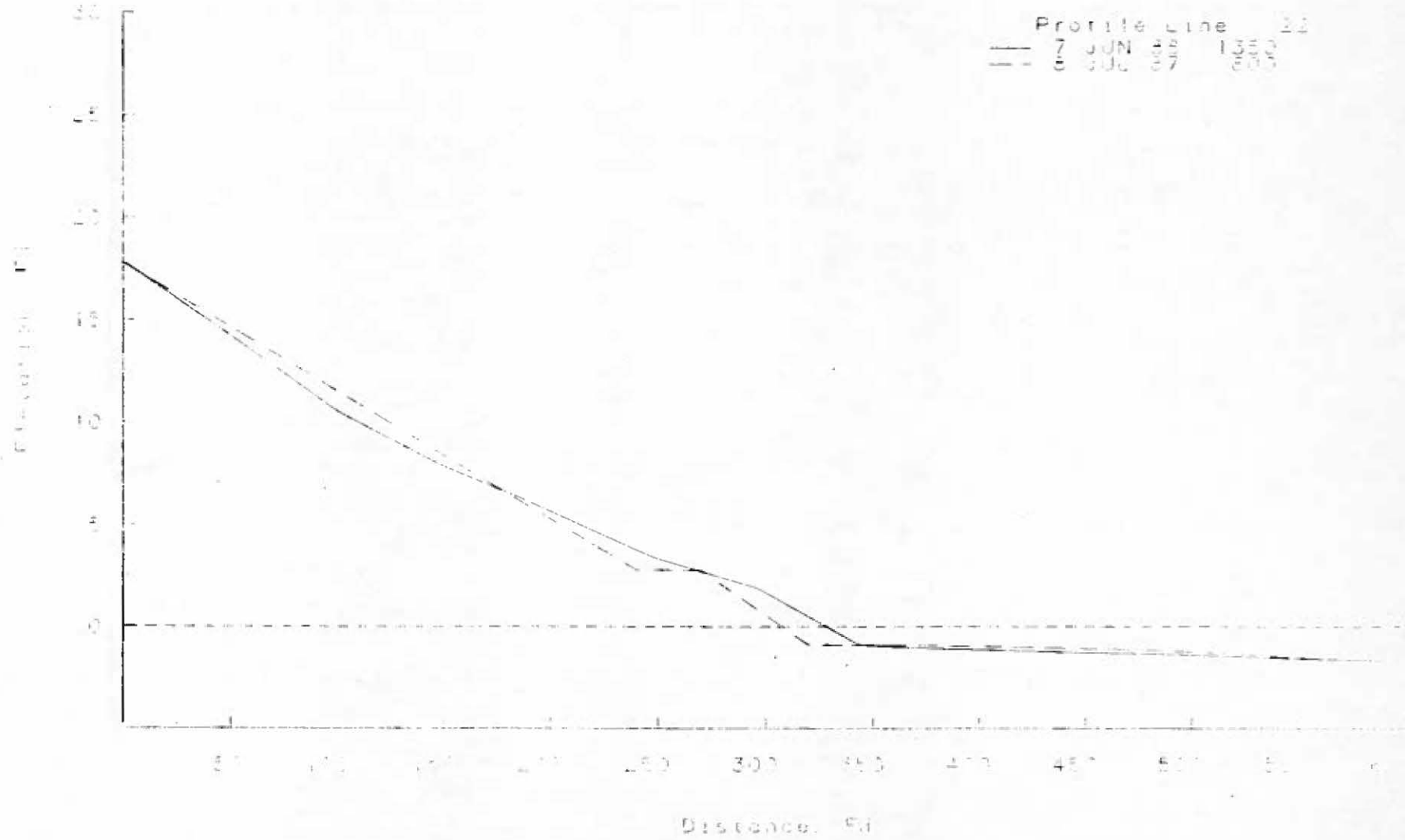
Figure D-20



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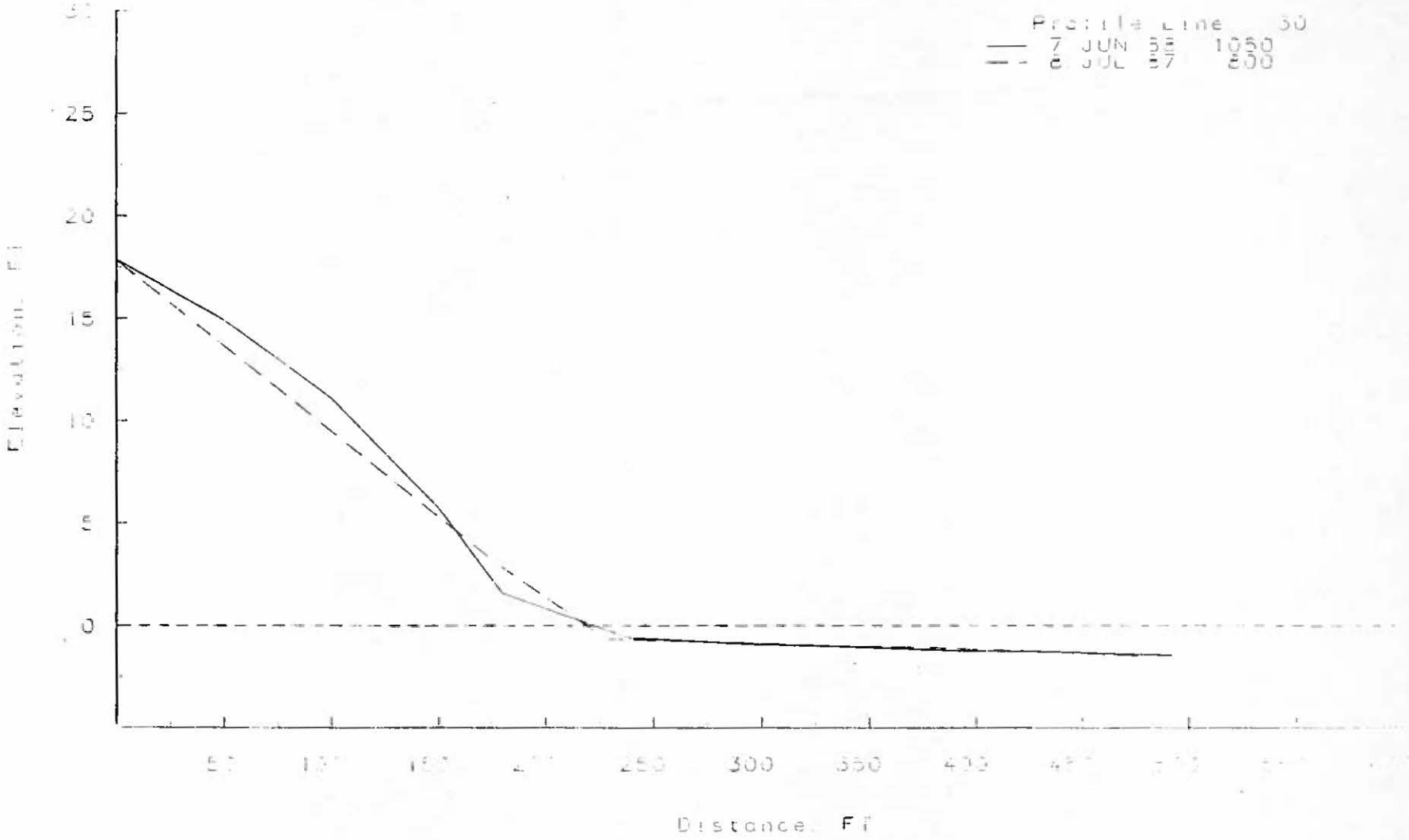
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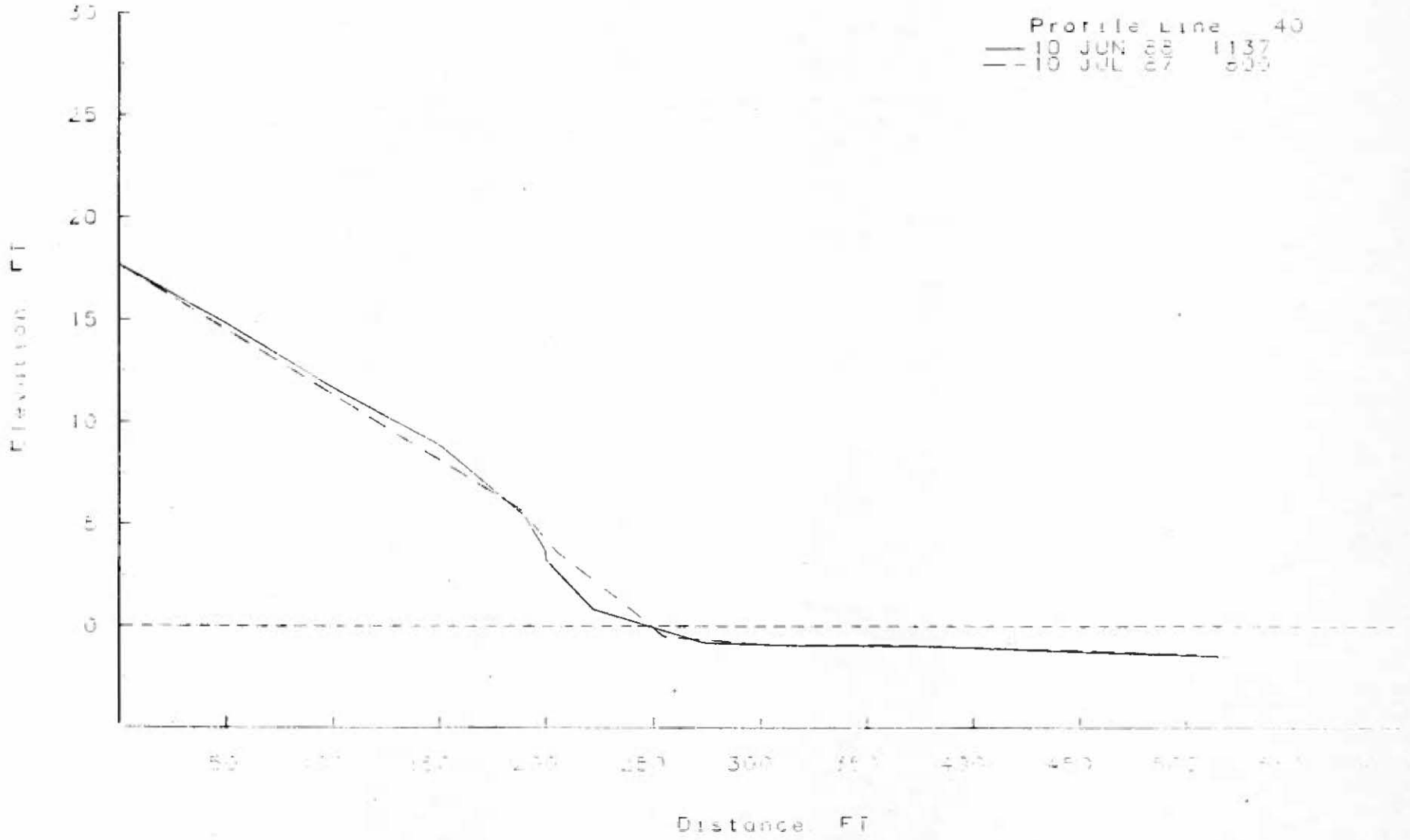
Figure D-22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0
Distance FT

Figure D-23


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10 JUL 87 800
25
20
15
10
0
Distance FT

Figure D-24

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PROJECT III

BENTHIC STUDIES

BY

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ABSTRACT

The benthic invertebrate populations in the vicinity of the dredged material containment facility at Hart-Miller Island were monitored in order to assess any possible effects of the operation of the facility on the biota. Nearfield infaunal and epifaunal samples were taken along with reference samples in December 1987 and April and August 1988. The infaunal samples were collected with a 0.05 m^2 Ponar grab and washed on a 0.5mm screen. Epibenthic samples were scraped either by a SCUBA diver or with a specially designed scraping apparatus from the pilings that support a series of piers which surround the containment facility. Thirteen infaunal stations were sampled on each cruise (8 experimental and 5 reference). The stations include nine silt-clay stations, three oyster shell stations and one sand substrate station. A total of 35 benthic species was collected from these thirteen stations. The most abundant species were the annelids, *Scolecolepides viridis*, *Heteromastus filiformis*, and *Tubificoides* sp.; the crustaceans, *Leptocheirus plumulosus*, and *Cyathura polita*; and the clams, *Rangia cuneata* and *Macoma balthica*.

Species diversity (H') values were evaluated at each station. The highest diversity value (3.1656) was obtained for a nearfield oyster shell station (S2) in August, whereas the lowest diversity value occurred at a nearfield silt/clay station (S3) in April. For the three sampling dates the highest diversity values overall occurred in August and the lowest in April.

The length-frequencies of the clams, *R. cuneata*, *M. balthica*, and *Macoma mitchelli* were examined at the nearfield and reference stations, and there was good correspondence in terms of the numbers of clams and the size groupings for the three sampling dates. Cluster analysis of the stations over the three sampling periods usually associated stations in response to bottom type and whether they were experimental or reference sites. Variations in recruitment might explain why some specific stations did not form tight groupings. The clusters were consistent with earlier studies and did not indicate any unusual groupings associated with the containment facility. A one way analysis of variance, using the Student Neuman-Keuls test, of the number of individuals of each species in the samples for each station, indicated that nearfield stations, S1 and S2 were significantly different in April and August, presumably because

of their shallow depth and sandy or shelly substrate. Rank-analysis of differences in the mean abundances of selected species at the stations with silt/clay substrates indicated significant differences for the nearfield stations in December and for the reference stations in April and August. Significant differences in means for the combined silt/clay nearfield and reference stations occurred only in August.

Epifaunal populations were similar to those observed in previous years. Samples were collected at depths below the winter ice scour zone. The epifaunal population persisted throughout the year at these deeper locations along the pilings. The nearfield and reference populations were very similar over all three sampling periods. As previously reported, the amphipod, *Corophium lacustre*, is one of the most abundant organisms present at both the reference and nearfield stations at all sampling periods. The colonial bryozoan, *Victorella pavida* was likewise present at both reference and nearfield stations at all sampling periods.

The results of the current monitoring effort suggest, once again, only localized and temporary effects on the benthos result from the containment facility. These effects, limited primarily to the area where dredged material is transferred from barges to the facility, are believed to be caused by a washing-away of the bottom by tugboat propellers. Although discharge of effluent from the facility occurred during this sampling year, no adverse effects on the benthic populations have been observed to date. Nonetheless, continued monitoring of the area is necessary during this period of increased activity around the facility and actual expansion in overall size of the containment facility.

INTRODUCTION

This report presents the results of studies conducted during the seventh consecutive year of benthic sampling for baseline and monitoring studies at the Hart-Miller Island containment facility. Estuarine areas such as the Hart-Miller Island site, with wide seasonal salinity changes and vast, shallow, soft-bottom shoals, are important to protect because they serve as important breeding and nursery grounds rich in nutrients for many commercial and non-commercial species of invertebrates and migratory fish.

Since it is an area that is environmentally unpredictable from year to year, it is important to maintain as complete a record as possible on all facets of the ecosystem. Holland (1985) and Holland et al. (1987) completed long-term studies of more stable mesohaline areas further down-Bay and found that most macrobenthic species showed significant year-to-year fluctuations in abundance, primarily as a result of slight salinity changes. Spring was a critical period for the establishment of both regional and long-term distribution patterns. One can thus expect even greater fluctuations in the benthic organisms inhabiting the region of the Hart-Miller Island containment facility, which is located in the highly variable oligohaline portion of Chesapeake Bay. Indeed past studies (Pfitzenmeyer and Tenore, 1987; Duguay, Tenore, and Pfitzenmeyer, 1988)indicate that the benthic invertebrate populations in this region are predominantly opportunistic or r-selected species with short life spans, small body size and often high numerical densities. These opportunistic species are characteristic of disturbed or highly variable regions (Beukema, 1988).

Dredge-related activities at Hart-Miller Islands during the current monitoring year were concentrated at the rehandling piers where dredged material from barges was unloaded into the containment facility. The volume of material inside the dike has now reached a sufficient level for treated effluent to be discharged from the facility. The dike is presently in the process of being expanded to receive additional dredged materials.

The objectives of the study presented in this report were:

1. To monitor the nearfield benthic populations for possible effects of discharged effluents and by following changes in population size and species composition over seasonal cycles.

2. To collect samples of the epibenthic fauna on the pilings along the perimeter of the island for any signs of detrimental effects.

3. To continue monitoring of benthic and epibenthic populations at established reference stations for inter-comparisons.

4. To provide selected species of benthic invertebrates and fish for chemical analysis of organics and metals by an outside laboratory (Martel, Inc.), in order to ascertain various contaminant levels as well as possible bioaccumulation.

METHODS

Sampling was conducted at a network of stations surrounding the disposal area (Figures 1 & 2, CBL and STATE designations, respectively). Six nearfield stations (S1-S6) were located within 90 m of the dike along its eastern side, extending within 90 m of the dike from the northern to the southern end. Station S7 was located about 180 m from the effluent pipes, and another station S8 was located about the same distance from the rehandling piers. Four reference stations were resampled during the year. They were HM16, a soft-bottom station located about 1.9 km southeast of the island; HM9 located on an oyster shell bottom about 36 m northeast of the island; HM22, a soft-bottom station located about 3.7 km north of the island; and HM7, located on soft-bottom about 35 m northwest of the island. Station HM26, located at the mouth of Back River, was resampled this year as a monitoring check of that critical area and its possible influence on the fauna to the west of the island. Epifaunal samples (R1-R4) were obtained from pilings located about 25 m from the dike, at depths of 1-1.3 m below the surface of the water and 1 m above the bottom (about 2-3m depth). An epifaunal reference station (R5), located on a navigational beacon at the Pleasure Island channel, was again sampled this year.

Three primary cruises were conducted on December 7-8, 1987, April 11-14, 1988, and August 1-2, 1988. Three replicate grabs were taken with a 0.05 m^2 Ponar grab at each benthic infaunal station for each sampling period. The samples were washed separately on a 0.5 mm screen and fixed in 10% formalin/seawater on board the ship. In the laboratory, the samples were again washed on a 0.5 mm sieve and transferred to 70% ethyl alcohol. The samples were then sorted, and each organism was removed, identified, and enumerated. Length-frequency measurements were made on the three most abundant mollusks. A qualitative sample was scraped from the pilings at the epifaunal stations (R1-R5) by either a SCUBA diver (December and April) or a specially designed piling scraping device constructed of aluminum (May, June and August). In April, we were unable to complete our epifaunal collections due to inclement weather and equipment problems. We returned to the containment facility on 17 May and 24 June to complete our spring epifaunal sampling and to test the newly designed scrape sampler against diver collected samples. The scrape samples

were treated similarly to the infaunal benthic samples with regard to preservation and general handling. However, only a qualitative or relative estimate of abundance was made for each species through a set of numerical ratings, which ranged from 1 (very abundant) to 3 (present).

Stations were located with the research vessel's radar and LORAN C. Station depths were recorded from the ship's fathometer. Water temperature and salinity were measured from surface water samples collected through the vessel's through-hull seawater intake hoses. Temperature was determined to the nearest 0.5 °C with a hand-held mercury thermometer (range of -20 to 110°C). Salinity was determined to the nearest ppt with an A.O. Goldberg hand-held salinometer .

The quantitative infaunal sample data were analyzed by a series of statistical tests. A method of rank analysis was used to determine dominant species (Fager, 1957). The Shannon-Wiener (H') diversity index was calculated for each station after data conversion to base$_2$ logarithms (Pielou, 1966). Stations were grouped according to numerical similarity of the fauna by cluster analysis (BMDP-77 Biomedical Computer Programs P-Series; Dixon and Brown, 1977). Analysis of variance and the Student-Neuman-Keuls multiple range test were used to determine differences in faunal abundance between stations (Nie et al., 1975). Friedman's non-parametric rank analysis test (Elliott 1977) was used to compare mean numbers of the eleven most abundant species, between the silt/clay, nearfield and reference stations, separately. Then the two sets of stations were added together and retested.

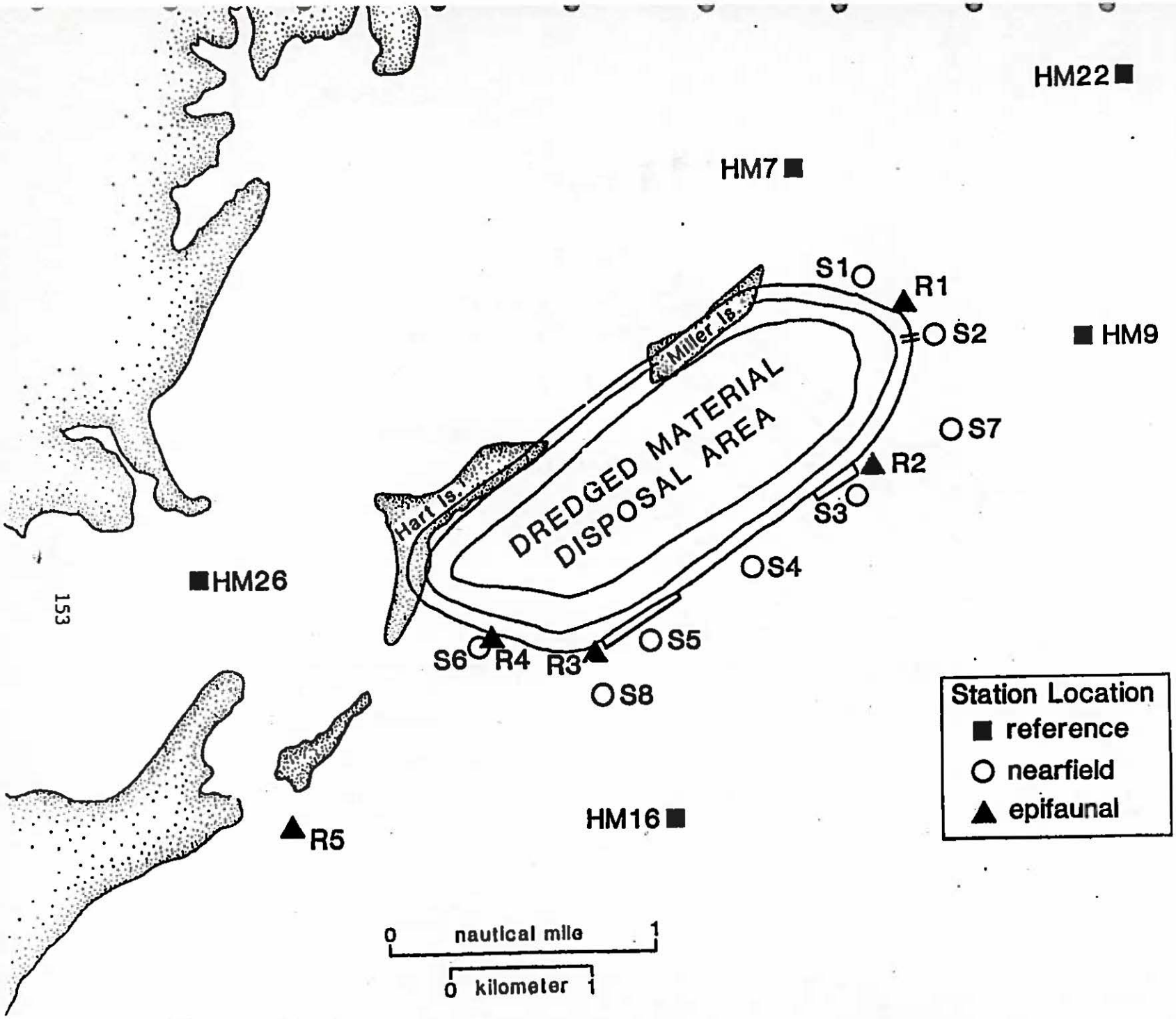

Figure 1: Benthic infaunal and epifaunal sampling station locations at the Hart-Miller Island containment facility. University of Maryland, Chesapeake Biological Lab designations.

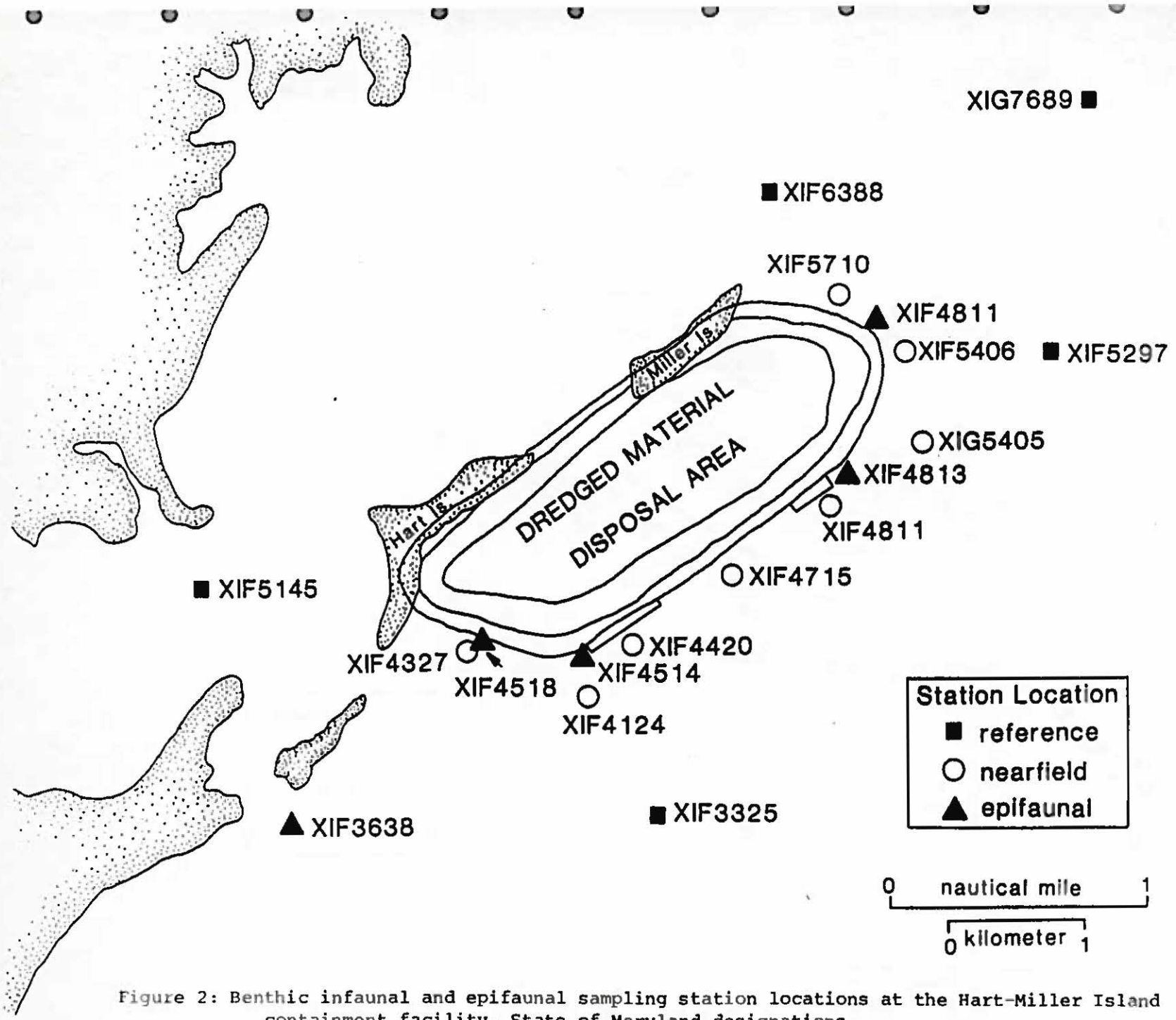

Figure 2: Benthic infaunal and epifaunal sampling station locations at the Hart-Miller Island containment facility. State of Maryland designations.

RESULTS AND DISCUSSION

Since the beginning of the project in 1981, a small number of species has dominated the populations of benthic invertebrates collected at the various nearfield and reference sites in the vicinity of the Hart-Miller Island containment facility. The most abundant species this year were the annelid worms, *Scolecolepides viridis*, *Heteromastus filiformis*, *Tubificoides* sp.; the crustaceans, *Cyathura polita* and *Leptochierus plumulosus*; followed by the clam, *Rangia cuneata*. Variations in the range and average number of *S. viridis*, *L. plumulosus*, and *R. cuneata* at the reference stations since February 1983 are presented in Table 1. The populations, particularly of the first two species, have remained relatively stable over this monitoring period. Variations in dominant or most abundant species occur primarily as a result of the different bottom types (Table 2). The annelid worms, *S. viridis*, *Tubificoides* sp. and *H. filiformis*, as well as by the crustaceans, *L. plumulosus* and *C. polita*, *prefer soft bottoms*. The most common inhabitants of the predominately old oyster shell substrates are more variable, with the barnacle, *Balanus improvisus*, and the worm, *Nereis succinea* often among the dominant organisms. There is occasionally some overlap between the bottom types, as evidenced in December for the reference stations. Then, the three dominant species were exactly the same: *R. cuneata*, *C. polita* and *H. filiformis* at both the soft and shell bottom stations. Sudden freshwater inflows during the spring spawning period have favored the recruitment success of *R. cuneata* in different years. During the sixth monitoring year, high influxes into the population were observed at several stations during the August 1987 sampling period which was reflected in high densities of small individuals in both the December 1987 and April 1988 samples. A similar influx was not observed in our August 1988 samples. If high salinities (>10 °/oo) occur and persist throughout the winter, then large mortalities of *Rangia* clams have been reported (Cain, 1975). This does not seem to be the case during the seventh year, as evidenced by the fairly large number of larger sized clams still present in August 1988. The worm, *H. filiformis*, has a preference for the higher salinity, mesohaline area of an estuary. It is an opportunist with the ability to increase its progeny rapidly in response to favorable saline conditions. It also has been acknowledged as a nitrate enrichment indicator (Dean and Haskin, 1964). Station HM26, at the mouth of the Back River has the most diverse annelid fauna with eight different species

present in December. The most abundant were, was *Tubificoides* sp. Which ranged from about 3800 - 15700 individuals per m^2 (Table 3).

The worm, *S. viridis*, and the crustacean, *C. polita*, occurred most frequently at both the nearfield and reference stations, being absent only in December at stations HM9 and S4, respectively. These two species were likewise among the numerically most abundant organisms at the various stations, including, on occasion, the hard bottom stations where shells are interspersed with silt (Tables 3 and 4). Over the course of these monitoring studies, the worm, *S. viridis* has frequently alternated with the crustaceans, *C. polita* and *L. plumulosus*, as the redundant dominant species. It appears that slight modifications in the salinity patterns during the recruitment period in late spring play an important role in determining the dominance of these species. The crustaceans, *C. polita* and *L. plumulosus*, are more abundant during low salinity years; *S. viridis* prefers slightly higher salinities. This particular year, *S. viridis* reached higher total densities primarily due to a very large population (15000 per m^2) at station S3 in April. During the sixth monitoring year, *L. plumulosus* was the numerically dominant species. However, this year it fell behind *C. polita* in terms of overall abundance, particularly as a result of a decline in the nearfield populations. The isopod crustacean, *C. polita*, tends to have a more stable population density at all seasons when compared to the other dominants. *C. polita* appears to be very tolerant of physical and chemical disturbances and repopulates areas such as dredged material disposal piles more quickly than other species (Pfitzenmeyer, 1985).

All of the dominant species, with the exception of *R. cuneata*, brood their young. This is an advantage in an area of unstable and variable environmental conditions such as the upper Chesapeake Bay. Organisms released from their parents as juveniles are known to have high survival and often reach high densities of individuals (Wells, 1961). The total number of individual organisms collected at the various reference and nearfield stations are quite comparable and ranged for the most part between 1000 and 4000 individuals per meter square. The lowest recorded values occurred at station HM7 in August (432 individuals/m^2) followed by station S3 in

TABLE 1. Abundances (#/m^2) of three of the major species present at the Hart-Miller Island Benthic Study Reference Stations from February 1983 to August 1988.

Major Species	Feb, May 1983	Sep 1983 Mar 1984	Oct 1984 Apr 1985	Dec 1985 Apr, Aug 1986	Dec 1986 Apr, Aug 1987	Dec 1987 Apr, Aug 1988
Scolecolepides						
Range/m^2	0-264		11-153	7-1287	13-447	0-567
Avg./m^2	69	546	92	398	179	178
Leptochierus						
Range/m^2	7-6626		20-441	7-1293	7-3312	0-3693
Avg./m^2	2259	614	272	308	1111	398
Rangia						
Range/m^2	0-135		0-75	0-273	13-3007	0-2267
Avg./m^2	22	455	27	102	687	359

TABLE 2: A list of the 3 numerically dominant benthic organisms collected from each bottom type on each sampling date during seventh year monitoring study at HMI.

STATION	December 1987	April 1988	August 1988
NEARFIELD SOFT BOTTOM (S3,4,5,6,8)			
	Cyathura polita	Scolecolepides viridis	Scolecolepides viridis
	Heteromastus filimormis	Cyathura polita	Heteromastus filiformis
	Tubificoides sp.	Heteromastus filimormis	Cyathura polita
NEARFIELD SHELL BOTTOM (S2,7)			
	Rangia cuneata	Tubificoides sp.	Heteromastus filiformis
	Heteromastus filiformis	Balanus improvisus	Nereis succinea
	Balanus improvisus	Scolecolepides viridis	Balanus improvisus
REFERENCE SOFT BOTTOM (HM7,16,22)			
	Rangia cuneata	Leptochierus plumulosus	Rangia cuneata
	Cyathura polita	Cyathura polita	Cyathura polita
	Heteromastus filiformis	Scolecolepides viridis	Heteromastus filiformis
REFERENCE SHELL BOTTOM (HM9)			
	Rangia cuneata	Tubificoides sp.	Scolecolepides viridis
	Cyathura polita	Balanus improvisus	Heteromastus filiformis
	Heteromastus filiformis	Scolecolepides viridis	Rangia cuneata
BAKC RIVER SOFT BOTTOM (HM26)			
	Tubificoides sp.	Tubificoides sp.	Tubificoides sp.
	Leptochierus plumulosus	Cyathura polita	Streblospio benedicti
	Heteromastus filiformis	Scolecolepides viridis	Lepochierus plumulosus

TABLE 3: Number of benthic organisms per m^2 found at the reference stations for the 7th year study (1987-1988) at the Hart-Miller Island containment facility.

SPECIES NAME	#	HR7 Dec	HR7 Apr	HR7 Aug	HR9 Dec	HR9 Apr	HR9 Aug	HR16 Dec	HR16 Apr	HR16 Aug	HR22 Dec	HR22 Apr	HR22 Aug	HR26 Dec	HR26 Apr	HR26 Aug	TOTALS
RHYNCHOCOELA (ribbon worms)																	
Diadeumene leucolena	1								20					253	33		306
Micrura leidyi	2	60	13	27	60	73	53	107	120	87	40	47	13	146	113	87	1046
ANNELIDA (worms)																	
Heteromastus filiformis	3	27	33	33	100	667	267	393	340	113	233	67	87	627	227	67	3282
Nereis succinea	5			13	7	600	107	20		7				20			767
Scoloplos fragilis	6					347											347
Hteone heteropoda	8													60			60
Polydora ligni	9						27						53		7	13	100
Scolecolepides viridis	10	80	213	53		487	313		567	127	53	353	47	60	300	20	2673
Streblospio benedicti	11	13	7	13	47		47	60	47	47	67		7	280		413	1048
Hypaniola grayi	12													80	133		213
Limnodrilus hoffmeisteri	13										13			87			100
Tubificoides sp.	14	20	160	33		2653	67	20	1613	167	40	53	87	3813	15780	4707	29213
Capitella capitata	15																
MOLLUSCA (mollusks)																	
Ischadium recurvus	16				33												33
Congeria leucophaeta	17				7	47											54
Macoma balthica	19	20	13	20	33		7	133	600	387	27	7		67	27	13	1354
Macoma mitchelli	20	20	7	13				107	113	60			7	273	107	40	747
Rangia cuneata	21	227	107	93	687		227	7	153	133	2267	713	327	180	33	120	5274
ARTHROPODA (crustaceans)																	
Balanus improvisus	27					560	13										573
Balanus subalbidus	28					40											40
Leucon americanus	29																0
Cyathura polita	30	207	353	80	200	227	153	513	767	233	233	273	40	513	500	140	4433
Cassidinidea lunifrons	31					20											20
Edotea triloba	33		7			7	7	7				13		500	73	33	647
Gammarus palustris	35																0
Leptocheirus plumulosus	36		260	40		20			1047	127		193	20	3693	200	340	5940
Corophium lacustre	37					20			13	7	20	7		200			267
Gammarus daiberi	38																0
Gammarus tigrinus	39																0
Melita nitida	40		13	7		180	27		13	7				73	27	27	374
Chirodotea almyra	41													7	7		14
Monoculodes edwardsi	42	27	33		7			20	100		7	87		53	33		367
Chironomid sp.	43	40	80								33	33			13	13	212
Rithropanopeus harrisi	44	7			47	213	20	67									354
Stylochus ellipticus	48			7								13	7		53	7	87
TOTAL NUMBERS		748	1299	432	1221	6160	1335	1455	5512	1502	3033	1860	695	10986	17666	6040	59944

TABLE 4: Number of benthic organisms per m^2 found at the nearfield stations for the 7th year study (1987-1988) at the Hart Miller Island containment facility.

SPECIES NAME	#	S1 Dec	S1 Apr	S1 Aug	S2 Dec	S2 Apr	S2 Aug	S3 Dec	S3 Apr	S3 Aug	S4 Dec	S4 Apr	S4 Aug
RHYNCHOCOELA (ribbon worms)													
Diadeumene leucolena	1												
Micrura leidyi	2			33		20	27	20	53	73	27	87	33
ANNELIDA (worms)													
Heteromastus filiformis	3	20	53	267	327	467	727	53	753	960	113	293	80
Nereis succinea	5		27	7	487	20	807	7			20	20	87
Scoloplos fragilis	6												
Eteone heteropoda	8												
Polydora ligni	9		300	653			273						
Scolecolepides viridis	10	173	1840	93		1127	20	80	15653	1187	7	627	647
Streblospio benedicti	11			47	646		67	13		27	13		107
Hypaniola grayi	12												7
Limnodrilus hoffmeisteri	13				40						7		
Tubificoides sp.	14	7	213	167	767	247	367	~~15~~	73	40	73	687	87
Capitella capitata	15			60				20					
MOLLUSCA (mollusks)													
Ischadium recurvus	16				60	33	33						
Congeria leucophaeta	17												
Macoma balthica	19							~~20~~	7	20	600	407	80
Macoma mitchelli	20							~~47~~		27			
Rangia cuneata	21	487	73	2160	13	7	33	~~27~~ 13		47	647	1300	7
ARTHROPODA (crustaceans)													
Balanus improvisus	27				1287	607	760						
Balanus subalbidus	28				220	40	120						
Leucon americanus	29		7										
Cyathura polita	30	80	107	120	60	233	53	307	120	120	missing	407	300
Cassidinidea lunifrons	31	7					33						
Edotea triloba	33			33		7	7	7	27			13	
Gammarus palustris	35		7										
Leptocheirus plumulosus	36	~~47~~	100			147			40			53	
Corophium lacustre	37	13	7		13	20	7	60	7		missing		20
Gammarus daiberi	38												
Gammarus tigrinus	39											7	
Melita nitida	40				80	20	213		7			missing	133
Chirodotea almyra	41												
Monoculodes edwardsi	42	27	107			13		7	953			107	
Chironomid sp.	43												
Rithropanopeus harrisi	44			20	420	53	420			7	missing		
Stylochus ellipticus	48						7						
TOTAL NUMBERS		847	2841	3660	4419	3061	3974	648	17694	2508	1507	4008	1588

TABLE 4 (continued): Number of benthic organisms per m² found at the nearfield stations for the 7th year study (1987-1988) at the Hart Miller Island containment facility.

S5			S6			S7			S8			Total
Dec	Apr	Aug	Dec	Apr	Aug	Dec	Apr	Aug	Dec	Apr	Aug	
27	33	87	220	220	73	87	13	33	27	60	140	1393
233	80	167	960	873	163	1660	573	907	20	67	327	10143
47	80	93		13		7	860	227	7			2816
												0
			87									87
			7					1293				2526
20	907	147	260	1220	140	367	513	460	7	193	427	26114
		40	2607		227	480		80	7		280	4628
												7
7			13						7			74
		60	6333	4867	967	73	1693	80	7	53	1380	18253
	60											120
							7					133
							53					53
	20		500	220	53	20	7	7	160	147	87	2355
			73	20	87	7					53	314
7	27	47	133	27	7	2193		660		13	27	7942
							1247	93				3994
							72	7				459
												7
340	473	167	767	907	400	653	80	200	353	547	200	6995
				7			60	7				114
	47	7	273	160				7		7	40	635
				640								7
7	420		140	720	187		7			53	160	2081
	13	13	40	13			33		80	7		333
							7					7
												7
		13	7	40			120	7				640
27												27
	153		240	187		40	73			167		2073
213			20	27	7							267
	27	27	47	40		60	320	113	33	107		1694
				40								47
928	2340	868	12727	9601	2311	5647	5739	4181	708	1421	3121	96345

December (648) and then by station HM22 in August (695) and station S8 in December (708). There did not appear to be any consistent pattern in terms of reference or nearfield stations. However, April values were generally above December and August, reflecting maximum recruitment at this time. The predominant benthic populations at both the nearfield and reference areas are similar and consist of detrital feeders which have an ample supply of fine substrates in this region of the Bay and particularly around the containment facility itself (Wells et al., 1984).

Surface salinity and temperature were recorded at all stations on all sampling dates (Table 5). Lower salinities occurred in December and April (ranging from 0-4 ppt) with somewhat higher salinities recorded in August of 6-8 ppt. These values were similar to past observations during these periods and quite comparable to values recorded last year in April when salinity was about 1 ppt and August salinity was 6.0 to 8.1 ppt. Temperature was likewise very comparable to the sixth year study, although August's temperatures were slightly higher ranging from 29-30°C, compared with the previous year's values of 27 to 29°C.

Species diversity values must be interpreted carefully in analyzing benthic data from the upper Bay. Generally, high diversity values reflect a healthy, stable fauna with the number of all species in the population somewhat equally distributed and no obvious dominance by one or two species. However, in this area of the Chesapeake, the normal condition is for one, two or three species to assume numerical dominance. This dominance is variable from year to year depending on environmental factors, particularly the amount of freshwater entering the Bay, from the Susquehanna River. Because of the overwhelming numerical dominance of a few species, diversity values are fairly low in this productive area of the Bay when compared to values obtained elsewhere. Diversity values for each of the quantitative benthic samples for the three different sampling dates are presented in Tables 6, 7, 8. Again this year, the overall highest species diversity (overall average seasonal value of 3.1656, as well as 4 other stations with values greater than 3.0000) was found during the summer sampling period (Table 8). This result was postulated in the First Interpretive Report (Pfitzenmeyer et al., 1982). The lowest species diversity values occurred in April. The largest number of

species recorded for any one station was 20 at the Back River (HM26) reference site in December. The lowest number of species, eight, also recorded in December, was at the nearfield sand substrate station (S1). These rankings for the highest and lowest number of species occurred at the same two stations last year.

Three species of mollusks, *R. cuneata*, *M. balthica*, and *M. mitchelli*, were measured to the nearest mm in shell length to determine if any size/growth differences were noticeable between the reference and nearfield areas for these clams (Figures 3,4,5). The most abundant clam again this year was *R. cuneata*. In keeping with the observed large cohort of small sized *R. cuneata* observed in August 1987, we continued to find large numbers (100-300) of smaller sized individuals (6-20 mm) in December 1987 and April 1988. There were no significant differences in the overall numbers of *Rangia* found at the nearfield or reference sites. There was a general decline in the total number of *Rangia* in both sets of samples from our August 1987, highs through April 1988. Most of the *Rangia* collected in August 1988 ranged in size from 21-30 mm which indicated that last spring's set was growing well. However, no new spring set and grow up appears to have occurred this year either at the reference or nearfield stations. This may be a result of variations in salinity, which seem to have a strong effect on settlement and growth of these bivalves.

In the case of *M. balthica* (Figure 4), in December the population was dominated by the 8-10 and the 11-15 mm size classes. Some 70-80 individuals were present at the nearfield stations, but only 10 -20 individuals at the reference stations. These findings were in keeping with the somewhat higher number of specimens recorded at the nearfield stations last August. The organisms, particularly those in the 8-10 mm size class may possibly reflect a late summer spawning and grow up over the fall period. This is in keeping with the approximate 2.0 mm per month growth rate which we observed last year around Hart-Miller Island

TABLE 5: Salinity (in 0/00) and temperature (in ^{0}C) data for the nearfield and epifaunal stations on the different collection dates during the seventh year of benthic monitoring studies at Hart-Miller Island.

CBL STA #	STATE STA #	DEC 87 SAL	DEC 87 TEMP	APR 88 SAL	APR 88 TEMP	MAY 88 SAL	MAY 88 TEMP	JUNE 88 SAL	JUNE 88 TEMP	AUG 88 SAL	AUG 88 TEMP
R1	XIF4811	0	6			4	21				
R2	XIF4813	0	6					6	27.5		
R3	XIF4514	0	6			4	21	6	27.5		
R4	XIF4518	4	6			4	21	6	27.5		
R5	XIF3638	4	6			4	21	6	27.5		
S1	XIF5710	2	6	1	13					6	29.5
S2	XIF5406	2	6.5	1	13					6	29.5
S3	XIF4811	2	6.5	2	13					8	29
S4	XIF4715	2	7	2	12.5					8	29
S5	XIF4420	2	7	2	12.5					7	29.5
S6	XIF4327	2	7	2	12.5					7	29.5
S7	XIG5405	2	6	2	12.5					6	29.5
S8	XIF4124	2	7	2	12.5					8	29
HM7	XIF6388	1	6	2	13					6	29.5
HM9	XIF5297	0	6	2	13					6	29.5
HM16	XIF3325	2	7	2	12					8	29
HM22	XIG7689	0	6	2	14					6	29.5
HM26	XIF5145	0	6	2	14					6	30

TABLE 6. Number of species and total number of individuals for three grabs (0.05 m^2 each) collected at the various stations for December 1987. Also shown are bottom substrates, species diversity (H1), and dominance factor (S.I.). Seventh Year HMI.

	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS (H1)	SPECIES DIVERSITY	DOMINANCE S.I.
NEARFIELD					
S1	Sand	8	127	1.8746	0.38595
S2	Shell	13	663	2.9138	0.16612
S3	Silt/Clay	13	114	2.8129	0.21422
S4	Silt/Clay	12	230	2.3965	0.26692
S5	Silt/Clay	10	139	2.3044	0.25584
S6	Silt/Clay	19	1909	2.4460	0.30233
S7	Shell	12	847	2.3136	0.26721
S8	Silt/Clay	11	106	2.1902	0.31897
REFERENCE					
HM16	Silt/Clay	12	218	2.6302	0.22161
HM7	Silt/Clay	12	112	2.8263	0.29467
HM22	Silt/Clay	12	455	1.5048	0.57163
HM9	Shell	10	183	2.1301	0.35728
BACK RIVER					
REFERENCE					
HM26	Silt/Clay	20	1648	2.7243	0.24385

TABLE 7. Number of species and total number of individuals found in three grab samples (0.05 m^2 each) at the various infaunal stations for April 1988. Also shown are bottom substrate, species diversity (H1), and dominance factor (S.I.). Seventh Year HMI.

	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H1)	DOMINANCE S.I.
NEARFIELD					
S1	Sand	12	426	1.9231	0.44174
S2	Shell	16	459	2.7105	0.21353
S3	Silt/Clay	11	2654	0.7311	0.78749
S4	Silt/Clay	12	601	2.7505	0.18646
S4	Silt/Clay	13	351	2.6157	0.23152
S6	Silt/Clay	18	1428	2.4369	0.30157
S7	Shell	18	861	2.8876	0.17893
S8	Silt/Clay	16	213	2.7950	0.20377
REFERENCE					
HM16	Silt/Clay	14	827	2.9169	0.16931
HM7	Silt/Clay	14	195	2.9100	0.16818
HM22	Silt/Clay	13	279	2.6544	0.22092
HM9	Shell	16	924	2.7954	0.22809
BACK RIVER REFERENCE					
HM26	Silt/Clay	18	2650	0.8432	0.79938

TABLE 8. Number of species and total number of individuals found in three grabs (0.05 m^2 each) collected at the various infaunal stations for August 1988. Also shown are bottom substrate, species diversity (H1), and dominance factor (S.I.). Seventh Year HMI.

	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H1)	DOMINANCE S.I.
NEARFIELD					
S1	Sand	12	549	2.0263	0.38990
S2	Shell	18	596	3.1656	0.14022
S3	Silt/Clay	10	376	1.8201	0.37483
S4	Silt/Clay	12	238	2.6999	0.22513
S4	Silt/Clay	12	130	3.1193	0.13550
S6	Silt/Clay	11	348	2.4587	0.23052
S7	Shell	16	627	2.8223	0.18710
S8	Silt/Clay	11	468	2.6241	0.24341
REFERENCE					
HM16	Silt/Clay	13	225	3.1515	0.13683
HM7	Silt/Clay	13	65	3.2869	0.12521
HM22	Silt/Clay	11	104	2.4961	0.26849
HM9	Shell	14	200	3.0709	0.15025
BACK RIVER					
REFERENCE					
HM26	Silt/Clay	15	906	1.3971	0.61646

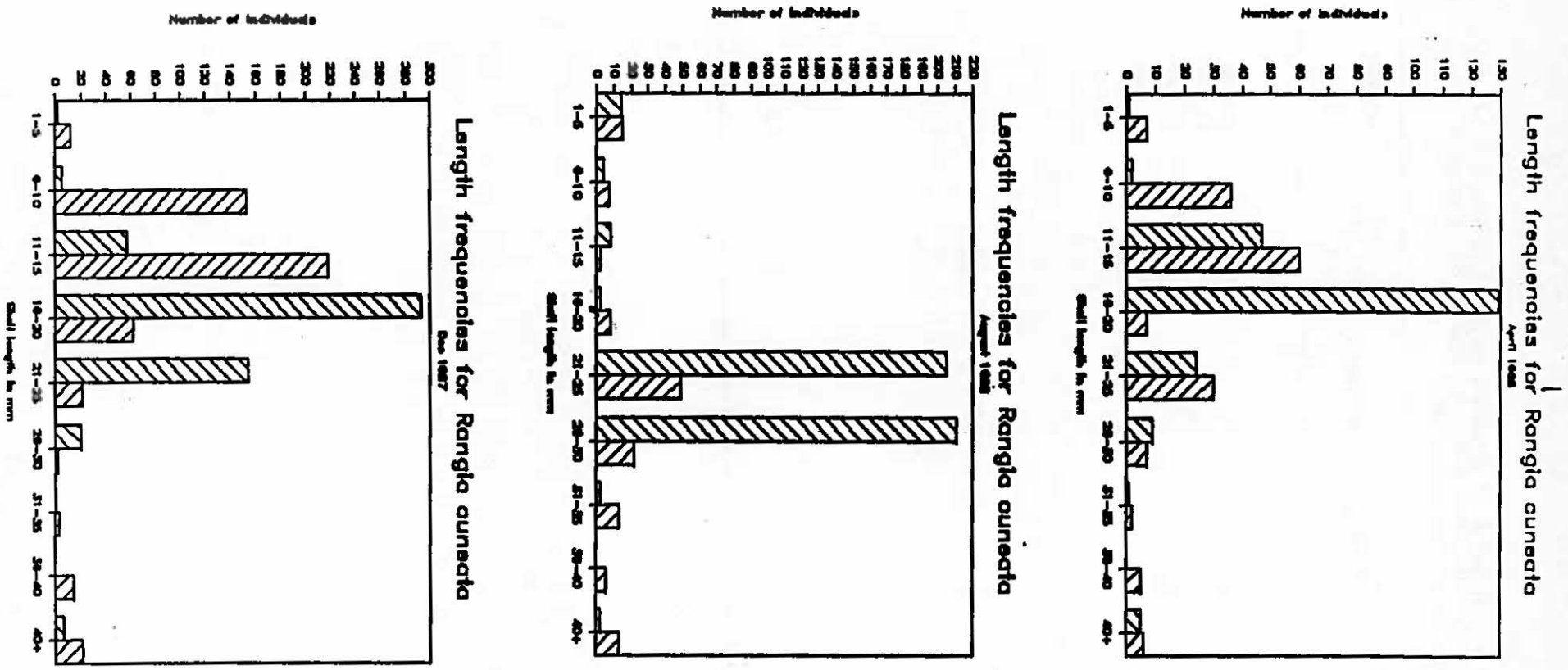

FIGURE 3: Length frequency distribution of the clam, Rangia cuneata, (shell length in mm), during the seventh year of monitoring at Hart and Miller Island

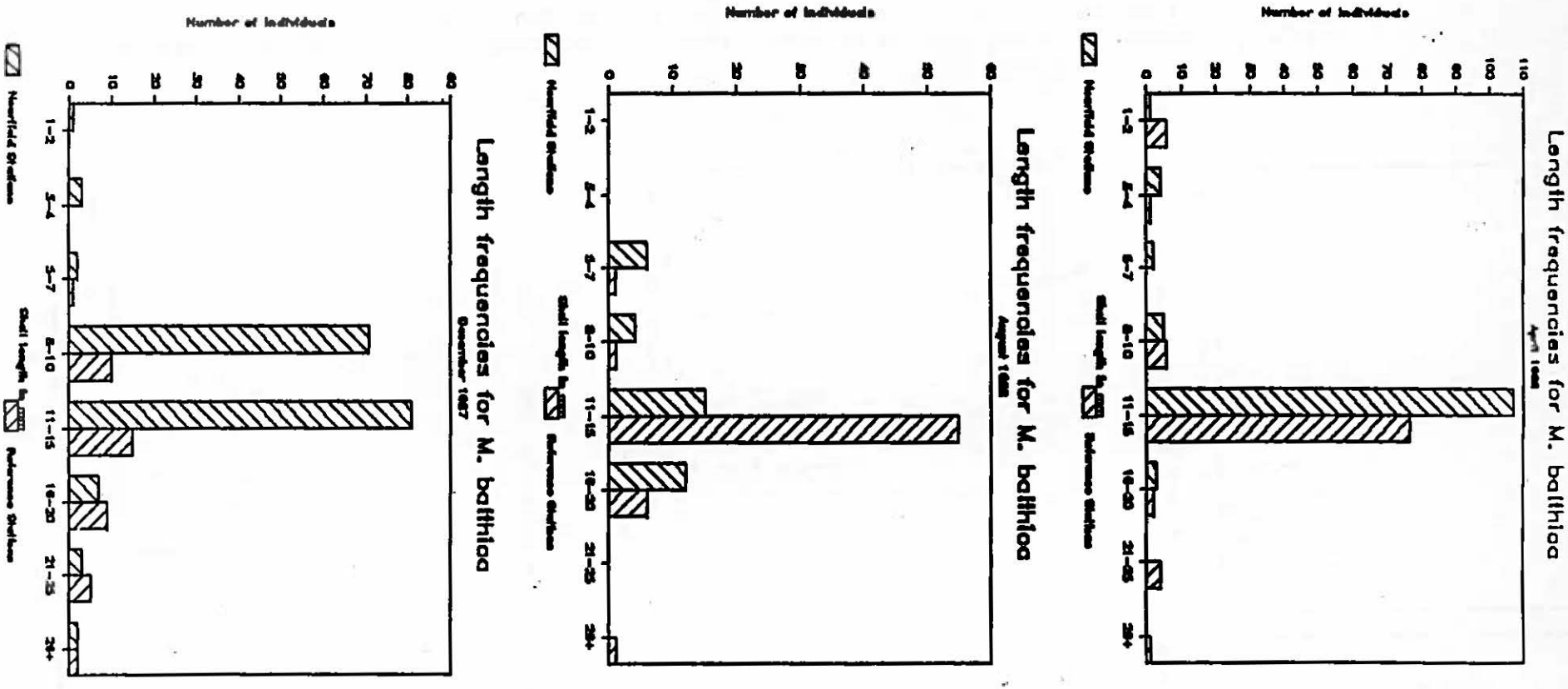

FIGURE 4: Length frequency distribution (shell length in mm) for the clam, Macoma balthica, during the seventh year of monitoring at Hart and Miller Island.

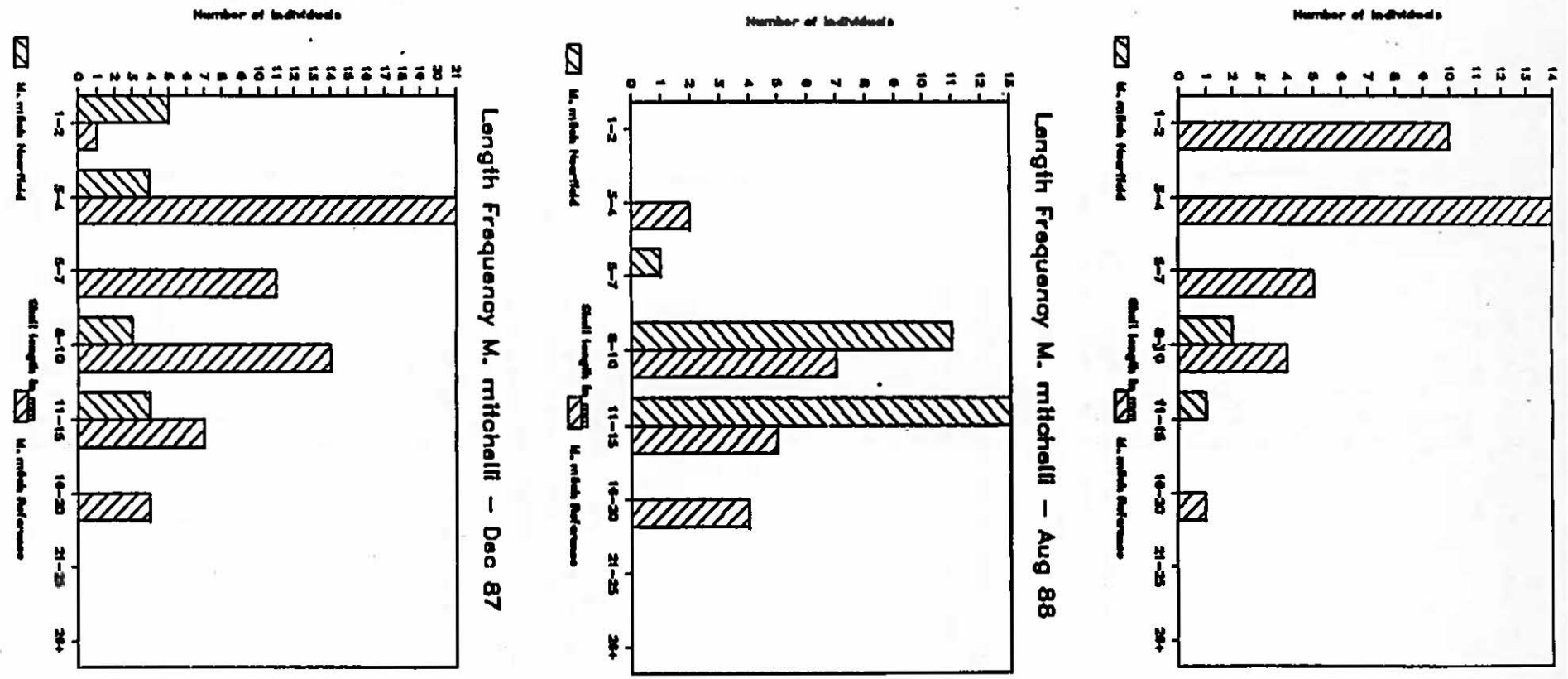

FIGURE 5: Length frequency distribution (shell length in mm) for the clam, Macoma mitchelli, during the seventh year of benthic monitoring at Hart and Miller Isalnds.

for this species and also within the range reported by Holland, et al. (1987) of 1.9 to 2.3 mm per month at their middle Potomac River stations. In April 1988, there was a slight increase in the absolute numbers of *M. balthica* at both the nearfield (100-110) and the reference stations (70-80) in the dominant size class of 11-15 mm, possibly reflecting growth of the 8-10 mm size class over this period which in turn showed an overall decline at both sets of stations to about five individuals. In August 1988, there was an overall decline in the number of *M. balthica* at both sets of stations, however, the decline was somewhat more dramatic at the nearfield stations at this time with a 77% reduction in numbers versus only a 16% drop at the reference station. The greater decline in the number of *M. balthica* at the nearfield stations may reflect the very heavy barge traffic in this area during the summer months.

The length frequency and abundance pattern of the third mollusk *M. mitchelli* was somewhat similar to that observed last year. *M. mitchelli* had a generally lower abundance than either of the other two species. In December and April the various size classes (1-20 mm) were fairly evenly distributed (5-20 individuals), although the smaller sized (1-4 mm) organisms were slightly more abundant. In August the larger size classes (8-20 mm) predominated. Only one-two individuals were encountered in the (1-7 mm) range, possibly reflecting grow up over the April to August period. There was also a continued decline in the overall numbers of *M. mitchelli* found in this region of the Bay, indicating continued less favorable conditions for this particular species. A major difference this year was a generally reduced number of M. mitchelli at the nearfield stations compared with the reference stations. In April only three specimens were collected at the nearfield stations, and they were all in the size range of 8-15 mm. However the nearfield populations rebounded in August when there was a greater number of *M. mitchelli* at the nearfield stations. The exact causes of the variations in numbers and size frequency of the two *Macoma* species' in particular *M. mitchelli*, are not readily apparent and bear careful monitoring in the next sampling season. As reported last year, (Duguay et al., 1988) there has been a shift in relative dominance to greater numbers of *M. balthica* than *M. mitchelli* over the past two years.

We again employed cluster analysis in this year's study in order to examine relationships among the different groups of stations based upon the numerical distribution of the numbers of species and individuals of a species. In Figures 6, 7 and 8 the stations with faunal similarity (based on chi-square statistics derived from the differences between the values of the variables for two stations), are linked by horizontal connections in the three dendrograms. Essentially, each station was considered to be a cluster of its own and at each step (amalgamated distances) the clusters with the shortest distance between them were combined (amalgamated) and treated as one cluster. Cluster analysis in past studies at Hart-Miller Island has clearly indicated a faunal response to bottom type (Pfitzenmeyer, 1985). Any unusual grouping of stations tends to suggest that changes are occurring due to factors other than bottom type, and further examinations of these stations is required. Most of the time, experience and familiarity with the area under study can help to explain away the differences. However, when they cannot be explained, extraneous factors must be investigated further.

Figure 6 presents the basic grouping of stations for the December 1987 sampling period. There is an initial joining of a mixture of nearfield (S3, S8) and reference (HM7) soft bottom silt/clay type stations. The next station to join the grouping is S1, a nearfield shell bottom station which is located at the northern end of the island near reference station HM9, which is also a shell station and the next to fall in to line. Again, a series of nearfield and reference soft bottom stations lined up in a sequential manner in the dendrogram. Reference station HM16 and nearfield station S5 formed a tight cluster together at this point in the dendrogram. They are both located in the southern region of the study area, and it is not surprising that their populations would in general be similar. Subsequently, two nearfield shell bottom stations (S2 and S7) joined the cluster at the outer edge. The last two stations to be joined were S6 and HM26. These two stations are located near one another in the southwestern area of the study. HM26, the station located near Back River, is frequently one of the final stations to join the dendrogram. The clustering of stations located in the same general regions and bottom types is highly desirable, indicating that no anomalous changes are occurring at the nearfield stations.

In April, the basic grouping was again formed by a joining of silt/clay reference (HM22, HM7, HM16) and nearfield (S8,S4,S5) stations (Figure 7) . However, the exact set of stations making up the inner grouping differed from that in December. The next series to fall in at this juncture were the shell/sand

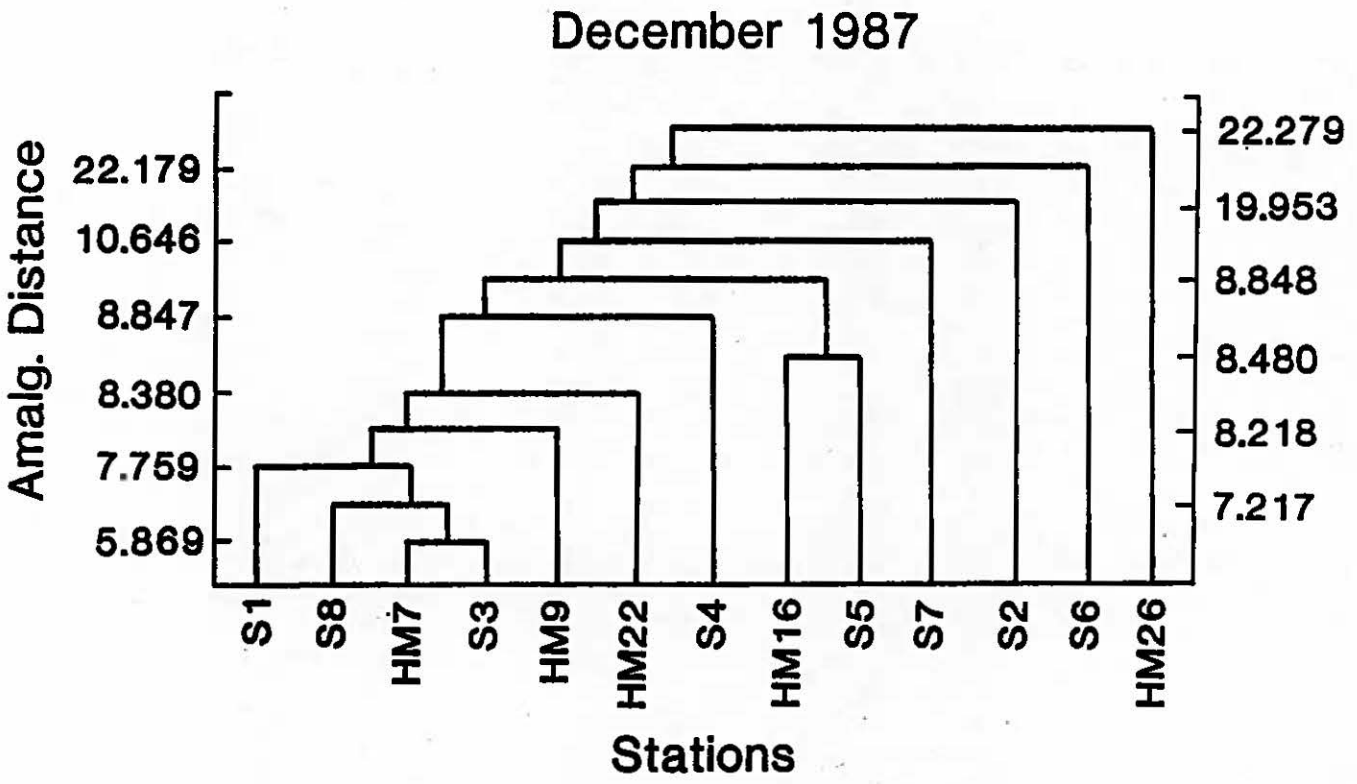

FIGURE 6: Cluster analysis for all of the Hart Miller Island sampling station in December 1987 during the 7th year of benthic studies.

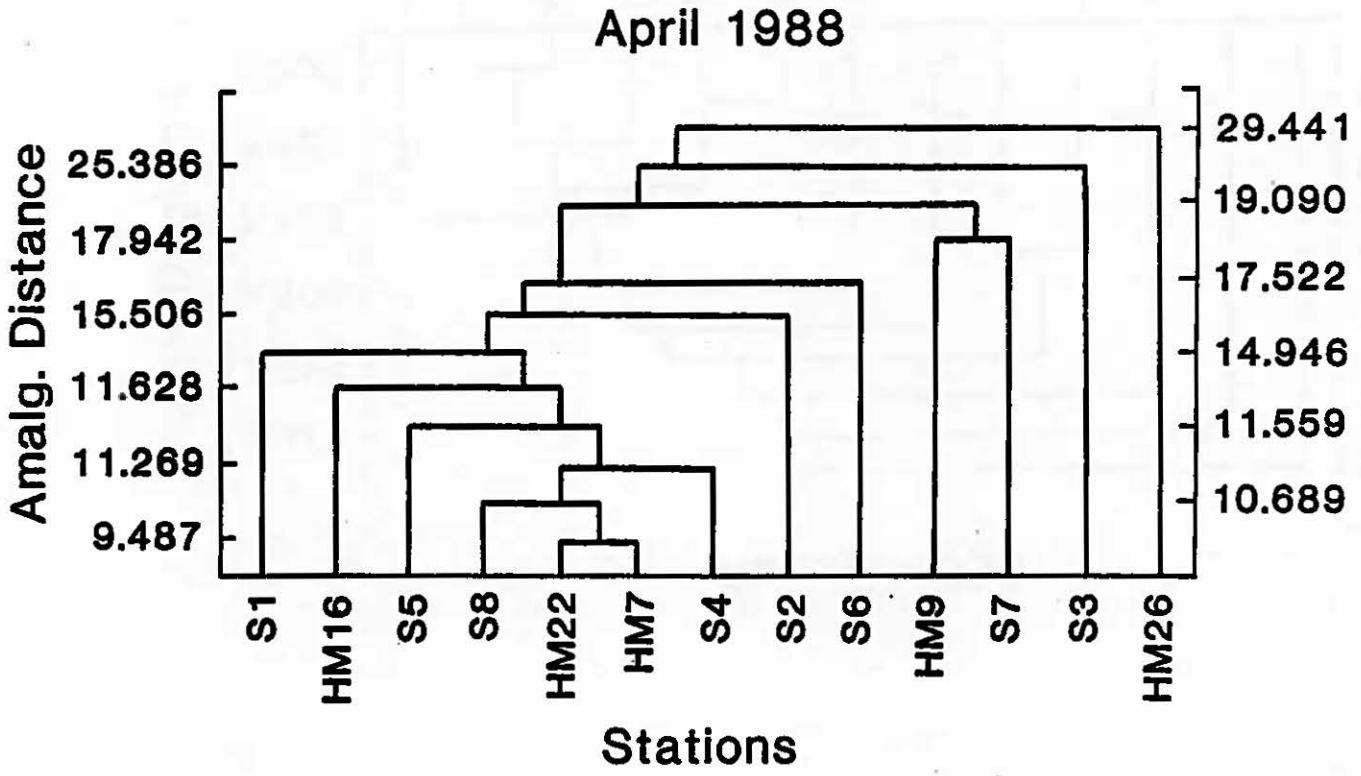

FIGURE 7: Cluster analysis for all of the Hart Miller Island sampling stations in April 1988 during the 7th year of benthic studies.

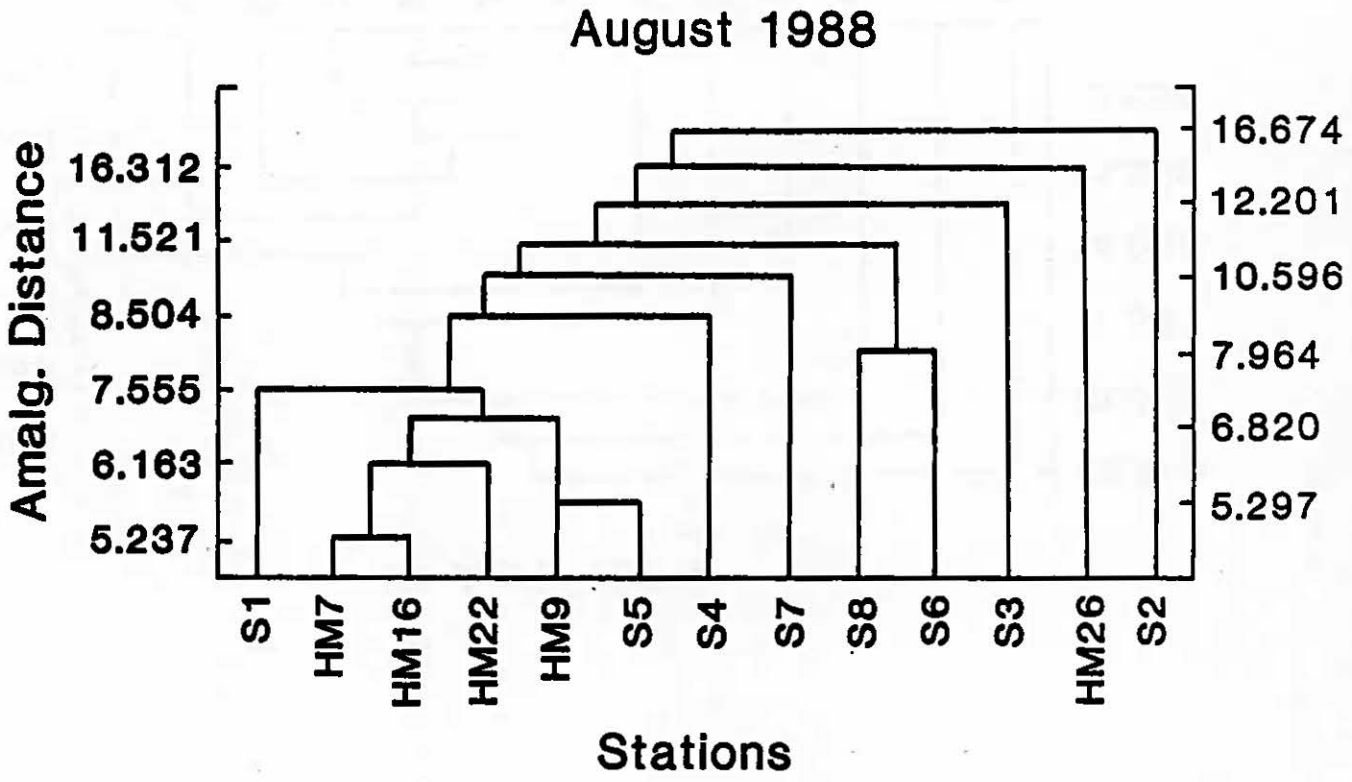

Figure 8: Cluster analysis for all of the Hart Miller Island stations in August 1988 during the 7th year of benthic studies.

bottom stations (S1, S2, S7, HM9). Mixed in at this point were two soft bottom stations S6 and S3. The final station to join the dendrogram was, as in December, HM26.

The summer sampling period in August represents the season of greatest recruitment for the majority of benthic species, as well as a period of heavy stress from predatory activities, high salinity, and high water temperature. These stresses exert a moderating effect on the benthic community holding the various populations in check. The four main reference sites (HM7,HM16,HM22,HM9) formed the innermost cluster. HM9 formed a tight cluster with S5, which is not readily explainable. Next in line was S1, which had been closely associated with HM9 in December. The remainder of the soft bottom silt/clay stations along with shell station S7 then joined the dendrogram. The outermost members of the cluster were HM26 and S2, which was very similar to the pattern observed last August.

The clusters formed over these three sampling dates during the 87-88 sampling period represented a normal grouping with no unusually isolated stations. These clusters, consistent with earlier studies, primarily grouped stations according to bottom type and general location within the study area. If these fauna were affected by some extraneous force it would definitely appear in the groupings, and no such indications were found during the three sampling periods.

The Student-Neuman-Keuls multiple range test was again used to determine if a significant difference could be detected when population means of benthic invertebrates were compared at the various sampling stations. The total number of individuals of each species was transformed (log) before the analysis was performed. Subsets of groups, the highest and lowest means of which do not differ by more than the shortest significant range for a subset of that size, are listed as homogenous subsets. The results of these tests for the three different sampling dates are presented in Tables 9, 10, and 11.

In December 1987, the stations were sorted into just two subsets (Table 9). Six nearfield stations, S1 through S6, formed the first subset. The

second subset was made up of all of the reference stations, including HM26, as well as nearfield stations S7 and S8. This was in keeping with the analysis made for December 1986 (Duguay et al.,1988) and last year's report (Pfitzenmeyer and Tenore, 1987), which identified essentially two groups of stations -- the nearfield and the references stations. Within the two groupings the stations are interrelated and occasionally S7 and S8 do overlap with the reference stations. The one-way analysis of variance F-test did not indicate any significant differences between the stations.

In April, four subsets were evident (Table 10). The first subset was comprised of the two sand/shell stations at the northeastern corner of the island. These two stations, most likely because of their hard bottoms and general location, remained separated from the other nearfield stations. The remaining nearfield stations (S3-S8) comprised the second subset along with HM7, HM9, and HM16. The third subset dropped stations S3-S8 and brought in HM26. The final subset was made up of the 5 reference stations as well as S8. As in December, the reference stations and nearfield stations formed relatively discernible groups. Again, the analysis of variance for this sampling period resulted in no significant differences between or within groups. Finally, analysis of the August 1988 data with the Student-Neuman Keuls test indicated nothing unusual. Indeed, the August subsets were somewhat similar to the April findings. There were five subsets versus the four in April but again the first subset was comprised of the harder bottom nearfield stations S1 and S2. The second subset at this time consisted of five of the remaining six nearfield stations, only S8 was not in this group. The third subset grouped S7 and S6 with HM9 and HM7, which is not readily explainable. The fourth and fifth subsets

TABLE 9. The Student-Neuman-Keuls test of significance among mean number of individuals per station for December 1987. Subsets show grouping of different stations ($P<0.05$). Stations in a separate vertical column and row are significantly different from others. Seventh year HMI.

DECEMBER 1987

SUBSET	STATION NUMBERS											
1	S1	S2	S3	S4	S5	S6						
2							S7	HM26	HM7	S8	HM16	HM22	HM9

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F. RATIO	F. PROB
Between Groups	12	99162.3	8263.5	19.19	0.00
Within Groups	26	11195.7	430.6		
TOTAL	38	110358.2			

TABLE 10. The Student-Neuman-Keuls test of significance among mean number of individuals per station for April 1988. Subsets show grouping of different stations ($P<0.05$). Stations in a separate vertical column and row are significantly different from others. Seventh year HMI.

APRIL 1988

SUBSET	STATION NUMBERS										
1	S1	S2									
2			S3	S6	S4	S5	S7	HM9	HM7	S8	HM16
3							S7	HM9	HM7	S8	HM16	HM26
4								HM9	HM7	S8	HM16	HM26	HM22

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F. RATIO	F. PROB
Between Groups	12	181035.5	15086.0	10.12	0.00
Within Groups	26	38770.3	1491.1		
TOTAL	38	219805.8			

TABLE 11. The Student-Neuman-Keuls test of significance among mean number of individuals per station for August 1988. Subsets show grouping of different stations ($P<0.05$). Stations in a separate vertical column and row are significantly different from others. Seventh year Hart-Miller Island monitoring.

APRIL 1988

SUBSET	STATION NUMBERS										
1	S1	S2									
2			S4	S3	S5	S7	S6				
3						S7	S6	HM9	HM7		
4								HM9	HM7	HM16	S8	HM26	
5										HM16	S8	HM26	HM22

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F. RATIO	F. PROB
Between Groups	12	38073.2	3172.7	18.82	0.00
Within Groups	26	4383.2	168.6		
TOTAL	38	42456.5			

sequentially dropped these four stations, S6 and S7 in the fourth subset followed by HM9 and HM7 in the fifth subset, and picked up HM26 and S8 in the fourth and finally HM22 in the fifth. The final subset consisted of HM16, S8, HM26, and HM22, which was identical to the final subset observed in the April sampling period of the sixth year study. As in the case of the December and April data, the analysis of variance for this period did not indicate any significant differences between or with groups.

Table 12 presents the results of Friedman's non-parametric test for differences in the means of samples (ranked abundances of 11 selected species) taken at the silt/clay nearfield and reference stations only. Significant differences ($p<0.05$) were found at the nearfield stations during the December sampling period. Station S6 had a high number of individuals, particularly of the annelid worms, *Tubificoides* sp. and *Streblospio benedicti*, which reached combined densities of almost 9000 worms/m^2 compared with less than 1300 worms/m^2 at any of the other nearfield silt/clay stations. This station is located in the southwestern region of the study site close to the Back River reference area which frequently has unusually high concentrations of annelid worms (Duguay et al., 1988). In April and August significant differences were observed between the three reference stations with silt/clay bottom type (HM16, HM7, and HM22). At these times station HM16 had a two-four fold greater number of individuals than either of the other two stations. In April the observed differences between the reference stations were similar to the nearfield differences reported for December, due primarily to a ten-fold difference in the number of individuals of the annelid worm, *Tubificoides* sp. at station HM16, again a station in the southern region of the Hart-Miller Island and possibly falling under the influence of the Back River region. In August, on the other hand, the difference (see Table 13) appeared to result simply from a greater overall abundance of organisms at station HM16 rather than due to any one individual organism. In August there was also a significant difference between the reference stations and the nearfield stations when they were tested together. This is again consistent with results reported in both the fifth and sixth year interpretive reports (Pfitzenmeyer and Tenore, 1987 and Duguay et al. 1988, respectively).

The results for the epifaunal samples scraped from a series of pilings around the facility and one located in the Pleasure Island boat channel are presented in Table 13. Samples this year were again limited to depths of 1.0 to 1.3 m below the surface and at 2-3 m to avoid the region of ice scour, where the fauna becomes depauperate in winter. A reasonably well developed fauna occurred on all three sampling dates, and there were no major differences between the upper and lower samples. The densities and distribution of the various epifaunal species on both the nearfield pilings (R1-R4) and the reference piling (R5) are quite similar and sometimes nearly identical. Essentially, the same ten species observed this year were the predominant species over the past two study years (Pfitzenmeyer and Tenore, 1987, and Duguay et al. 1988). The amphipod, *C. lacustre* again was one of the most abundant and most widespread species (Pfitzenmeyer and Tenore, 1987, and Duguay et al., 1988). It was either the first or second most abundant organism at all stations on all dates with the single exception of the deeper sample from the reference station in December when it ranked fourth behind the bryozoan, *Victorella* and two worms *Polydora* and *Capitella*. This small crustacean is extremely opportunistic and constructs tubules out of detritus in which it lives a protected existence on the piling. The tubules are quite tough and other colonial forms attach themselves to the tubule network. *Corophium* is not limited to the pilings but also occurs on shell and/or other hard surfaces on the bottom. No specific zonation of species was observed on the pilings. The same species found at the first meter were also collected at 2-3 m. The area is relatively shallow, and no specific depth restrictions would be expected for the common species. Two colonial forms the bryozoan, *Victorella* and the hydroid, *Cordylophora*, reached their greatest abundance in April and August their maximal reproductive and growth seasons.

TABLE 12. Results of Friedman's non-parametric test for differences in abundances of (11) selected species between stations with silt/clay substrate. (Nearfield = S3, S4, S5, S6, S8; Reference = HM7, HM16, HM22) for the seventh year study of HMI.

SOURCE	D.F.	X^2	$X^2(0.05)$
DECEMBER 1987			
Nearfield	4	16.00*	9.48
Reference	2	2.00	5.99
Nearfield & Reference	7	12.00	14.06
APRIL 1988			
Nearfield	4	1.00	9.48
Reference	2	9.00*	5.99
Nearfield & Reference	7	14.00	14.06
AUGUST 1988			
Nearfield	4	4.00	9.48
Reference	2	12.00*	5.99
Nearfield & Reference	7	15.00*	14.06

* Significant difference at 5% level.

TABLE 13. Benthic species in descending order of density found on the pilings surrounding the containment faiclity (R1-R4) and at one reference station (R5) for the 3 sampling periods at 2 different depths. Seventh year monitoring studies at HMI.

DECEMBER 1987

Nearfield Stations R1-R4		Reference R5	
1-1.3 m	2-3 m	1-1.3 m	2-3 m
Corophium	Corophium	Corophium	Victorella
Polydora	Polydora	Polydora	Polydora
Victorella	Capitella	Victorella	Capitella
Membranipora	Victorella	Capitella	Corophium
B. subalbidus	B. subalbidus	Dordylophora	B. improvisus
Capitella	B. improvisus	Membranipora	Membranipora

APRIL 1988

1-1.3 m	2-3 m	1-1.3 m	2-3 m
Victorella	Victorella	Victorella	Victorella
Corophium	Cordylophora	Corophium	Corophium
Cordylophora	Corophium	B. subalbidus	Cordylophora
Nereis	Nereis	Capitella	B. subalbidus
Stylochus	Polydora	Monoculodes	Polydora
			Capitella

AUGUST 1988

1-1.3 m	2-3 m	1-1.3 m	2-3 m
Corophium	Corophium	Corophium	Corophium
Victorella	Victorella	Victorella	Victorella
Polydora	Nereis	Polydora	B. improvisus
B. improvisus	Polydora	B. improvisus	Nereis
Cordylophora	B. subalbidus		Polydora
Nereis	Cordylophora		

CONCLUSIONS AND RECOMMENDATIONS

During this seventh year of sampling and monitoring the benthos at Hart-Miller Island, the sampling locations, sampling techniques and analysis of the data were again maintained as closely as possible to that of the previous two years, in order to eliminate as much variation as possible. Maintenance of sampling locations, techniques and analysis should render differences caused by of the containment facility more readily apparent. However, because of the hazards and rigors involved in diving, we did alter our method of sampling the epifaunal populations. We developed a special piling scraping device which yields samples very comparable if not superior to samples collected by divers.

The results presented in this report are quite similar to those presented in both the fifth year and sixth year reports. A total of 35 species (compared with 30 and 26 for the sixth and fifth years, respectively) were collected in the quantitative grab samples. Again, five species remain numerically dominant on soft bottoms. These five dominants are the annelids, *S. viridis* and *H. filiformis*, the crustaceans, *L. plumulosus* and *C. polita*, and the clam, *R. cuneata*. On the oyster shell substrates, the barnacle, *Balanus improvisus*, the worm, *N. succinea*, and the crab,*Rithropanopeus harrisi* were the most common inhabitants, with some overlap of the five most abundant soft bottom species occasionally becoming dominant on this substrate as well. Salinity variations on yearly and seasonal time scales appear to determine the position of dominance of the major species.

The average number of individuals per square meter was comparable for the nearfield and reference stations over the three sampling periods. Pfitzenmeyer and Tenore (1987) reported a greater number of individuals at the nearfield than at the reference stations for the fifth monitoring year, which they attributed to an abundance of finer sediments close to the containment facility dike. Perhaps the increased barge traffic throughout the region has increased the distribution of fine sediments into the reference areas as well. This was the same trend which we observed last year during the sixth year study.

The highest average species diversity values were again found during the August sampling period. Predation is generally greatest during the summer. Pfitzenmeyer and Tenore (1987) suggested that the most abundant benthos, which are important food organisms for bottom feeding fish and crabs, are consumed at this time, resulting in more even populations among the different benthic species.

Length frequencies and cohort sizes of the clam *R. cuneata* living close to the containment facility were comparable to populations at the reference stations. This was not the case for the other two common bivalves *M. balthica* and *M. mitchelli*. *M. balthica* had higher concentrations at the nearfield sites when compared with the reference sites. *M. mitchelli* showed the opposite trend with reduced numbers at the nearfield sites when compared with the reference areas. There was no apparent major set and grow up of these three bivalve clams over the present sampling study, but rather a general overall decline from the high values reported in August 1987. The decline appeared at both the nearfield and reference stations and may be a result of less favorable salinities in the region.

Cluster analysis grouped stations of similar faunal composition in response to sediment type and general location within the study area. There were no incidences of individual stations being isolated from common groupings during the three sampling periods. The Back River station HM26 frequently was the last station to join the cluster, as was the nearfield oyster shell substrate station S2. The Student-Neuman-Keuls multiple range test divided the stations into subsets primarily on the basis of whether they were nearfield or reference stations and also indicated that significant differences in fauna exist between stations S1 and S2 (the sand and oyster shell substrates). In April and August stations S1 and S2 formed a separate subset. Friedman's non-parametric test indicated significant differences in stations in the southwest region of the Hart-Miller Island facility near Back River.

Epifaunal species were quite similar in terms of distribution at the nearfield and reference stations for all three sampling periods. Since sampling this year was again confined to the region below winter ice scour and low tide dehydration, no absence or spuriousness of species from the pilings was

recorded. The amphipod *Corophium* was again one of the most abundant organisms as was the bryozoan *Victorella*. At present, there do not appear to be any discernible differences in the nearfield and reference populations resulting directly from the containment facility. The barge activity to churns up and scours the area, but the opportunistic species inhabiting this oligohaline region of the Bay appear to be readily capable of repopulating disturbed areas.

The Hart-Miller Island Containment Facility is now fully operational and, indeed, is in the process of expansion. It is strongly recommended that sampling of the infaunal and epifaunal populations continue at the established locations during this critical period of maximal operation and expansion. Station locations and sampling techniques should be maintained as closely as possible to the last few years to eliminate sampling variation and permit rapid recognition of effects resulting from the operation and expansion of the containment facility.

PROJECT IV

ANALYTIC SERVICES

Seventh Annual Interpretive Report

Performed by

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SUMMARY

Selected metal and organic contaminants are analyzed in sediments and biota as part of the Hart-Miller Island Containment Facility Environmental Assessment Monitoring Program. This monitoring involves sampling sediments and biota in the region of the facility in order to determine if contaminant levels have significantly increased and/or exceeded baseline levels established in prior monitoring years (1981--August 1987). In this monitoring year, 1987-1988, 110 samples of sediment and biota were collected to determine the concentrations of 43 trace organic contaminant compounds in fish, benthos, and sediment in the region of Hart and Miller Islands. Biological samples (fish, benthos) were also analyzed for concentrations of six metals: chromium, copper, iron, manganese, nickel, and zinc.

In all of the sediment samples, organic contaminant levels were below the laboratory-determined detection limits. The only organic constituents that were consistently found above detection limits in biota were chlordane and total PCBs. The isopod, *Cyathura polita* exhibited concentrations far above the detection limit for chlordane in a sample collected in August of 1988. The chlordane concentrations were ten times greater in *Cyathura* than in white perch collected during the same sampling periods. Chlordane and PCBs were consistently higher in all the April and August, 1988 samples, but these concentrations were lower than concentrations for the entire Bay based upon the report by Maryland Department of Health and Mental Hygiene (DHMH) for 1976-1980.

In order to interpret trends in contaminant data, a tissue concentration equal to the average baseline level plus two standard deviations was used as a level of concern. For PCBs, this level was exceeded in three white perch samples. For chlordane, one blue crab sample exceeded average baseline plus two standard deviations. These were the only samples that exceeded the levels of concern. The average chlordane and PCB levels in biological samples have decreased since the earlier monitoring studies.

Only four species were consistently sampled: *Rangia cuneata* (brackish water clam), *Macoma* sp. (clam [Mitchells or balthic]), *Cyathura polita* (isopod), and *Morone americana* (white perch). The benthic species showed consistently higher levels of iron compared to the fish species. The metals data from the seventh year analyses will be used to re-establish baseline levels for future comparisons.

In general, higher levels of organics and metals were detected south and west of the facility in all species. This may indicate influences from Back River. The data on organics in sediment do not appear to implicate the facility, since all constituents were below the detection limits. This includes station 21-B which is located adjacent to spillway #1. Analysis of the data indicates that contaminants are in the area surrounding the facility because the biota around the facility appear to be bioconcentrating organic contaminants; however no clear evidence can directly implicate the facility because of the spatial distribution of contaminants. Concentrations at stations adjacent to the facility revealed lower concentrations of contaminants than stations further away from the facility. This may indicate greater influences from other areas than the facility. Differences in contaminant concentrations between species are likely to result from many factors including life history, feeding strategies, range of movement and habitat. The benthic species are in greater contact with the sediments and therefore are likely to accumulate organics which tend to remain in the bottom sediments. The fish species are mobile and consequently can accumulate toxics from areas not directly adjacent to the facility.

INTRODUCTION

Selected metals and organic contaminants are analyzed in sediments and biota on a continuing basis as a part of the Hart-Miller Island Containment Facility Environmental Assessment Monitoring Program. Levels of metals and organics have been used in this program as indicators of undesirable impacts upon the environment.

In order to assess environmental impacts of this facility, a number of studies have been carried out beginning in 1981 and continuing through 1988. These programs dealt with the currents surrounding the island, the concentrations of contaminants in the water surrounding the facility, and surveys of fish populations. Study of these and other projects were determined by the Hart-Miller Island Technical Review committee to provide important information relating to the potential environmental impacts of the facility. The current project using concentrations of metals and organics in fish, benthos and sediment has been used since project inception in 1981.

In order to monitor the facility's environmental impact, the Tidewater Administration, Power Plant and Environmental Review Division has the

responsibility of overseeing the monitoring studies as well as providing the interpretation of laboratory analysis data. The samples for this study period were collected by Chesapeake Biological Laboratory (CBL) and Maryland Geological Survey (MGS) in conjunction with their routine cruises for determining any physical or biological impacts from the facility. Physical impacts include changes in particle size fractions, while biological impacts include changes in species composition or diversity. A series of sampling stations were located near the facility. Physical and metals analysis of sediments were performed by MGS. Martel Laboratories (ML) analyzed the fish and benthos samples for metals and organics. Sediment samples were also analyzed by ML for organic contaminants. The results of these laboratory analyses have been used to determine environmental impacts related to the facility.

Baseline information from earlier studies (CRC, 1983, 1984) demonstrated that sediments and biota in the area surrounding the containment facility were contaminated with organic compounds before construction. This information showed that three classes of organic compounds were detectable in sediments and biota. These compounds were chlorinated hydrocarbons such as DDT and PCBs, phthalates, and polynuclear aromatic hydrocarbons (PAH). Chlorinated hydrocarbons include polychlorinated biphenyls or PCBs which have low vapor pressure, high resistance to combustion and chemical stability. Because of these and other characteristics, PCBs were used in transformers and for other industrial uses. The phthalates are used as solvents and plasticizers in industry and painting materials. Polynuclear aromatic hydrocarbons or PAHs, are by-products of combustion. Historically, concentrations of some of these compounds were quite high in benthic species. These compounds are almost entirely products of human activity, although the specific sources of the various substances can be industrial, municipal, agricultural, maritime, or atmospheric (Tidewater, 1987; 6th year report).

Analysis of baseline data also suggested some degree of metal uptake in biota. However, data for comparative purposes were sparse, so that the observed metal concentrations could not be attributed to anthropogenic contamination with any certainty. The metals which were analyzed all have natural sources so that their presence alone does not indicate anthropogenic contamination.

Concentrations of contaminants must be compared with baseline data, or with concentrations from physically similar areas known to be uncontaminated, to be meaningful. Only trace amounts of chromium and nickel should be detectable in

organisms not exposed to contamination of their environment (Tidewater Admin., 1987). The monitoring of these metals and organics in the sediment and biota was established to partially satisfy the wetland permit for construction and operation of the facility.

METHODOLOGY

The first effort to study the impact of the Hart-Miller Island facility was initiated in 1981. The present study represents the seventh year in the effort to monitor possible environmental impacts using organics and metals as indicators of contamination. In this monitoring period, six benthic stations, four fish stations and ten sediment stations were sampled in 1987-1988. Fourteen species of biota were sampled including two species (flounder, blue crab) that had been sampled only during the sixth monitoring year. *Rangia*, *Macoma*, and *Cyathura* were collected at each of the six benthic stations. White perch and yellow perch were primarily collected at the fish sampling stations. Sample collection was limited by species availability. The two, sometimes three, most dominant fish species collected were then analyzed. These species were selected because they were the most dominant at the stations. The locations of the sediment, benthic, and sampling stations are given in Figures 1 - 3. The stations, located north and east of the facility, are closest to the discharge from spillway #1.

Sediment samples were collected by the Sedimentary Environment project (Maryland Geological Survey). Benthic and fish samples were collected by Benthic Studies project (University of MD, CBL). Undisturbed samples of the upper 8-10 cm of the sediment were obtained for organic analysis with a dip-galvanized Peterson sampler. Benthic samples were collected with a 0.05 m^2 Ponar grab. The fish samples were collected with an 15-18 foot otter trawl with a 1 1/2" bar mesh towed for five minutes. The benthic and fish samples were separated by species before submission for metals and organic analysis. Only the muscle tissue of the samples was analyzed for metals and organic concentrations. Appendix A shows the samples collected by the monitoring program and includes parameters such as sample number, date of sample, station and type of laboratory analysis to be undertaken.

Sediment and biota samples were collected and frozen in pre-cleaned glass containers until extraction and then were analyzed using standard EPA techniques

for contaminant analysis. Laboratory techniques used for analysis of sediments and biota are found in Table 1. Organochlorine pesticides and PCBs were analyzed by gas chromatography. Semi-volatile organics (phthalates and PAHs) were analyzed using a gas chromatograph / mass spectrometer. Metals were analyzed using an atomic absorption, direct aspiration technique.

In analyzing data such as these for monitoring purposes, it must be remembered that data for trace organics are difficult to analyze using standard statistical techniques. The data set contains many values which

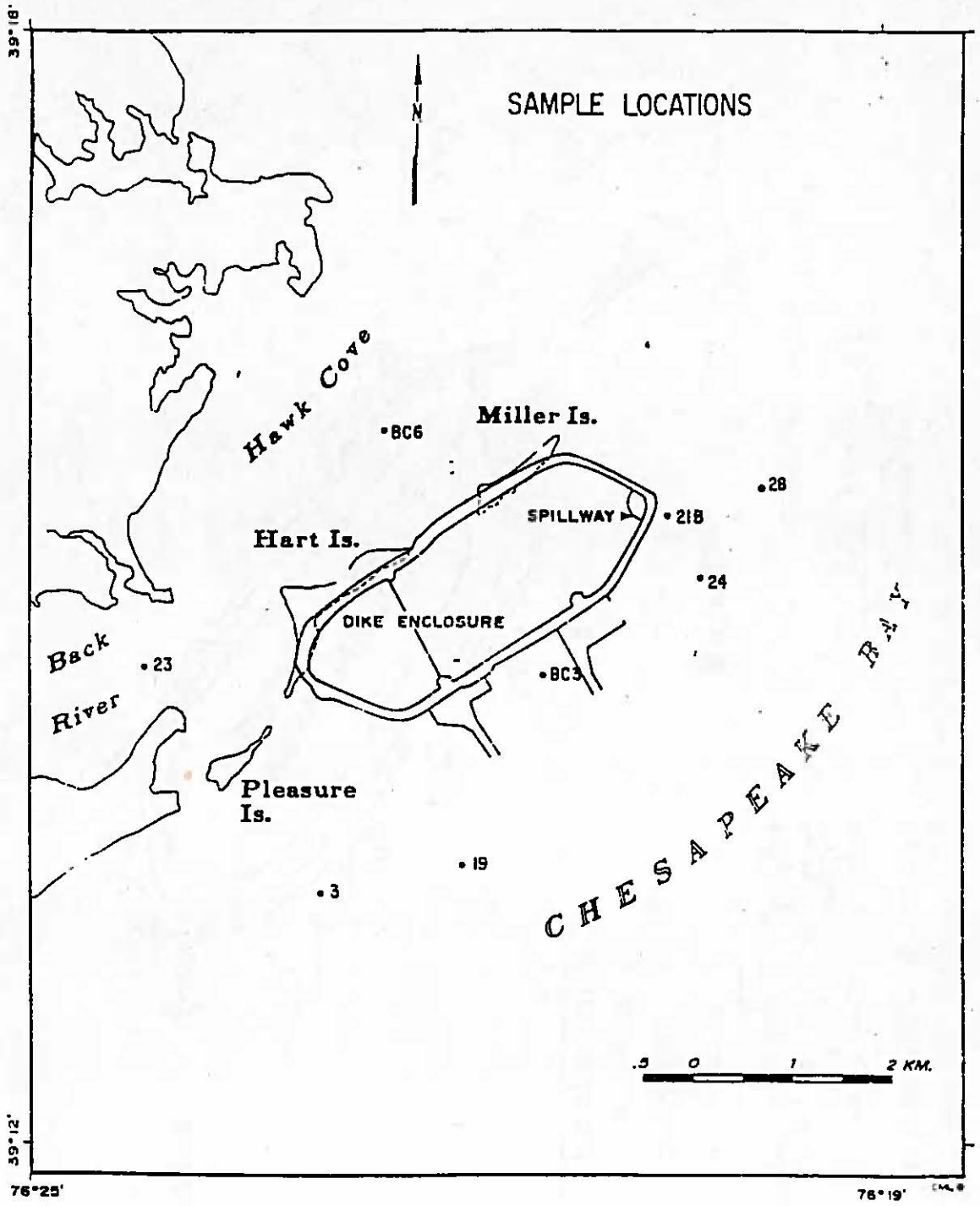


Figure 1. Sediment Sampling Stations for the Seventh Monitoring Year (1987-1988)

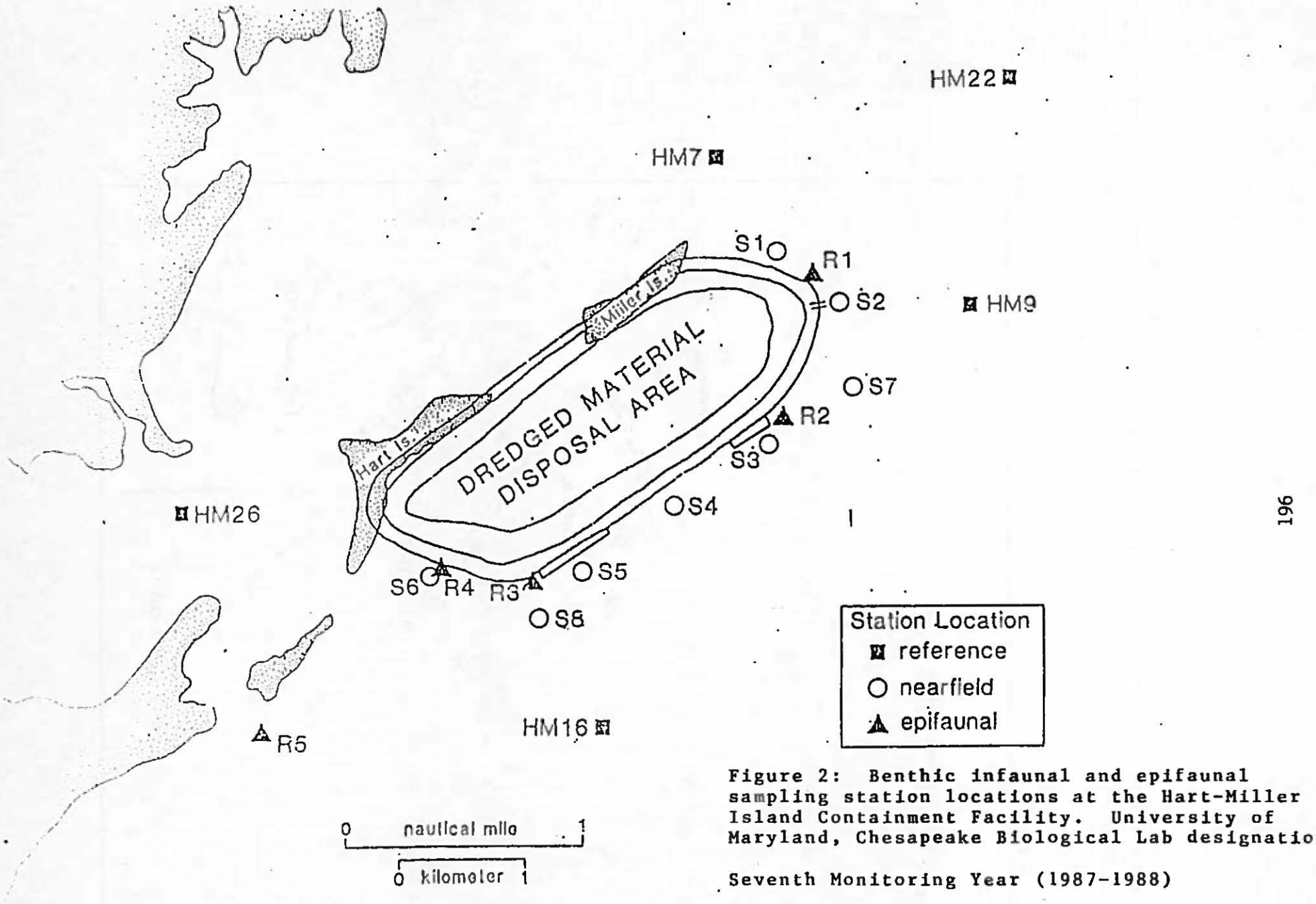


Figure 2: Benthic infaunal and epifaunal sampling station locations at the Hart-Miller Island Containment Facility. University of Maryland, Chesapeake Biological Lab designation

Seventh Monitoring Year (1987-1988)

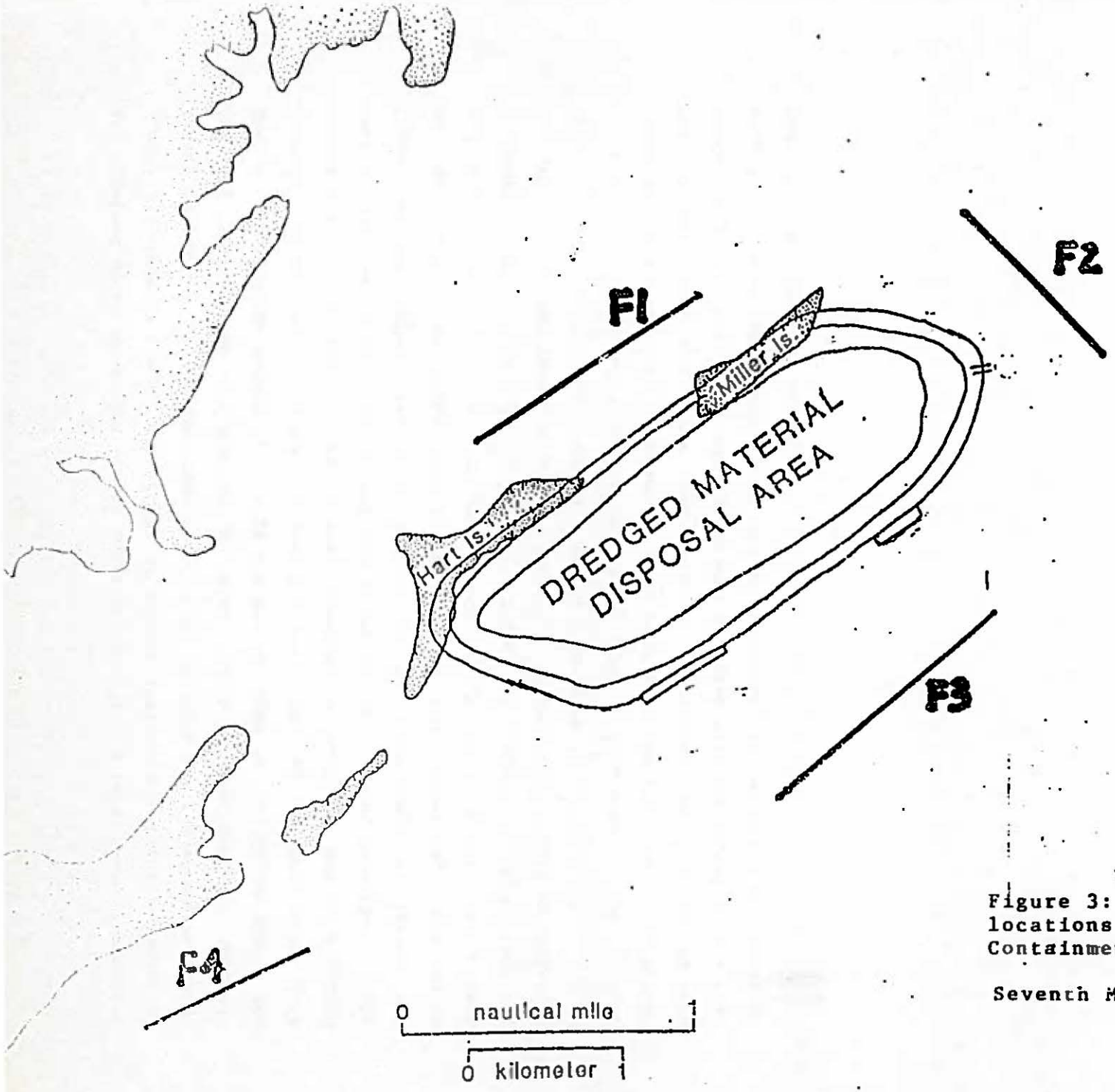


Figure 3: Fish trawling station locations at the Hart-Miller Island Containment Facility.

Seventh Monitoring Year (1987-1988)

are reported below detection limits as determined by the laboratory. Detection limits are dependent upon the amount of tissue available and the presence of interferences as well as instrument accuracy. Limits are therefore variable, not only between media or species but also within a given media or species. Because data below detection limits cannot be used to calculate means and standard deviations, ranges and medians were used as one method of data analysis and comparison. When it was necessary to calculate means, a second method was used which determined the value to be 1/2 the detection limit. These two approaches give equal weight to low (undetectable) levels and extremely high values which occur in the data set and, therefore, yield median and mean values which are more representative of the data set than a mean calculated by excluding all data below detection limits. EA Engineering suggested using two standard deviations from the baseline levels established during earlier monitoring years as a level of concern (EA, 1985).

A comparison of concentration levels was used to determine if the facility impacted the environment. Historical data were also analyzed using mainframe-SAS to determine the means and standard deviations on the contaminant concentrations. This was possible because all past data contained levels that were above detection limits and it was not necessary to calculate the value at one-half the detection limit.

Table 1

Description of analytical methodology used for samples collected August 1987-August 1988 to determine concentration in metals and organic concentrations in sediment and biota

Parameter	Media	EPA Method Number/Reference[1]	
Chromium (Cr)	Tissues	(EPA 218.1)	(EPA, 1983)
Manganese (Mg)	Tissues	(EPA 243.1)	(EPA, 1983)
Iron (Fe)	Tissues	(EPA 236.1)	(EPA, 1983)
Copper (Cu)	Tissues	(EPA 220.1)	(EPA, 1983)
Zinc (Zn)	Tissues	(EPA 289.1)	(EPA, 1983)
Nickel (Ni)	Tissues	(EPA 249.1)	(EPA, 1983)
Pesticides	Tissues/Sediments	(EPA 608) (EPA 8080)	(EPA, 1986)
Phthalate esters and Petroleum hydrocarbon	Tissues/Sediments	(EPA 606)	
Polynuclear Aromatic Hydrocarbons	Tissues/Sediments	(EPA 610)	

[1] EPA (1983). Methods for Chemical Analysis of Water and Wastes. Env. Monit. Support Lab EPA-600-014-79-020 (Revised March 1983).

EPA 1986. Test Methods for Evaluating Solid Wastes. SW-846. Third Ed. Office of Solid Waste & Emergency Response. Washington, D.C.

Comparison of current biological data with third, fourth, fifth, and sixth year data was difficult because samples during these years were not separated by species to determine trends. Current organic contaminant data in biological muscle tissues were analyzed using first and second year data for comparison. A suggested level of concern was then calculated using the mean of past data plus two standard deviations.

Chlordane and PCBs levels were also compared to Food and Drug Administration (FDA) action levels for fish and shellfish. Since chlordane and PCBs were the only organic contaminants that were consistently above detection limits, the discussions of organics data refers only to these two organics. Historical data can be found in Appendix B from the 1981-82 and 1982-83 surveys. These data are included for comparison with 1987-88 values. Comparisons should take into consideration differences in detection limits, and sample preparation procedures. A summary of the ranges and medians of all parameters analyzed by Martel for the seventh monitoring year (December 1987-August 1988) is found in Appendix C. The detection limits are available in the accompanied data report. The "less than" values presented in the summary sheets were the laboratory detection limits.

Data were summarized by determining the number of samples for each sample period that were above the detection limits. Contaminants that were consistently below detection limits were not discussed. A range of the values and medians was then calculated for each of the fourteen species by sample period. The current data were compared to FDA action levels for organics and to historical data, if available. If the historical data were available, a mean plus two standard deviations was used as a level of concern.

The fourteen species of biota were also tested for six metals: chromium (Cr), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), and nickel (Ni). Zn and Cu, while toxic at high concentrations, are biologically necessary in small amounts. Only trace amounts of chromium and nickel should be detectable in organisms not exposed to contamination of their environments (Tidewater Admin., 1987). Two of the metals measured, iron and manganese, are not toxic except at extremely high concentrations and are monitored only as indicator substances for changes in the environment. Only spatial comparisons were determined for this years metals data. The current data will be used to establish baselines for metals in biota on a wet weight basis.

The values of metals concentrations from the first two monitoring years are presented with the discussion of each species only as an attempt to document the historical data related to this project. It should be noted that data on metals in biota presented in this year's report were presented in ppm wet weight, prior metals data for the Hart-Miller monitoring project were presented in ppm dry weight. Because of this, these two values cannot be directly compared. The first and second monitoring report used an empirically derived conversion value of "8". This value was not used on a continuing basis. The Department of Health and Mental Hygiene (DHMH) 1976-1980 data should provide some information for comparison since these data were also presented in ppm wet weight.

RESULTS AND DISCUSSION

As a part of the continuing monitoring program to determine the impacts of the Hart-Miller Island on the environment, 110 samples of sediment and biota were collected to determine the concentrations of 43 trace organic contaminants. The biota samples were also analyzed for six metals: chromium (cr), copper (Cu), iron (fe), manganese (Mn), nickel (Ni), and zinc (Zn). Analysis of the data revealed that only PCBs and chlordane were consistently above detection limits. The metals analysis revealed that Cu, Fe, Mn, and Zn were consistently above the detection limits.

The current metals data will be used to re-establish reliable baselines. The organic analyses was compared with prior monitoring data when available. The FDA action levels are presented to provide a basis for comparison to regulatory levels for fish and shellfish for chlordane and PCBs. A suggested level of concern was then calculated according to EA recommendations (EA, 1985) if historical data were available on that particular species. Two standard deviations from the baseline levels earlier established from prior monitoring years were used. The metals analyses were compared with Department of Health and Mental Hygiene (DHMH) data where possible. The current metals data will also provide a reliable baseline for future comparisons to determine impacts on the environment. Historical data using statistical techniques (means, standard deviations) of metals concentrations are discussed by species only to document the historical data of this project. The historical metals data are presented in ppm dry weight, the current metals data are presented in ppm wet weight.

FISH SPECIES

Catfish

Two samples of catfish were analyzed for organics and metals concentrations from the April 1988 survey. These samples do not provide enough data for a spatial comparison to determine impact on the environment. The specific species of catfish analyzed in the present study were not reported. Total PCB concentrations were 100 ppb at station F1 and 240 ppb at F2. These two samples of catfish were submitted for metals analyses as well. The concentrations of metals in the two samples varied very little between the two samples collected.

Flounder

Only one sample of flounder was collected in December 1987 (Sixth monitoring year) and the species was not reported. In the organic analysis, this sample contained 500 ppb PCBs and 360 ppb chlordane. The PCB concentration was below the FDA action level of 2 (mg/kg) or 2000 ppb. The chlordane concentration exceeded the FDA action level of 0.3 mg/kg or 300 ppb. This may indicate that this species or station should be sampled and data analyzed carefully. The metals concentrations were all below 10 ppm. This was lower than the concentrations found in other demersel fish. Without comparison to other data points, this sample is difficult to use as an indicator of trend.

Spot

Samples were only collected and analyzed for organic and metal concentrations at three stations located at F2, F3, F4 (Figure 3). Three samples collected at one station for August 1988 indicated that the highest concentrations of PCBs were detected at station F4. Two samples, one from August 1987 and one from August 1988, were collected at this station. The concentration of PCBs differed by 50% between the first and second sample. The highest concentration of PCBs detected from the stations that were sampled was 540 ppb at station F4. The highest concentration of chlordane (61 ppb) was found at this station. The highest values were below the FDA action levels for fish and shellfish. Twenty five samples of spot from 1981-1983 produced a mean chlordane concentration of 88.9 ppb (standard deviation 87.4). Twenty five samples of spot from 1981-1983 produced mean PCB concentration of 277.56 ppb

(standard deviation 436.64). All samples were below the suggested level of concern for PCBs and chlordane based on the baseline data (two standard deviations above baseline data).

The three samples from August 1988 indicated that the distribution of the four primary metals (Fe, Mn, Cu, Zn) was very similar among the three stations. The metals concentrations were low, less than 22 ppm wet weight. The mean concentrations and standard deviation of metals in spot tissue from the first two monitoring years are: Cr 6.07 (standard deviation 10.5), Ni 2.88 (standard deviation 2.32), Mn 186.34 (standard deviation 91.7), Zn 60.72 (standard deviation 24.5), Cu 7.05 (standard deviation 9.0)ppm dry weight. Iron was not tested in biota from 1981-1983.

Hogchoker

Two samples of hogchoker were analyzed for organics and metals content, one in August 1987 at station F4 (sixth monitoring year) and one in April 1988 (seventh monitoring year) at station F3. The highest concentration of PCBs was 320 ppb at station F4 with the highest chlordane concentration also at this station (150 ppb). Both measurements were below FDA action levels. No historical data were available to determine a trend or derive a suggested level of concern. The highest metal concentration of the two samples was 57 ppm of Mn at station F3 (April 1988). This was an increase compared to a value of 13 ppm in August of 1987 (sixth monitoring year) at the same station.

Menhaden

Three samples of menhaden were analyzed in December 1987 at stations F3 and F4. The highest concentration of PCBs and chlordane was detected at Station F4 (PCB, 680 ppb; chlordane 400 ppb). This further indicates that concentrations of chlordane in the F-4 area were consistently above the detection limits. The chlordane concentration exceeds the FDA action level. It has already been demonstrated that Station F4 contained higher concentrations of organic constituents. Since menhaden was not collected in other sampling periods, no trend can be determined. The metals concentrations in biota at F-

3 and F-4 stations were similar. No background data on metals in menhaden from the Hart-Miller Island area were available for comparison to current data.

White Perch

Organics and metals were analyzed in sixteen samples of white perch. Although each site contained four samples they were not all from the same sampling periods. Three samples exceeded the mean of the baseline data for PCB, plus two standard deviations (719.5 ppb). These samples came from stations F1 and F4 (Figure 3), which are not adjacent to the unloading stations.

The highest concentrations of PCB were detected at station F1 (940 ppb), but this did not follow the trend of PCB data for station F1 compared to the other species. Most of the other fish species showed higher concentrations at station F-4. The median value for PCBs during the same sample period was 440 ppb. Although elevated concentrations of PCBs were detected in all the August 1988 samples, the highest concentrations of PCBs were consistently detected at station F4. The highest concentrations of chlordane were detected at stations F1 (295 ppb) and F4 (290 ppb) which approach the FDA action level of 300 ppb. The median values for chlordane and PCBs by sample period are presented in Appendix C. The median values for chlordane in December 1987, April 1988, and August 1988 were 200 ppb, <200 ppb and 117 ppb respectively. Both chlordane and PCB concentrations were below FDA action levels. Twenty eight samples were analyzed for PCBs from historical data and produced a mean of 237.5 (standard deviation 241.5). Forty one samples of white perch were analyzed from 1981-1983 for chlordane with a mean of 84.0 ppb (standard deviation 70.7). Three of the samples of white perch collected this sampling year exceeded the mean of baseline plus two standard deviations (224 ppb) for chlordane. These samples were from stations F1, F2, and F4. These are three stations which are not adjacent to the barge unloading stations.

The metals analysis indicated Zn and Fe consistently revealed the highest concentrations of the six metals analyzed. No single area can be isolated as having the largest accumulation of metals because of the high seasonal and sample variability. One sample in April 1988 at station F2 revealed the highest concentrations of metals in white perch (Fe 58 ppm, Mn 78 ppm wet weight.). Two samples collected in August at the same station demonstrated that these concentrations decreased in the summer months (Fe 8, 18 ppm; Mn 4,3) ppm wet

weight. These data can be used to establish a baseline for wet weight comparison of metals in white perch. The mean concentrations and standard deviation of metals in white perch tissue from the first two monitoring years are: Cr 3.08 (standard deviation 3.2), Ni 1.01 (standard deviation 0.68), Mn 49.41 (standard deviation 33.0), Zn 1261.77 (standard deviation 8719.4), Cu 38.23 (standard deviation 42.7) ppm dry weight.

Yellow Perch

Of the six samples of yellow perch that were analyzed for organics, the highest concentrations of PCBs were at station F3. It was unusual to find a higher concentration of PCBs at station F3 (460 ppb) rather than station F4 (310 ppb). The other species sampled during the seventh monitoring year indicated the highest concentrations of contaminants were detected at station F-4. Without other data points at the same station for comparison, no variance can be estimated. There are insufficient samples to take into account seasonal and sample variations. There were no historical samples of yellow perch analyzed to determine baseline levels. Seven samples of yellow perch were analyzed for metals during the April 1988 and August 1988 sampling periods. Although sampling was not consistent over time and stations, the three samples collected in April seem to indicate higher concentrations of metals were found south and west of the facility. These metals analyses will provide a baseline for future comparisons.

BENTHIC SPECIES

Blue Crab

No samples for blue crab were collected during the 7th monitoring year. Samples were collected in August 1987, (sixth monitoring year), but the three samples were insufficient to develop any trend for organic and metals analyses, and each sample was collected at a different station. The highest concentrations of 200 ppb for PCBs and 160 ppb for chlordane were below FDA action levels for fish and shellfish. Twelve samples of blue crab analyzed from 1981-1983 were tested for chlordane and produced a mean value of 40.6 (standard deviation 28.7) and PCBs concentrations produced a mean of 133.1 ppb (standard deviation 175.3). One sample of blue crab with 160 ppb of chlordane exceeded the EA suggested level, the baseline plus two standard deviations (96.6 ppb).

The highest concentration of metals was Mn followed by Zn, this is consistent with the trend in baseline data. These data can be used to provide a wet weight baseline for future comparisons. The mean concentrations and standard deviation of metals in blue crab tissue from the first two monitoring years are: Cr 1.48 (standard deviation 1.2), Ni 2.13 (standard deviation 1.8), Mn 810.86 (standard deviation 479.6), Zn 79.78 (standard deviation 43.35), Cu 45.79 (standard deviation 44.5 ppm)(dry weight).

Polychaetes

One sample of polychaetes was analyzed for organics and metals during the seventh year. There are no historical data on organics in polychaetes from prior years and consequently no comparison can be made for both chlordane and PCBs. This sample was taken adjacent to spillway #1 and revealed no organics above detection limits in the tissue tested. As with organics, there are no historical data on metals in polychaetes. The highest concentration of metals was Fe. These concentrations were lower then any of the other concentrations in the benthic species monitored (ie. *Cyathura*, *Macoma*).

Rhithropanopeus harissii (mud crab)

One sample of *Rhithropanopeus harissii* was tested for organic and metals concentrations during the seventh year. There are no historical data on organics in *Rhithropanopeus* and consequently no comparison can be made for both chlordane and PCBs. This sample was taken adjacent to spillway #1 and revealed no organics above detection limits. While this sample appeared to show higher concentrations of the four primary metals (Fe, Mn, Cu, Zn), this could be related to one of several explanations including location, species biology or season. It is difficult to reach any conclusion about trends from this sample point without other data for comparison.

Macoma sp.

Seven samples of *Macoma* were analyzed for organics and metals concentrations. The samples were collected mostly on the south and east side of the dike at stations S4, S6 and HM16. The analysis of the samples revealed only one sample with PCBs above the detection limit. The sample at station S-6 had a concentration of 81 ppb of PCBs which is far below the FDA action level

of 2000 ppb. Chlordane concentrations were below the FDA action level of 0.3 mg/kg or 300 ppb in all samples. The highest concentration of chlordane was 62 ppb at station S4. No historical data on the genus *Macoma* were available for comparison. The highest metal concentrations were for Fe at station S-4 (1370, 990 ppm). The samples collected revealed consistently higher concentrations of Fe than any of the six metals. Mn was revealed as the next highest concentration of metals detected.

Rangia sp.

Thirty samples of *Rangia* were analyzed for organics and metals content. These samples were from both the sixth and seventh monitoring years. Two samples at station S6 revealed the highest concentrations of PCBs (76, 100 ppb). One sample revealed a chlordane concentration of 2000 ppb of chlordane which greatly exceeded the FDA action level of 300 ppb of chlordane. This sample did not show a concentration of PCBs similar to the other samples collected. One sample of *Rangia* was sampled in February of 1982. This sample had a chlordane concentration of 155 ppb and a PCB concentration of 195 ppb. All the samples of *Rangia* excluding the one sample with 2000 ppb of chlordane were below the baseline levels for PCBs and chlordane from historical data. B-BHC was detected in only one tissue sample of *Rangia sp.* at a level of 5 ppb. Metals data collected in the seventh year tends to indicate lower concentrations of metals were detected at station S-6 on the south and west sides of the dike. This is in contrast to the organics data which tends to indicate higher concentrations of organics in that same area. The metals concentrations seem to be fairly consistent with the highest concentration of iron detected in the August samples. All other metals concentrations were below 100 ppm with the exceptions of Fe and two samples of Mn. The sample at station S-4 revealed a Mn concentration at 116 ppm, and a sample from station HM-22 revealed a Mn concentration of 123 ppm. No historical data (1981-83) on metals concentrations in *Rangia* were available for comparison with current data.

Amphipods (unidentified)

One sample of unidentified amphipods was analyzed for organics and metals during the seventh year in April, 1988. There are no other data on organics in unidentified amphipods from prior years. Consequently no comparison can be made

of both chlordane and PCBs. The one sample analyzed was located near spillway #1 at station S1 and both chlordane and PCB were below detection limits. This sample alone is insufficient to determine a pattern for metals analysis.

Cyathura sp.

Fifteen samples of *Cyathura* were analyzed for organics and metals content. Samples indicated no PCBs concentrations greater than the detection limit. The samples revealed concentrations of chlordane ranging from 80 ppb - 83000 ppb. This species could be used as an indicator for chlordane in the environment because higher concentrations of chlordane were detected in this species than in any other species. The lowest concentrations of chlordane were detected in December, followed by April with the highest concentrations detected in August. The August samples showed a range of 533 up to 8300 ppb. Four of the fifteen samples exceeded FDA action levels for chlordane (300 ppb) in fish and shellfish. These samples were from stations S2, S4, and HM-16. It should be emphasized that FDA action levels are designed for edible species and therefore cannot be directly applied to this species. No samples exceeded the suggested level of concern for PCBs which is 3012.8 ppb. This level was based on the two samples collected in earlier monitoring years (1981-1983). Nine samples of *Cyathura* collected in 1981-1983 produced a mean chlordane concentration of 5720 ppb (standard deviation 367.7). Two samples tested for PCBs during the same time period revealed a mean concentration of 2730 ppb with a standard deviation of 141.4. The mean of these samples exceeded the FDA action level of 2000 ppb. One sample at station S-6 (83000 ppb) exceeded the suggested level of concern mean of baseline plus two standard deviations (6455.4 ppb) for chlordane. The highest metals concentrations in *Cyathura* were for Fe and Mn. The data seems to indicate, lower concentrations of all four primary metals (Fe, Cu, Zn, Mn) during the December sampling period. The iron and manganese concentrations were two to three times greater in the April and August sampling periods, than in the December sampling. Generally all other metals were below 100 ppm with the exception of two samples collected at station S-2 in August 1988. These two samples of *Cyathura* indicated elevated concentrations of Zn (140, 111 ppm). The zinc enrichment factor (4) in sediment from the sixth year monitoring seemed to indicate an enrichment of Zn north and east of the facility. This is compared to a lower zinc enrichment factor (approximately 2) close to the unloading

facilities. This might account for the increased concentrations of Zn at that station. This will provide a baseline for wet weight metals analysis in *Rangia*. The mean concentrations and standard deviation in *Cyathura* tissue from 1981-1983 were: Cr 14.0 (standard deviation. 14.8), Ni 6.6 (standard deviation. 6.7), Mn 434.5 (standard deviation. 496.6), Zn 487.7 (standard deviation. 339.7), Cu 136.3 (168.6) ppm dry weight.

SEDIMENT (TRACE ORGANICS)

Surficial sediments were collected in November 1987 and April 1988 at eight stations: 3, 19, 24, 21-B, 23, BC-3, and BC-6. Triplicate samples were collected at station 24. None of these stations had any concentrations of organics above the detection limits. Detection limits were reduced in the eighth monitoring year to determine if concentrations of organics were below the current detection limits. Metals analysis of sediment samples are included in section II of this report (Sedimentary Environment), results are presented in the sedimentary environment section.

The distribution and range of the enrichment factor for Zn in the exterior sediments were similar to those found in previous monitoring years. Average enrichment factors for the fluid mud remained lower than pre-construction values. However, slight increases in enrichment factors were observed in the bioturbated zone of the fluid mud layer, indicating that benthic activity contributed to the enrichment of sediments with that metal and, by association, others as well.

CONCLUSIONS

Of the fourteen species sampled during the seventh monitoring year, five species were also sampled during the first and second monitoring years. Only four species have been consistently sampled during the seventh monitoring year and these were *Rangia* (brackish water clam), *Macoma* (clam [mitchells or balthic]), *Cyathura* (isopod), and *Morone americana* (white perch). These four species should establish some reliable baseline for eighth year comparisons.

For the two organics detected (chlordane and PCBs), there is considerable variation between season, station, and species. However, it appears that there are higher concentrations of PCBs in biota southwest and southeast area of the dike near trawl stations F3 and F4. Analysis of white perch, yellow perch, and spot data seemed to indicate that higher concentrations of these constituents were found at station F4. The only sample of flounder tested had a high concentration of PCB 500 ug/kg (ppb). This sample was taken at station F4 and seemed to be consistent with the other data at that station. These concentrations were usually below FDA action levels. Levels below the FDA action levels may still have lethal or sub-lethal effects on organisms. These contaminants can not necessarily be linked to the dike because of the possibility of contaminants emanating from Back River.

The MDE issued a health advisory for chlordane in catfish from the Back River area (Tidewater Admin., 1989) which may implicate this area as a source of the compounds. It is interesting to note that no organics were found above detection limits in sediment. It is therefore possible that organisms that were collected from the bottom will most likely bioaccumulate these contaminants. Since most of these fish species are mobile it is difficult to assess if these accumulated concentrations can be linked to the operation of the facility.

Fish Tissue

In the December 1987, April and August 1988 samples, concentrations of chlordane and PCBs were detectable in samples of white perch, yellow perch, hogchoker, catfish, and spot. Some of these fish are demersal and therefore live in intimate association with bottom sediment. Organic chemicals tend to accumulate in bottom sediments due to their insolubility in water. Although there were no organic chemicals above the detection limits in sediment, the

levels in the biota may indicate the presence of these contaminants. Chlordane has high bioconcentration factors. All white perch concentrations of both chlordane and PCBs were below FDA action levels. The second year report (CRC, 1983) indicated elevated concentrations of PCBs and chlordane in white perch at stations HM9 and F10 compared to current data. These stations are located in the same general area as Station F1 from this years data which also revealed the highest concentrations of chlordane and PCBs in white perch, although this year's data showed decreasing concentrations compared to historical data.

Benthos

The isopod, *Cyathura*, consistently revealed concentrations of chlordane and PCBs above the detection limits. All the samples of this *Cyathura* were below baselines established during 1981-1983 monitoring with the exception of one sample in August of 1988. The August samples revealed contaminant concentrations that were 10 times higher than either of the other two sample periods. *Cyathura* consistently displayed higher concentrations of chlordane than any other of the benthic species. This may indicate that *Cyathura* should be carefully monitored for chlordane.

All samples of *Rangia cuneata* showed a decreased concentration of chlordane compared to the first year of monitoring with the exception of one sample in August of 1988. The sample contained 2000 ppb compared to the 195 ppb found in the 1981-1982 sampling year. This sample was described as a large clam and did not follow the general trend of the other samples that were tested that year. Differences in concentration levels related to the size of the sample is one of the many factors affecting levels of contaminants in biota.

All the samples of *Macoma* exhibited at least a 100 fold decrease in the organics concentrations from the 1981-1982 sampling year. This was also true for both chlordane and PCBs. The concentration of PCBs in *Macoma* decreased from the 1981-1982 range of 2384-76000 ppb (average range) to a range of <10-81 ppb in the seventh monitoring year. The average chlordane range in the second monitoring year was 1289-4310 ppb compared to 43.6-50 ppb during the 1987-1988 monitoring year. Both sets of organics data were presented in ppb wet weight. Averaged ranges were calculated by computing the arithmetic mean of the high and low values of the ranges presented in the first and second year report. This seems to indicate the range of concentrations of trace organics surrounding the

facility are decreasing. All other trace organics were consistently below detection limits.

The *Rangia* and fish data both indicated higher concentrations of organics in biota south and west of the facility (near Black March S6, HM16) only six of the other samples that were not in the southwest area showed any organic concentrations at or above the detection limits.

Organics in Sediment

The failure to detect any of the organic contaminants in sediment samples was an indication that (1) the containment facility and associated transportation and unloading of dredged material had not been sources of contamination of the environment with toxic organic compounds and (2) that concentrations of these compounds have continued to decline since the pre-construction sampling in the early 1980's (CRC, 1984). In the fourth monitoring year, sediment samples at several stations revealed detectable concentrations of PCBs ranging from 12 to 162 ppb (Tidewater Admin., 1987). However, the fifth year detection limit for PCBs (200 ppb) was considerably higher than that for the fourth year analyses (10 ppb) (Tidewater Admin., 1987). Detection limits during the seventh year (50 ppb) were much lower than the fifth year, these detection limits were further decreased in the eighth monitoring year. Metals concentrations in sediment were analyzed under Project II - Sedimentary Environment.

Metals in biota

Only five species had enough sample points to indicate a pattern for the analysis for metals concentrations. Most species revealed concentrations of chromium and nickel near or below detection limits for all of the species sampled. This tends to imply that these samples were not exposed to contamination of their environment. Chromium and nickel are two metals which come primarily from anthropogenic sources. Of all the species sampled, *Cyathura* revealed generally higher concentrations of the four primary metals (Fe, Mg, Cu, Zn). The benthic species had concentrations of metals ten times higher than the concentrations found in most of the fish species. This is most likely because the benthic organisms live in intimate association with the bottom sediment where metals tend to settle. The metals data were very

difficult to compare to previous years because the earlier data were presented in ppm dry weight, the current metals data in biota are presented in ppm wet weight. This year's data should provide a good baseline for comparison with future analyses. The data for white perch indicated that higher metals concentrations can be expected in the April sampling periods, based on this year's data. Concentrations of Fe in *Rangia* appeared to be lower than the concentrations shown for the one sample of polychaetes. This difference in concentration between benthic species may be related to the biology of the species and may indicate that these species are likely to accumulate metals, without other data for statistical analyses this is difficult to determine. The benthic organisms also tend to be filter feeders which can also cause an accumulation of contaminants within the tissues.

RECOMMENDATIONS

1. It is imperative to continue monitoring the concentrations of toxic contaminants in both biota and sediments because increased concentrations of these contaminants could indicate a point source of pollutants. The Hart-Miller facility can be considered a point source, especially in relation to sample stations adjacent to the spillways.

2. Develop consistent methodology for sampling, laboratory analysis, and data analysis.

3. If possible, it may be beneficial to reduce the detection limit on sediment analyses. This would enable us to better determine the actual concentration of organics in the sediment. When data are "below detection limits" the question is: how far below the detection limit is the true concentration? Some contaminants may have sub-lethal effects below the given detection limits.

4. It is recommended that samples be better documented in reference to station location to prevent confusion during data analysis. It is also recommended that stations be standardized to make comparison to baseline data easier. Continued monitoring should allow an examination of trends in the data.

5. A pre-determined list of common species should be sampled for all sampling periods. Sample points that can not be compared lose their value when statistical analyses are performed.

6. Use of a contractual laboratory has dramatically reduced the time to analyze the samples for contaminants. It is therefore recommended that the analyses of sediment and biota continue to use the laboratory under contract to maintain consistency in the data. The lab data has now become very consistent for the last two years. This is due to the use of a contractual laboratory that provided quality assurance and control. The reporting of the lab data has also improved since the contractual laboratory was used.

7. Samples should especially be taken at station HM-22 to determine if there are any significant effects at this station. Station F4 should also be monitored carefully since the highest levels of contaminants have been reported at that station.

8. It is recommended that metals data be standardized and either measured in wet weight or dry weight and report the percent solids in tissues because comparison between the two forms is not possible.

9. The contaminant data for the seventh year should begin to serve as a good baseline for future sampling years.report

Appendix A

Hart-Miller Exterior Monitoring Program Samples Collected for 1987-88

H.M.I. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS REQUIRED
870380	F4	8-24-87	YEAR #6 SUMMER	1644	0	EBB	9-12	HOGCHOCKER	BLACK MARSH AREA	PFITZENMEYER	METALS
870381	F3	8-24-87	"	1631	0	"	9-12	CATFISH	@ SS# XIE4715	PFITZENMEYER	METALS
870382	F3	8-24-87	"	1631	0	"	9-12	HOGCHOCKER	@ SS# XIE4715	PFITZENMEYER	METALS
870383	F1	8-24-87	"	1503	0	"	9-12	BLUE CRAB	SLUICE GATE AREA	PFITZENMEYER	ORGANICS
870384	F4	8-24-87	"	1644	0	"	9-12	HOGCHOCKER	BLACK MARSH AREA	PFITZENMEYER	ORGANICS
870385	F1	8-24-87	"	1503	0	"	9-12	BLUE CRAB	SLUICE GATE AREA	PFITZENMEYER	METALS
870386	F2	8-24-87	"	1545	0	"	9-12	BLUE CRAB	@ SS# XIE5406	PFITZENMEYER	METALS
870387	F2	8-24-87	"	1545	0	"	9-12	FLOUNDER	@ SS# XIE5406	PFITZENMEYER	METALS
870388	F2	8-24-87	"	1545	0	"	9-12	BLUE CRAB	@ SS# XIE5406	PFITZENMEYER	ORGANICS
870389	F3	8-24-87	"	1631	0	"	9-12	BLUE CRAB	@ SS# XIE4715	PFITZENMEYER	METALS
870390	F3	8-24-87	"	1631	0	"	9-12	BLUE CRAB	@ SS# XIE4715	PFITZENMEYER	ORGANICS
870391	F4	8-24-87	"	1644	0	"	9-12	FLOUNDER	BLACK MARSH AREA	PFITZENMEYER	METALS
870392	F4	8-24-87	"	1644	0	"	9-12	FLOUNDER	BLACK MARSH AREA	PFITZENMEYER	ORGANICS
870393	F4	8-24-87	"	1644	0	"	9-12	SPOT	BLACK MARSH AREA	PFITZENMEYER	ORGANICS
870394	S4	8-24-87	"	1631	0	"	9-12	RANGIA	SS# XIE4715	PFITZENMEYER	ORGANICS
870395	S4	8-24-87	"	1631	0	"	9-12	RANGIA	SS# XIE4715	PFITZENMEYER	METALS
870396	HM22	8-24-87	"	1253	0	"	9-12	RANGIA	SS# XIE6689	PFITZENMEYER	ORGANICS
870397	HM22	8-24-87	"	1253	0	"	9-12	RANGIA	SS# XIE6689	PFITZENMEYER	METALS
870398	HM7	8-24-87	"	1232	0	"	9-12	RANGIA	SS# XIE6388	PFITZENMEYER	METALS
870399	HM7	8-24-87	"	1232	0	"	9-12	RANGIA	SS# XIE6388	PFITZENMEYER	ORGANICS

*SS#= STATE STATION #

* WEATHER CODE #0 = CLEAR

* SAMPLES ARE PACKED IN PLASTIC ZIPLOC BAGS, AND HAVE BEEN FROZEN SINCE TIME OF SAMPLING.
* SAMPLES FOR ORGANIC ANALYSIS HAVE BEEN WRAPPED IN ALUMINUM FOIL TO PREVENT CONTAMINATION.

> SAMPLES FOR ORGANIC ANALYSIS INCLUDE ALL THOSE ANALYSIS LISTED IN TABLE #5 OF AGREEMENT
> SAMPLES FOR METAL ANALYSIS INCLUDE THE FOLLOWING SIX TRACE METALS:
* CHROMIUM * IRON * MANGANESE * COPPER * ZINC * NICKEL

SAMPLES DELIVERED TO HMI LABORATORY ON: 12/7/87 0945 SAMPLES RELINQUISED BY: H.J. PFITZENMEYER
SAMPLES RECIEVED BY: J. HILGARTNER

> SAMPLES DELIVERED TO MARTEL LABORATORY ON: 1/21/88 1500 SAMPLES RELINQUISED BY: L. FRITZ
SAMPLES RECIEVED BY: J. WOLFKILL

Appendix A
(continued)

H.M.I. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS REQUIRED
870405	HM 16-1	12-7-87	YEAR #7 FALL	1034	C,S	SL	17	CYATHUNA	XIF3325	PFITZENMEYER	MET/ORG
870406	HM 16-2	12-7-87	"	1045	C,S	SBE	17	RANGIA	XIF3325	PFITZENMEYER	MET/ORG
870407	HM 16-3	12-7-87	"	1118	C,S	SBE	27	RANGIA	XIF3325	PFITZENMEYER	MET/ORG
870408	S 6-1	12-7-87	"	1200	C,S	SBE	11	CYANTHUNA	XIF4327	PFITZENMEYER	MET/ORG
870409	S 6-2	12-7-87	"	1208	C,S	SBE	11	MACOMA	XIF4327	PFITZENMEYER	MET/ORG
870410	S 6-3	12-7-87	"	1215	C,S	SBE	11	RANGIA	XIF4327	PFITZENMEYER	MET/ORG
870411	S 6-4	12-7-87	"	1225	C,S	SBE	11	RANGIA	XIF4327	PFITZENMEYER	MET/ORG
870412	S 4-1	12-7-87	"	1343	C,S	SBE	13.5	RANGIA	XIF4715	PFITZENMEYER	MET/ORG
870413	S 4-2	12-7-87	"	1350	C,S	SBE	13.5	RANGIA	XIF4715	PFITZENMEYER	MET/ORG
870414	S 4-3	12-7-87	"	1400	C,S	SBE	13.5	MACOMA	XIF4715	PFITZENMEYER	MET/ORG
870415	S 7-1	12-7-87	"	1450	C,S	SBE	13.1	RANGIA	XI65405	PFITZENMEYER	MET/ORG
870416	S 7-2	12-7-87	"	1455	C,S	SBE	13.1	RANGIA	XI65405	PFITZENMEYER	MET/ORG
870417	S 1-1	12-7-87	"	1510	1	SBE	5	RANGIA	XIF5710	PFITZENMEYER	MET/ORG
870418	S 1-2	12-7-87	"	1510	1	SBE	5	RANGIA	XIF5710	PFITZENMEYER	MET/ORG
870419	HM 22-1	12-7-87	"	1630	1	SBE	14	RANGIA	XI67689	PFITZENMEYER	MET/ORG
870420	HM 22-2	12-7-87	"	1640	1	SBE	14	RANGIA	XI67689	PFITZENMEYER	MET/ORG
870421	F -1	12-8-87	"	1215	C,O	SBE	11	Y.PERCH	NORTH SIDE/HMI	PFITZENMEYER	MET/ORG
870422	F -2	12-8-87	"	1220	C,O	SBE	11	Y.PERCH	NORTH SIDE/HMI	PFITZENMEYER	MET/ORG
870423	F 3-1	12-8-87	"	1405	C,O	SBE	16	MENHADEN	SOUTH/UNLOADER	PFITZENMEYER	MET/ORG
870424	F 3-2	12-8-87	"	1415	C,O	SBE	16	MENHADEN	SOUTH/UNLOADER	PFITZENMEYER	MET/ORG
870425	F 4-1	12-8-87	"	1500	C,O	SBE	16	MENHADEN	BLACK MARSH @	PFITZENMEYER	MET/ORG
870426	F 4-2	12-8-87	"	1500	C,O	SBE	16	W.PERCH	BLACK MARSH @	PFITZENMEYER	MET/ORG

OTHER PERTINENT INFORMATION:

* WEATHER CODES: C,S = CALM & SUNNY 1 = CLOUDY C,O = CALM & OVERCAST * TIDE CODE SBE = SLACK BEFORE EBB
* SAMPLES ARE PACKED IN 250ML GLASS JARS WITH TEFLON LINERS * SAMPLES HAVE BEEN FROZED SINCE TIME OF SAMPLING
* ALL SAMPLES ARE TO BE SPLIT FOR ORGAINC ANALYSIS (ALL ANALYSIS LISTED IN TABLE #5 OF AGREEMENT)
  AND FOR METAL ANALYSIS OF THE FOLLOWING SIX TRACE METALS:
  * CHROMIUM * IRON * MANGANESE * COPPER * ZINC * NICKEL

* SAMPLES DELIVERED TO HMI LABORATORY ON: 12/8/87 1345 SAMPLES RELINQUISED BY: H.T. PFITENMEYER
  SAMPLES RECIEVED BY: L. FRITZ

* SAMPLES DELIVERED TO MARTEL LABORATORY ON: 1/21/88 1500 SAMPLES RELINQUISED BY: L. FRITZ
  SAMPLES RECIEVED BY: J. WOLFKILL

H.M.I. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME CODE	WEATHER CODE	TIDE CODE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS TO BE DONE
870223	3	11-3-87	YEAR #7 FALL	N/A	1	N/A	15	SEDIMENT	X=27636.5/Y=42886.5	HENNESSEE	ORGANICS
870224	19	11-3-87	"	N/A	1	N/A	17	SEDIMENT	X=27632.3/Y=42889.0	HENNESSEE	ORGANICS
870225	BC-3	11-3-87	"	N/A	1	N/A	14	SEDIMENT	X=27633.3/Y=42901.9	HENNESSEE	ORGANICS
870226	24-1	11-3-87	"	N/A	1	N/A	16.5	SEDIMENT	X=27629.8/Y=42909.0	HENNESSEE	ORGANICS
870227	24-2	11-3-87	"	N/A	1	N/A	16.5	SEDIMENT	X=27629.8/Y=42909.0	HENNESSEE	ORGANICS
870228	24-3	11-3-87	"	N/A	1	N/A	16.5	SEDIMENT	X=27629.8/Y=42909.0	HENNESSEE	ORGANICS
870229	28	11-3-87	"	N/A	1	N/A	19.5	SEDIMENT	X=27629.4/Y=42915.1	HENNESSEE	ORGANICS
870230	21 B	11-3-87	"	N/A	1	N/A	13	SEDIMENT	X=27632.1/Y=42912.9	HENNESSEE	ORGANICS
870231	BC-6	11-3-87	"	N/A	1	N/A	11.5	SEDIMENT	X=27643.4/Y=42917.1	HENNESSEE	ORGANICS
870232	23	11-3-87	"	N/A	1	N/A	11	SEDIMENT	X=27646.8/Y=42900.5	HENNESSEE	ORGANICS

* LORAN READINGS

OTHER PERTINENT INFORMATION:

* WEATHER CODE #1 = PARTLY CLOUDY

* SAMPLES ARE IN GLASS JARS WITH ALUMINUM FOIL UNDER LID
* SAMPLES HAVE BEEN FROZEN SINCE TIME OF SAMPLING

> SAMPLES DELIVERED TO HMI LABORATORY ON: 11/3/87 1430 SAMPLES RELINQUISED BY: E.L. HENNESSEE
SAMPLES RECIEVED BY: L. FRIIZ

> SAMPLES DELIVERED TO MARTEL LABORATORY ON: 1/21/88 1500 SAMPLES RELINQUISED BY: L. FRIIZ
SAMPLES RECIEVED BY: J. WOLEKILL

> ALL SAMPLES TO BE ANALYZED FOR ORGANICS LISTED IN TABLE #5

Appendix A
(continued)

H.M.. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE	DE. FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANAL. REQUIRED
880156	HM 16-1	4/11/88	YEAR #7 SPRING	0953	C	EBB	15	CYATHUNA	XIF3325	DUGUAY	MET/ORG
880157	HM 16-2	4/11/88	"	0953	C	EBB	15	MACOMA	XIF3325	DUGUAY	MET/ORG
880158	HM 16-3	4/11/88	"	0953	C	EBB	15	RANGIA	XIF3325	DUGUAY	MET/ORG
880159	S 6-1	4/11/88	"	1035	C	FLOOD	15	CYANTHUNA	XIF4327	DUGUAY	MET/ORG
880160	S 6-2	4/11/88	"	1035	C	FLOOD	15	MACOMA	XIF4327	DUGUAY	MET/ORG
880161	S 6-3	4/11/88	"	1035	C	FLOOD	15	RANGIA	XIF4327	DUGUAY	MET/ORG
880162	S 6-4	4/11/88	"	1121	C	FLOOD	15	CYANTHUNA	XIF4715	DUGUAY	MET/ORG
880163	S 4-1	4/11/88	"	1121	C	FLOOD	15	MACOMA	XIF4715	DUGUAY	MET/ORG
880164	S 4-2	4/11/88	"	1121	C	FLOOD	15	RANGIA, LG	XIF4715	DUGUAY	MET/ORG
880165	S 4-3	4/11/88	"	1121	C	FLOOD	15	RANGIA, SM	XIF4715	DUGUAY	MET/ORG
880166	S 2-1	4/11/88	"	1208	C	FLOOD	12	CYANTHUNA	XIF5406	DUGUAY	MET/ORG
880167	S 2-2	4/11/88	"	1208	C	FLOOD	12	POLYCHEATES	XIF5406	DUGUAY	MET/ORG
880168	S 2-3	4/11/88	"	1208	C	FLOOD	12	RANGIA, LG	XIF5406	DUGUAY	MET/ORG
880169	S 2-4	4/11/88	"	1208	C	FLOOD	12	RANGIA, SM	XIF5406	DUGUAY	MET/ORG
880170	S 1-1	4/11/88	"	1240	C	FLOOD	5	CYANTHUNA	XIF5710	DUGUAY	MET/ORG
880171	S 1-2	4/11/88	"	1240	C	FLOOD	5	AMPHIPODS	XIF5710	DUGUAY	MET/ORG
880172	S 1-3	4/11/88	"	1240	C	FLOOD	5	RANGIA	XIF5710	DUGUAY	MET/ORG
880173	HM 22-1	4/11/88	"	1406	C	FLOOD	12	CYANTHUNA	XIG7689	DUGUAY	MET/ORG
880174	HM 22-2	4/11/88	"	1406	C	FLOOD	12	RANGIA, LG	XIG7689	DUGUAY	MET/ORG
880175	HM 22-3	4/11/88	"	1406	C	FLOOD	12	RANGIA, SM	XIG7689	DUGUAY	MET/ORG
880176	F 4-1	4/11/88	"	1454	C	FLOOD	15	WHITE PERCH	42876.9 x 27640.1 (reference station)	DUGUAY	MET/ORG
880177	F 4-2	4/11/88	"	1454	C	FLOOD	15	WHITE PERCH	"	DUGUAY	MET/ORG
880178	F 4-3	4/11/88	"	1454	C	FLOOD	15	YELL. PERCH	"	DUGUAY	MET/ORG
880179	F 3-1	4/11/88	"	1535	C	FLOOD	15	WHITE PERCH	42916.6 x 27642.2 (south side of is.)	DUGUAY	MET/ORG
880180	F 3-2	4/11/88	"	1535	C	FLOOD	15	WHITE PERCH	"	DUGUAY	MET/ORG
880181	F 3-3	4/11/88	"	1535	C	FLOOD	15	YELL. PERCH	"	DUGUAY	MET/ORG
880182	F 3-4	4/11/88	"	1535	C	FLOOD	15	HOGCHOCKER	"	DUGUAY	MET/ORG

Appendix A
(continued)

H.M SAMPLE ID	NRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANAL REQU
880183	F 2-1	4/11/88	"	1547	C	FLOOD	17	WHITE PERCH	Buoy #1;Middle Rive	DUGUAY	MET/ORG
880184	F 2-2	4/11/88	"	1547	C	FLOOD	17	WHITE PERCH	"	DUGUAY	MET/ORG
880185	F -3	4/11/88	"	1547	C	FLOOD	17	CATFISH	"	DUGUAY	MET/ORG
880186	F 1-1	4/11/88	"	1607	C	FLOOD	10	WHITE PERCH	42916.6 x 27642.2 Hawks Cove	DUGUAY	MET/ORG
880187	F 1-2	4/11/88	"	1607	C	FLOOD	10	WHITE PERCH	"	DUGUAY	MET/ORG
880188	F 1-3	4/11/88	"	1607	C	FLOOD	10	YELL. PERCH	"	DUGUAY	MET/ORG
880189	F 1-4	4/11/88	"	1607	C	FLOOD	10	CATFISH	"	DUGUAY	MET/ORG

* WEATHER CODES: C = CLEAR
* SAMPLES ARE PACKED IN 250ML GLASS JARS WITH TEFLON LINERS * SAMPLES HAVE BEEN FROZED SINCE TIME OF SAMPLING
* ALL SAMPLES ARE TO BE SPLIT FOR ORGAINC ANALYSIS (ALL ANALYSIS LISTED IN TABLE #5 OF AGREEMENT) AND FOR METAL ANALYSIS OF THE FOLLOWING SIX TRACE METALS:
  * CHROMIUM * IRON * MANGANESE * COPPER * ZINC * NICKEL

* SAMPLES DELIVERED TO HMI LABORATORY ON: 4/12/88 SAMPLES RELINQUISED BY: H.T. FFITZENMEYER
SAMPLES RECIEVED BY: T.R. BANTA

* SAMPLES DELIVERED TO MARTEL LABORATORY ON: 4/13/88 1600 SAMPLES RELINQUISED BY: T.R. BANTA
SAMPLES RECIEVED BY: P. BELL

Appendix A
(continued)

H.M.I. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE CODE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS TO BE DONE
880190	3	4-12-88	YEAR #7 WINTER	N/A	2	N/A	16.5	SEDIMENT	XIF 3430	HENNESSEE	ORGANICS
880191	19	4-12-88	"	N/A	2	N/A	19	SEDIMENT	XIF 3620	HENNESSEE	ORGANICS
880192	BC-3	4-12-88	"	N/A	2	N/A	16	SEDIMENT	XIF 4615	HENNESSEE	ORGANICS
880193	24-1	4-12-88	"	N/A	2	N/A	18	SEDIMENT	XIF 5302	HENNESSEE	ORGANICS
880194	24-2	4-12-88	"	N/A	2	N/A	18	SEDIMENT	XIF 5302	HENNESSEE	ORGANICS
880195	24-3	4-12-88	"	N/A	2	N/A	18	SEDIMENT	XIF 5302	HENNESSEE	ORGANICS
880196	28	4-12-88	"	N/A	2	N/A	20	SEDIMENT	XIG 5699	HENNESSEE	ORGANICS
880197	21-B	4-12-88	"	N/A	2	N/A	14	SEDIMENT	XIF 5505	HENNESSEE	ORGANICS
880198	BC-6	4-12-88	"	N/A	2	N/A	13	SEDIMENT	XIF 5925	HENNESSEE	ORGANICS
880197	23	4-12-88	"	N/A	2	N/A	13	SEDIMENT	XIF 4642	HENNESSEE	ORGANICS

OTHER PERTINENT INFORMATION:

* WEATHER CODE #2 = CONTINUOUS LAYERS OF CLOUDS

* SAMPLES ARE IN GLASS JARS * SAMPLES HAVE BEEN FROZEN SINCE TIME OF SAMPLING

SAMPLES DELIVERED TO HMI LABORATORY ON: 4/12/88 SAMPLES RELINQUISED BY: E.L. HENNESSEE
SAMPLES RECIEVED BY: T.R. BANTA

SAMPLES DELIVERED TO MARTEL LABORATORY ON: 4/13/88 1600 SAMPLES RELINQUISED BY: T.R. BANTA
SAMPLES RECIEVED BY: P. NELL

ALL SAMPLES TO BE ANALYZED FOR ORGANICS LISTED IN TABLE #5

Appendix A
(continued)

MES SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE *	TIDE	DEPTH IN FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS TO BE DONE
880525	HM 16-1	8-1-88	YEAR #8 SUMMER	10:25	1	FLOOD	18	RANGIA	STATE STA # XIF3325	PFITZENMEYER	MET/ORG
880526	HM 16-2	8-1-88	"	10:25	1	SLACK	18	MACOMA	STATE STA # XIF3325	PFITZENMEYER	MET/ORG
880527	HM 16-3	8-1-88	"	10:25	1	SLACK	18	CYATHURA	STATE STA # XIF3325	PFITZENMEYER	MET/ORG
880528	-S6-1	8-1-88	"	12:15	1	SLACK	12.5	RANGIA	STATE STA # XIF4420	PFITZENMEYER	MET/ORG
880529	-S6-2	8-1-88	"	12:15	1	SLACK	12.5	MACOMA	STATE STA # XIF4420	PFITZENMEYER	MET/ORG
880530	-S6-3	8-1-88	"	12:15	1	SLACK	12.5	CYATHURA	STATE STA # XIF4420	PFITZENMEYER	MET/ORG
880531	S4-1	8-1-88	"	13:10	1	EBB	15	RANGIA	STATE STA # XIF4715	PFITZENMEYER	MET/ORG
880532	-S4-2	8-1-88	"	13:10	1	EBB	15	CYATHURA	STATE STA # XIF4715	PFITZENMEYER	MET/ORG
880533	-S2-1	8-1-88	"	14:45	1	EBB	13	RANGIA	STATE STA # XIF5406	PFITZENMEYER	MET/ORG
880534	-S2-2	8-1-88	"	14:45	1	EBB	13	RITHROPANOPEUS	STATE STA # XIF5406	PFITZENMEYER	MET/ORG
880535	-S2-3	8-1-88	"	14:45	1	EBB	13	CYATHURA	STATE STA # XIF5406	PFITZENMEYER	MET/ORG
880536	S1-1	8-1-88	"	15:45	1	EBB	7	RANGIA	STATE STA # XIF5710	PFITZENMEYER	MET/ORG
880537	S1-2	8-1-88	"	15:45	1	EBB	7	CYATHURA	STATE STA # XIF5710	PFITZENMEYER	MET/ORG
880538	HM 22-1	8-1-88	"	16:15	1	EBB	14	RANGIA	STATE STA # X167689	PFITZENMEYER	MET/ORG
880539	HM 22-2	8-1-88	"	16:15	1	EBB	14	RANGIA	STATE STA # X167689	PFITZENMEYER	MET/ORG
880540	HM 22-3	8-1-88	"	16:15	1	EBB	14	CYATHURA	STATE STA # X167689	PFITZENMEYER	MET/ORG
880541	F -1-1	8-1-88	"	17:25	1	EBB	10	YELLOW PERCH	LAT/LONG START-STOP ✓ 39 15.5' - 39 15.7' 76 23.2' - 76 22.9'	PFITZENMEYER	MET/ORG
880542	F -1-2	8-1-88	"	17:25	1	EBB	10	WHITE PERCH	39 15.5' - 39 15.7' 76 23.2' - 76 22.9'	PFITZENMEYER	MET/ORG
880543	F (1)-3	8-1-88	"	17:25	1	EBB	10	WHITE PERCH	39 15.5' - 39 15.7' 76 23.2' - 76 22.9'	PFITZENMEYER	MET/ORG
880544	F (2)-1	8-1-88	"	17:55	1	EBB	10-13	SPOT	39 15.8 - 39 16.1' 76 20.7 - 76 20.8'	PFITZENMEYER	MET/ORG
880545	F 2-2	8-1-88	"	17:55	1	EBB	10-13	WHITE PERCH	39 15.8 - 39 16.1' 76 20.7 - 76 20.8'	PFITZENMEYER	MET/ORG
880546	F (2)-3	8-1-88	"	17:55	1	EBB	10-13	WHITE PERCH	39 15.8 - 39 16.1' 76 20.7 - 76 20.8'	PFITZENMEYER	MET/ORG
880547	F (3)-1	8-1-88	"	18:20	1	EBB	10-12	SPOT	39 14.6' - 39 76 21.4' - 76	PFITZENMEYER	MET/ORG

* WEATHER CODE: 1 = CLEAR

Appendix A
(continued)

MES SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE *	TIDE	DEPTH IN FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS TO BE DONE
880548	F 3-2	8-1-88	*	18:20	1	EBB	10-14	WHITE PERCH	39 14.6' - 39 76 21.4' - 76	PFITZENMEYER	MET/ORG
880549	F 3-3	8-1-88	*	18:20	1	EBB	10-14	WHITE PERCH	39 14.6' - 39 76 21.4' - 76	PFITZENMEYER	MET/ORG
880550	F 4-1	8-1-88	*	18:40	1	EBB	15	SPOT	39 12.3' - 39 12.5 76 24.1' - 76 24.4'		

Concentrations (ug/kg) of Selected Organic Contaiminants in Rangia at Station HM-14.

COMPOUND	FEB 1982
alpha-BHC	<3.4
lindane	<3.4
beta-BHC	<3.4
aldrin	4.3
heptachlor	12.5
heptachlor epoxide	<3.4
dieldrin	176
naphthalene	<3.4
fluorene	3.4
phenanthrene	8.0
anthracene	9.8
fluoranthene	8.0
pyrene	8.0
benzo(a)pyrene	5.4
benzo(a)anthracene	<3.4
benzo(k)fluoranthrene	<3.4
3,4 benzofluoranthene	<3.4
chrysene	3.4
acenaphthylene	<3.4
benzo(ghi)perylene	<3.4
dibenz(a,h)anthracene	<3.4
indeno(1,2,3-cd)pyrene	<3.4
acenaphthene	<3.4
PCBs, total	195
kepone	<3.4
dimethyl phthalate	5.4
diethyl phthalate	228
dibutyl phthalate	275
di-2-ethyl hexyl phthalate	262
di octyl phthalate	39.3
atrazine	<3.4
simazine	<3.4
trifluraline	<3.4
chlordane	155
diazinon	<3.4
DDE	5.4
DDD	3.4
DDT	3.4
linuron	<3.4
butyl benzyl phthalate	76.8
endrin	<3.4
malathion	<3.4
methyl parathion	<3.4
ethyl parathion	<3.4

Ranges (ppb) of concentrations for 44 compounds in Macoma.

COMPOUND	RANGE OBSERVED AUG 1981	MAY 1982
alpha-BHC	N.D.	N.D.
lindane	<141 - 251	N.D.
beta-BHC	N.D.	N.D.
aldrin	1006 - 4780	318 - 1216
heptachlor	141 - 2012	N.D.
heptachlor epoxide	N.D.	N.D.
dieldrin	755 - 1260	<79 - 676
naphthalene	N.D.	<135 - 397
fluorene	<141 - 251	N.D.
phenanthrene	<141 - 377	N.D.
anthracene	<141 - 377	N.D.
fluoranthene	<251 - 9560	954 - 1890
pyrene	<251 - 9980	1030 - 2290
benzo(a)pyrene	N.D.	N.D.
benzo(a)anthracene	N.D.	N.D.
benzo(k)fluoranthrene	N.D.	N.D.
3,4 benzofluoranthene	N.D	N.D.
chrysene	N.D.	N.D.
acenaphthylene	N.D.	N.D.
benzo(ghi)perylene	N.D.	N.D.
dibenz(a,h)anthracene	N.D.	N.D.
indeno(1,2,3-cd)pyrene	N.D.	N.D.
acenaphthene	N.D.	N.D.
PCBs, total	1509 - 8580	3260 - 6620
kepone	N.D.	N.D.
dimethyl phthalate	141 - 1257	N.D.
diethyl phthalate	<141 -16300	2150 - 5135
dibutyl phthalate	8800 -64200	8268 -29300
di-2-ethyl hexyl phthalate	141 - 1760	477 - 540
di octyl phthalate	141 - 251	<135 - 159
atrazine	N.D.	N.D.
simazine	N.D.	N.D.
trifluraline	N.D.	N.D.
chlordane	2260 - 6050	318 - 2570
diazinon	N.D.	N.D.
DDE	<141 - 251	N.D.
DDD	<141 - 377	N.D.
DDT	N.D.	N.D.
linuron	N.D.	N.D.
butyl benzyl phthalate	421 - 2515	N.D.
endrin	N.D.	N.D.
malathion	N.D.	N.D.
methyl parathion	N.D.	N.D.
ethyl parathion	N.D.	N.D.

N.D. - not detected.

Concentrations of Selected Organic Contaiminants in Cyathura at Stations HM6, HM10, May 1983.

COMPOUND	HM6 CONCENTRATION, ug/kg	HM10
alpha-BHC	3510	4240
lindane	4210	4860
beta-BHC	3930	3650
aldrin	3700	2630
heptachlor	2650	6000
heptachlor epoxide	<2800	<1660
dieldrin	2915	3070
naphthalene	<2800	<1660
fluorene	<2800	<1660
phenanthrene	<2800	<1660
anthracene	<2800	<1660
fluoranthene	<2800	<1660
pyrene	<2800	<1660
benzo(a)pyrene	<2800	<1660
benzo(a)anthracene	<2800	<1660
benzo(k)fluoranthrene	<2800	<1660
3,4 benzofluoranthene	<2800	<1660
chrysene	<2800	<1660
acenaphthylene	<2800	<1660
benzo(ghi)perylene	<2800	<1660
dibenz(a,h)anthracene	<2800	<1660
indeno(1,2,3-cd)pyrene	<2800	<1660
acenaphthene	<2800	<1660
PCBs, total	2830	2630
kepone	<2800	<1660
dimethyl phthalate	<2800	<1660
diethyl phthalate	<2800	<1660
dibutyl phthalate	<2800	<1660
di-2-ethyl hexyl phthalate	27000	24000
di octyl phthalate	<2800	<1660
atrazine	<2800	<1660
simazine	<2800	<1660
trifluraline	<2800	<1660
chlordane	5980	5460
diazinon	<2800	<1660
DDE	<2800	5540
DDD	45000	1660
DDT	<2800	<1660
linuron	<2800	<1660
butyl benzyl phthalate	7400000	<1660
endrin	<2800	<1660
malathion	<2800	<1660
methyl parathion	<2800	<1660
ethyl parathion	<2800	<1660

(continued)

Ranges (ppb) of concentrations for 44 compounds in Macoma.

COMPOUND	May[1] 1983	July[1] 1983
alpha-BHC	ND	ND
lindane	685-14900	828-5280
beta-BHC	ND	ND
aldrin	127-37100	81-300
heptachlor	<120-<1680	ND
heptachlor epoxide	ND	ND
dieldrin	820-5270	330-1990
napthalene	<200-6400	ND
fluorene	ND	ND
phenanthrene	<120-1800	ND
anthracene	<120-<1680	ND
fluoranthene	<1680-140	<81-1710
pyrene	<200-<1680	<81-1710
benzo(a)pyrene	<200-<1680	ND
benzo(a)anthracene	200-<1680	ND
benzo(k)fluoranthrene	ND	ND
3,4 benzofluoranthene	<1680-200	ND
chrysene	ND	ND
acenaphthylene	ND	ND
benzo(ghi)perylene	ND	ND
dibenz(a,h)anthracene	ND	ND
indeno(1,2,3-cd)pyrene	ND	ND
acenaphthene	ND	ND
PCBs, total	<120-6700	1500-2730
kepone	ND	ND
dimethyl phthalate	ND	ND
diethyl phthalate	<321-80000	<81-18000
dibutyl phthalate	<1250-860000	2300-335000
di-2-ethyl hexyl phthalate	7700-1500000	32000-1400000
di octyl phthalate	<120-520000	<171-140000
atrazine	ND	ND
simazine	ND	ND
trifluraline	ND	ND
chlordane	1762-7020	388-1510
diazinon	ND	ND
DDE	<120-8760	<81-<300
DDD	<120-48300	<81-1240
DDT	ND	ND
linuron	ND	ND
butyl benzyl phthalate	470-6200000	<300-17100
endrin	ND	ND
malathion	ND	ND
methyl parathion	ND	ND
ethyl parathion	ND	ND

ND = not detected.

[1] N = 6
[2] N = 3

Appendix C: Ranges and medians of concentrations of selected contaminants in selected species from Hart-Miller Exterior Monitoring (1987-1988).

Concentrations in Catfish	sample date		sample date		sample date	
Contaminant	range	median	range	median	range	median
Sample Date			04/11/88			
Aldrin			<5			
α - BHC			<5			
Atrazine			<10			
β - BHC			<5			
γ - BHC (Lindane)			<5			
Chlordane			<200			
4,4' - DDD			<5			
4,4' - DDE			<5			
4,4' - DDT			<5			
Diazinon			<10			
Dieldrin			<5			
Endrin			<5			
Ethyl parathion			<10			
Heptachlor			<5			
Heptachlor epoxide			<5			
Linuron			<10			
Malathion			<10			
Methyl parathion			<10			
Toxaphene			<50			
Trifluraline			<10			
PCB's (total)			240-1100 670			
Butyl benzyl phthalate			<100			
Dis-n-octyl phthalate			<500			
Bis (2-ethylhexyl) phthalate			<500			
Di-n-butyl phthalate			<100			
Diethyl phthalate			<50			
Dimethyl phthalate			<50			
Benzo (b) fluoranthene			<50			
Acenaphthylene			<50			
Benzo (a) anthracene			<50			
Benzo (g,h,i) perylene			<100			
Chrysene			<50			
Fluoranthene			<50			
Indeno (1,2,3-cd) pyrene			<100			
Phenanthrene			<50			
Acenaphthene			<50			
Anthracene			<50			
Benzo (a) pyrene			<50			
Benzo (k) flouranthene			<100			
Dibenzo (a,h) anthracene			<100			
Fluorene			<50			
Naphthalene			<50			
Pyrene			<50			
Chromium			<2			
Iron			8			
Manganese			<2			
Copper			2			
Zinc			12			
Nickel			<5			
Number of samples			2			

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix C: (cont.)

Concentrations of contaminants in Flounder

Contaminant / Sample Date	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
	8/24/87					
Aldrin	<5					
α - BHC	<5					
Atrazine	<10					
β - BHC	<5					
γ - BHC (Lindane)	<5					
Chlordane	360					
4,4' - DDD	<5					
4,4' - DDE	<5					
4,4' - DDT	<5					
Diazinon	<10					
Dieldrin	<5					
Endrin	<5					
Ethyl parathion	<10					
Heptachlor	<5					
Heptachlor epoxide	<5					
Linuron	<10					
Malathion	<10					
Methyl parathion	<10					
Toxaphene	<50					
Trifluraline	<10					
PCB's (total)	500					
Butyl benzyl phthalate	<100					
Dis-n-octyl phthalate	<500					
Bis (2-ethylhexyl) phthalate	<500					
Di-n-butyl phthalate	<100					
Diethyl phthalate	<50					
Dimethyl phthalate	<50					
Benzo (b) fluoranthene	<50					
Acenaphthylene	<50					
Benzo (a) anthracene	<50					
Benzo (g,h,i) perylene	<100					
Chrysene	<50					
Fluoranthene	<50					
Indeno (1,2,3-cd) pyrene	<100					
Phenanthrene	<50					
Acenaphthene	<50					
Anthracene	<50					
Benzo (a) pyrene	<50					
Benzo (k) flouranthene	<50					
Dibenzo (a,h) anthracene	<100					
Fluorene	<50					
Naphthalene	<50					
Pyrene	<50					
Chromium	<5					
Iron	5-7	6				
Manganese	<2-3	2.5				
Copper	<5					
Zinc	5-7	6				
Nickel	<5					
Number of samples	* 2 metals samples, 1 organic sample					

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix C: (cont.)

Concentrations of contaminants in Spot

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date					08/01/88	
Aldrin					<1	
α - BHC					<1	
Atrazine					<10	
- BHC					<1	
τ - BHC (Lindane)					<3-<1	
Chlordane					<10	
4,4' - DDD					<1	
4,4' - DDE					<1	
4,4' - DDT					<1	
Diazinon					<10	
Dieldrin					<1	
Endrin					<1	
Ethyl parathion					<10	
Heptachlor					<3-<1	<1
Heptachlor epoxide					<1	
Linuron					<10	
Malathion					<10	
Methyl parathion					<10	
Toxaphene					<10	
Trifluraline					<10	
PCB's (total)					<100-217	82
Butyl benzyl phthalate					<1	
Dis-n-octyl phthalate					<1	
Bis (2-ethylhexyl) phthalate					<10	
Di-n-butyl phthalate					<1	
Diethyl phthalate					<1	
Dimethyl phthalate					<1	
Benzo (b) fluoranthene					<1	
Acenaphthylene					<1	
Benzo (a) anthracene					<1	
Benzo (g,h,i) perylene					<2	
Chrysene					<1	
Fluoranthene					<1	
Indeno (1,2,3-cd) pyrene					<2	
Phenanthrene					<1	
Acenaphthene					<1	
Anthracene					<1	
Benzo (a) pyrene					<1	
Benzo (k) flouranthene					<1	
Dibenzo (a,h) anthracene					<2	
Fluorene					<1	
Naphthalene					<1	
Pyrene					<1	
Chromium					<2	
Iron					13-22	15
Manganese					12-15	12
Copper					<1-5	1
Zinc					9-15	13
Nickel					<2	

* values display in parts per billion (PPb)

** metals in parts per million

Appendix C: (cont.)

Concentrations of contaminants in Hogchoker

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date			04/11/88			
Aldrin			<5			
α - BHC			<5			
Atrazine			<10			
β - BHC			<5			
γ - BHC (Lindane)			<5			
Chlordane			<50			
4,4' - DDD			<5			
4,4' - DDE			<5			
4,4' - DDT			<5			
Diazinon			<10			
Dieldrin			<5			
Endrin			<5			
Ethyl parathion			<10			
Heptachlor			<5			
Heptachlor epoxide			<5			
Linuron			<10			
Malathion			<10			
Methyl parathion			<10			
Toxaphene			<50			
Trifluraline			<10			
PCB's (total)			170			
Butyl benzyl phthalate			<100			
Dis-n-octyl phthalate			<500			
Bis (2-ethylhexyl) phthalate			<500			
Di-n-butyl phthalate			<100			
Diethyl phthalate			<50			
Dimethyl phthalate			<50			
Benzo (b) fluoranthene			<50			
Acenaphthylene			<50			
Benzo (a) anthracene			<50			
Benzo (g,h,i) perylene			<100			
Chrysene			<50			
Fluoranthene			<50			
Indeno (1,2,3-cd) pyrene			<100			
Phenanthrene			<50			
Acenaphthene			<50			
Anthracene			<50			
Benzo (a) pyrene			<50			
Benzo (k) flouranthene			<100			
Dibenzo (a,h) anthracene			<100			
Fluorene			<50			
Naphthalene			<50			
Pyrene			<50			
Chromium			<2			
Iron			19			
Manganese			57			
Copper			2			
Zinc			26			
Nickel			<5			
Number of samples			1			

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix C: (cont.)

Concentrations of contaminants in Manhaden

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	12/08/87					
Aldrin	<5					
α - BHC	<5					
Atrazine	<10					
β - BHC	<5					
γ - BHC (Lindane)	<5					
Chlordane	46-400	72				
4,4' - DDD	<5					
4,4' - DDE	<5					
4,4' - DDT	<5					
Diazinon	<10					
Dieldrin	<5					
Endrin	<5					
Ethyl parathion	<10					
Heptachlor	<5					
Heptachlor epoxide	<5					
Linuron	<10					
Malathion	<10					
Methyl parathion	<10					
Toxaphene	<50					
Trifluraline	<10					
PCB's (total)	94-680	98				
Butyl benzyl phthalate	<100					
Dis-n-octyl phthalate	<500					
Bis (2-ethylhexyl) phthalate	<500					
Di-n-butyl phthalate	<100					
Diethyl phthalate	<50					
Dimethyl phthalate	<50					
Benzo (b) fluoranthene	<50					
Acenaphthylene	<50					
Benzo (a) anthracene	<50					
Benzo (g,h,i) perylene	<100					
Chrysene	<50					
Fluoranthene	<50					
Indeno (1,2,3-cd) pyrene	<100					
Phenanthrene	<50					
Acenaphthene	<50					
Anthracene	<50					
Benzo (a) pyrene	<50					
Benzo (k) flouranthene	<50					
Dibenzo (a,h) anthracene	<100					
Fluorene	<50					
Naphthalene	<50					
Pyrene	<50					
Chromium	<5					
Iron	9-11	11				
Manganese	<2-4	2				
Copper	<1					
Zinc	4-6					
Nickel	<5	5				
Number of samples	3					

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in White perch

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Aldrin	<5		<5		<1	
α - BHC	<5		<5		<1	
Atrazine	<10		<10		<10	
β - BHC	<5		<5		<1	
γ - BHC (Lindane)	<5		<5		<1	
Chlordane	290	290	<500-<50	<200	<10-295	117
4,4' - DDD	<5		<5		<1	
4,4' - DDE	<5		<5		<1	
4,4' - DDT	<5		<5		<1	
Diazinon	<10		<10		<10	
Dieldrin	<5		<5		<1	
Endrin	<5		<5		<1	
Ethyl parathion	<10		<10		<10	
Heptachlor	<5		<5		<1	
Heptachlor epoxide	<5		<5		<1	
Linuron	<10		<10		<10	
Malathion	<10		<10		<10	
Methyl parathion	<10		<10		<10	
Toxaphene	<50		<50		<10	
Trifluraline	<10		<10		<10	
PCB's (total)	720	720	<50-940	440	208-708	255
Butyl benzyl phthalate	<100		<100		<1	
Dis-n-octyl phthalate	<500		<500		<1	
Bis (2-ethylhexyl) phthalate	<500		<500		<10	
Di-n-butyl phthalate	<100		<100		<1	
Diethyl phthalate	<50		<50		<1	
Dimethyl phthalate	<50		<50		<1	
Benzo (b) fluoranthene	<50		<50		<1	
Acenaphthylene	<50		<50		<1	
Benzo (a) anthracene	<50		<50		<1	
Benzo (g,h,i) perylene	<100		<100		<2	
Chrysene	<50		<50		<1	
Fluoranthene	<50		<50		<1	
Indeno (1,2,3-cd) pyrene	<100		<100		<2	
Phenanthrene	<50		<50		<1	
Acenaphthene	<50		<50		<1	
Anthracene	<50		<50		<1	
Benzo (a) pyrene	<50		<50		<1	
Benzo (k) flouranthene	<50		<100		<1	
Dibenzo (a,h) anthracene	<100		<100		<2	
Fluorene	<50		<50		<1	
Naphthalene	<50		<50		<1	
Pyrene	<50		<50		<1	
Chromium	<5		<2		<2	
Iron	9		10-58	14	8-19	16.5
Manganese	<2		<2-78	12.5	3-9	3.5
Copper	<1		2-12	2.5	1-2	1
Zinc	6		10-45	21.5	12-21	16.5
Nickel	<5		<5-6	5	<2	
Number of samples	1		8		6	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix C (cont.)

Concentrations of contaminants in Yellow Perch

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	12/08/87		04/11/88		08/01/88	
Aldrin	<5		<5		<1	
α - BHC	<5		<5		<1	
Atrazine	<10		<10		<10	
β - BHC	<5		<5		<1	
γ - BHC (Lindane)	<5		<5		<1	
Chlordane	81-89	85	<200-<50	<100	95	
4,4' - DDD	<5		<5		<1	
4,4' - DDE	<5		<5		<1	
4,4' - DDT	<5		<5		<1	
Diazinon	<10		<10		<10	
Dieldrin	<5		<5		<1	
Endrin	<5		<5		<1	
Ethyl parathion	<10		<10		<10	
Heptachlor	<5		<5		<1	
Heptachlor epoxide	<5		<5		<1	
Linuron	<10		<10		<10	
Malathion	<10		<10		<10	
Methyl parathion	<10		<10		<10	
Toxaphene	<50		<50		<10	
Trifluraline	<10		<10		<10	
PCB's (total)	310-860	335	<50-450	310	183	
Butyl benzyl phthalate	<100		<100		<1	
Dis-n-octyl phthalate	<500		<500		<1	
Bis (2-ethylhexyl) phthalate	<500		<500		<10	
Di-n-butyl phthalate	<100		<100		<1	
Diethyl phthalate	<50		<50		<1	
Dimethyl phthalate	<50		<50		<1	
Benzo (b) fluoranthene	<50		<50		<1	
Acenaphthylene	<50		<50		<1	
Benzo (a) anthracene	<50		<50		<1	
Benzo (g,h,i) perylene	<100		<100		<2	
Chrysene	<50		<50		<1	
Fluoranthene	<50		<50		<1	
Indeno (1,2,3-cd) pyrene	<100		<100		<2	
Phenanthrene	<50		<50		<1	
Acenaphthene	<50		<50		<1	
Anthracene	<50		<50		<1	
Benzo (a) pyrene	<50		<50		<1	
Benzo (k) flouranthene	<50		<50		<1	
Dibenzo (a,h) anthracene	<100		<100		<2	
Fluorene	<50		<50		<1	
Naphthalene	<50		<50		<1	
Pyrene	<50		<50		<1	
Chromium	<5		<2		<2	
Iron	6-8	7	10-31	11	57	
Manganese	<2		<2-35	6	4-8	
Copper	<1		2-5	3	<1	
Zinc	5-7	6	11-30	19	10	
Nickel	<5		<5		<2	
Number of samples	2		3		1	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Blue Crab

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	8/24/87					
Aldrin	<5					
α - BHC	<5					
Atrazine	<10					
β - BHC	<5					
γ - BHC (Lindane)	<5					
Chlordane	<50-160	<50				
4,4' - DDD	<5					
4,4' - DDE	<5					
4,4' - DDT	<5					
Diazinon	<10					
Dieldrin	<5					
Endrin	<5					
Ethyl parathion	<10					
Heptachlor	<5					
Heptachlor epoxide	<5					
Linuron	<10					
Malathion	<10					
Methyl parathion	<10					
Toxaphene	<50					
Trifluralina	<10					
PCB's (total)	<10-200	30				
Butyl benzyl phthalate	<100					
Dis-n-octyl phthalate	<500					
Bis (2-ethylhexyl) phthalate	<500					
Di-n-butyl phthalate	<100					
Diethyl phthalate	<50					
Dimethyl phthalate	<50					
Benzo (b) fluoranthene	<50					
Acenaphthylene	<50					
Benzo (a) anthracene	<50					
Benzo (g,h,i) perylene	<100					
Chrysene	<50					
Fluoranthene	<50					
Indeno (1,2,3-cd) pyrene	<100					
Phenanthrene	<50					
Acenaphthene	<50					
Anthracene	<50					
Benzo (a) pyrene	<50					
Benzo (k) flouranthene	<50					
Dibenzo (a,h) anthracene	<100					
Fluorene	<50					
Naphthalene	<50					
Pyrene	<50					
Chromium	<5					
Iron	11-22	12				
Manganese	92-214	162				
Copper	8-13	9				
Zinc	26-60	49				
Nickel	<5					
Number of samples	3					

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix C: (cont.)

Concentrations of contaminants in Polychedtes

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	04/11/88					
Aldrin	<5					
α - BHC	<5					
Atrazine	<10					
β - BHC	<5					
γ - BHC (Lindane)	<5					
Chlordane	<50					
4,4' - DDD	<5					
4,4' - DDE	<5					
4,4' - DDT	<5					
Diazinon	<10					
Dieldrin	<5					
Endrin	<5					
Ethyl parathion	<10					
Heptachlor	<5					
Heptachlor epoxide	<5					
Linuron	<10					
Malathion	<10					
Methyl parathion	<10					
Toxaphene	<50					
Trifluraline	<10					
PCB's (total)	<10					
Butyl benzyl phthalate	<100					
Dis-n-octyl phthalate	<500					
Bis (2-ethylhexyl) phthalate	<500					
Di-n-butyl phthalate	<100					
Diethyl phthalate	<50					
Dimethyl phthalate	<50					
Benzo (b) fluoranthene	<50					
Acenaphthylene	<50					
Benzo (a) anthracene	<50					
Benzo (g,h,i) perylene	<100					
Chrysene	<50					
Fluoranthene	<50					
Indeno (1,2,3-cd) pyrene	<100					
Phenanthrene	<50					
Acenaphthene	<50					
Anthracene	<50					
Benzo (a) pyrene	<50					
Benzo (k) flouranthene	<100					
Dibenzo (a,h) anthracene	<100					
Fluorene	<50					
Naphthalene	<50					
Pyrene	<50					
Chromium	<4					
Iron	128					
Manganese	52					
Copper	6					
Zinc	15					
Nickel	<10					
Number of samples	1					

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Mudcrab

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date					08/01/88	
Aldrin					<1	
α - BHC					<1	
Atrazine					<10	
β - BHC					<1	
γ - BHC (Lindane)					<1	
Chlordane					<10	
4,4' - DDD					<1	
4,4' - DDE					<1	
4,4' - DDT					<1	
Diazinon					<10	
Dieldrin					<1	
Endrin					<1	
Ethyl parathion					<10	
Heptachlor					<1	
Heptachlor epoxide					<1	
Linuron					<10	
Malathion					<10	
Methyl parathion					<10	
Toxaphene					<10	
Trifluraline					<10	
PCB's (total)					<10	
Butyl benzyl phthalate					<1	
Dis-n-octyl phthalate					<1	
Bis (2-ethylhexyl) phthalate					<10	
Di-n-butyl phthalate					<1	
Diethyl phthalate					<1	
Dimethyl phthalate					<1	
Benzo (b) fluoranthene					<1	
Acenaphthylene					<1	
Benzo (a) anthracene					<1	
Benzo (g,h,i) perylene					<2	
Chrysene					<1	
Fluoranthene					<1	
Indeno (1,2,3-cd) pyrene					<2	
Phenanthrene					<1	
Acenaphthene					<1	
Anthracene					<1	
Benzo (a) pyrene					<1	
Benzo (k) flouranthene					<1	
Dibenzo (a,h) anthracene					<2	
Fluorene					<1	
Naphthalene					<1	
Pyrene					<1	
Chromium					<5	
Iron					715	
Manganese					2000	
Copper					13	
Zinc					49	
Nickel					<5	
Number of samples					1	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix C: (cont.)

Concentrations of contaminants in Maccone

Contaminant	sample date range	median	sample date range	median	sample date range	median
Sample Date	12/7/87		4/11/88		8/1/88	
Aldrin	<5		<5		<1	
α - BHC	<5		<5		<1	
Atrazine	<10		<10		<10	
β - BHC	<5		<5		<1	
γ - BHC (Lindane)	<5		<5		<1	
Chlordane	<50		<50-62	<50	23-28	25.5
4,4' - DDD	<5		<5		<1	
4,4' - DDE	<5		<5		<1	
4,4' - DDT	<5		<5		<1	
Diazinon	<10		<10		<10	
Dieldrin	<5		<5		<1	
Endrin	<5		<5		<1	
Ethyl parathion	<10		<10		<10	
Heptachlor	<5		<5		<1	
Heptachlor epoxide	<5		<5		<1	
Linuron	<10		<10		<10	
Malathion	<10		<10		<10	
Methyl parathion	<10		<10		<10	
Toxaphene	<50		<50		<10	
Trifluraline	<10		<10		<10	
PCB's (total)	<10-81	45.5	<10		<10	
Butyl benzyl phthalate	<100		<100		<1	
Dis-n-octyl phthalate	<500		<500		<1	
Bis (2-ethylhexyl) phthalate	<500		<500		<10	
Di-n-butyl phthalate	<100		<100		<1	
Diethyl phthalate	<50		<50		<1	
Dimethyl phthalate	<50		<50		<1	
Benzo (b) fluoranthene	<50		<50		<1	
Acenaphthylene	<50		<50		<1	
Benzo (a) anthracene	<50		<50		<1	
Benzo (g,h,i) perylene	<100		<100		<2	
Chrysene	<50		<50		<1	
Fluoranthene	<50		<50		<1	
Indeno (1,2,3-cd) pyrene	<100		<100		<2	
Phenanthrene	<50		<50		<1	
Acenaphthene	<50		<50		<1	
Anthracene	<50		<50		<1	
Benzo (a) pyrene	<50		<50		<1	
Benzo (k) flouranthene	<50		<100		<1	
Dibenzo (a,h) anthracene	<100		<100		<2	
Fluorene	<50		<50		<1	
Naphthalene	<50		<50		<1	
Pyrene	<50		<50		<1	
Chromium	<5-6	5.5	3	3	<2	
Iron	1025.5	681-1270	466-900	790	402-560	
Manganese	121-133		101-152	118	145-208	
Copper	6-7	6.5	8	8	6-8	
Zinc	27-38	32.5	46-70	46	29-59	
Nickel	<5		<5-18	5	<2	
Number of samples	2		3		2	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Rang La

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	12/7/87		4/11/88		8/1/88	
Aldrin	<5		<5		<1	
α - BHC	<5		<5		<1	
Atrazine	<10		<10		<10	
β - BHC	<5		<5		<1	-5<1
γ - BHC (Lindane)	<5		<5		<1	
Chlordane	<50		<500-5	<50	<10-2000	<10
4,4' - DDD	<5		<5		<1	
4,4' - DDE	<5		<5		<1	
4,4' - DDT	<5		<5		<1	
Diazinon	<10		<10		<10	
Dieldrin	<5		<5		<1	
Endrin	<5		<5		<1	
Ethyl parathion	<10		<10		<10	
Heptachlor	<5		<5		<1	
Heptachlor epoxide	<5		<5		<1	
Linuron	<10		<10		<10	
Malathion	<10		<10		<10	
Methyl parathion	<10		<10		<10	
Toxaphene	<50		<50		<10	
Trifluraline	<10		<10		<10	
PCB's (total)	<10-100	<10	<10		<10	
Butyl benzyl phthalate	<100		<100		<1	
Dis-n-octyl phthalate	<500		<500		<1	
Bis (2-ethylhexyl) phthalate	<500		<500		<10	
Di-n-butyl phthalate	<100		<100		<1	
Diethyl phthalate	<50		<50		<1	
Dimethyl phthalate	<50		<50		<1	
Benzo (b) fluoranthene	<50		<50		<1	
Acenaphthylene	<50		<50		<1	
Benzo (a) anthracene	<50		<50		<1	
Benzo (g,h,i) perylene	<100		<100		<2	
Chrysene	<50		<50		<1	
Fluoranthene	<50		<50		<1	
Indeno (1,2,3-cd) pyrene	<100		<100		<2	
Phenanthrene	<50		<50		<1	
Acenaphthene	<50		<50		<1	
Anthracene	<50		<50		<1	
Benzo (a) pyrene	<50		<50		<1	
Benzo (k) flouranthene	<50		<100		<1	
Dibenzo (a,h) anthracene	<100		<100		<2	
Fluorene	<50		<50		<1	
Naphthalene	<50		<50		<1	
Pyrene	<50		<50		<1	
Chromium	<5-12	6 5	< 2-8	3	<2	
Iron	33-290	124	48-132	8 2	48-400	328
Manganese	3-123	17	19-116	44	8- 49	21
Copper	<1-5	1.5	3-25	5	2- 6	3
Zinc	4-16	9	2-20	1	15-25	19
Nickel	<5-9	6 5	<3-10	5	<2-11	3
Number of samples	12		9		7	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix C: (cont.)

Concentrations of contaminants in Amphipods

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	12/07/87		04/11/88		08/01/88	
Aldrin			<5			
α - BHC			<5			
Atrazine			<10			
β - BHC			<5			
γ - BHC (Lindane)			<5			
Chlordane			<50			
4,4' - DDD			<5			
4,4' - DDE			<5			
4,4' - DDT			<5			
Diazinon			<10			
Dieldrin			<5			
Endrin			<5			
Ethyl parathion			<10			
Heptachlor			<5			
Heptachlor epoxide			<5			
Linuron			<10			
Malathion			<10			
Methyl parathion			<10			
Toxaphene			<50			
Trifluralin			<10			
PCB's (total)			<10			
Butyl benzyl phthalate			<100			
Dis-n-octyl phthalate			<500			
Bis (2-ethylhexyl) phthalate			<500			
Di-n-butyl phthalate			<100			
Diethyl phthalate			<50			
Dimethyl phthalate			<50			
Benzo (b) fluoranthene			<50			
Acenaphthylene			<50			
Benzo (a) anthracene			<50			
Benzo (g,h,i) perylene			<100			
Chrysene			<50			
Fluoranthene			<50			
Indeno (1,2,3-cd) pyrene			<100			
Phenanthrene			<50			
Acenaphthene			<50			
Anthracene			<50			
Benzo (a) pyrene			<50			
Benzo (k) flouranthene			<100			
Dibenzo (a,h) anthracene			<100			
Fluorene			<50			
Naphthalene			<50			
Pyrene			<50			
Chromium	N/A		<4		N/A	
Iron	N/A		146		N/A	
Manganese	N/A		14		N/A	
Copper	N/A		9		N/A	
Zinc	N/A		9		N/A	
Nickel	N/A		<10		N/A	
Number of samples			1			

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix C: (cont.)

Concentrations of contaminants in Cyanthura

Contaminant	sample date range	median	sample date range	median	sample date range	median
Sample Date	12/7/87		4/11/88		8/1/88	
Aldrin	<5		<5		<1-197	
α - BHC	<5		<5		<1	
Atrazine	<10		<10		<10	
β - BHC	<5		<5		<1	
γ - BHC (Lindane)	<5		<5		<1	
Chlordane	<50		<100-110	65	<10-83000	966.5
4,4' - DDD	<5		<5		<1	
4,4' - DDE	<5		<5		<1	
4,4' - DDT	<5		<5		<1	
Diazinon	<10		<10		<10	
Dieldrin	<5		<5		<1	
Endrin	<5		<5		<1	
Ethyl parathion	<10		<10		<10	
Heptachlor	<5		<5		<1	
Heptachlor epoxide	<5	<5	<5		<1	
Linuron	<10		<10		<10	
Malathion	<10		<10		<10	
Methyl parathion	<10		<10		<10	
Toxaphene	<50		<50		<10	
Trifluraline	<10		<10		<10	
PCB's (total)	<10		<10		<10	
Butyl benzyl phthalate	<100		<100		<1	
Dis-n-octyl phthalate	<500		<500		<1	
Bis (2-ethylhexyl) phthalate	<500		<500		<10	
Di-n-butyl phthalate	<100		<100		<1	
Diethyl phthalate	<50		<50		<1	
Dimethyl phthalate	<50		<50		<1	
Benzo (b) fluoranthene	<50		<50		<1	
Acenaphthylene	<50		<50		<1	
Benzo (a) anthracene	<50		<50		<1	
Benzo (g,h,i) perylene	<100		<100		<2	
Chrysene	<50		<50		<1	
Fluoranthene	<50		<50		<1	
Indeno (1,2,3-cd) pyrene	<100		<100		<2	
Phenanthrene	<50		<50		<1	
Acenaphthene	<50		<50		<1	
Anthracene	<50		<50		<1	
Benzo (a) pyrene	<50		<50		<1	
Benzo (k) flouranthene	<50		<100		<1	
Dibenzo (a,h) anthracene	<100		<100		<2	
Fluorene	<50		<50		<1	
Naphthalene	<50		<50		<1	
Pyrene	<50		<50		<1	
Chromium	<5		<2-<20		10- 20	15
Iron	96-133	64.5	67-380		306-720	498
Manganese	28-47	37.5	25-380		222-920	382
Copper	18-19	18.9	17-90		20- 44	285
Zinc	23-26	24.5	23-140		59-140	93.5
Nickel	5		<5-<50		10- 20	15
Number of samples	2		6		6	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Sediment

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	11/03/87		04/12/88			
Aldrin	<1		<1			
α - BHC	<1		<1			
Atrazine	<1		<10			
β - BHC	<1		<1			
γ - BHC (Lindane)	<1		<1			
Chlordane	<10		<10			
4,4' - DDD	<1		<1			
4,4' - DDE	<1		<1			
4,4' - DDT	<1		<1			
Diazinon	<10		<10			
Dieldrin	<1		<1			
Endrin	<1		<1			
Ethyl parathion	<10		<10			
Heptachlor	<1		<1			
Heptachlor epoxide	<1		<1			
Linuron	<10		<10			
Malathion	<10		<10			
Methyl parathion	<10		<10			
Toxaphene	<10		<10			
Trifluraline	<10		<10			
PCB's (total)	<10		<10			
Butyl benzyl phthalate	<50		<50			
Dis-n-octyl phthalate	<50		<50			
Bis (2-ethylhexyl) phthalate	<50		<50			
Di-n-butyl phthalate	<50		<50			
Diethyl phthalate	<50		<50			
Dimethyl phthalate	<50		<50			
Benzo (b) fluoranthene	<50		<50			
Acenaphthylene	<50		<50			
Benzo (a) anthracene	<50		<50			
Benzo (g,h,i) perylene	<50		<50			
Chrysene	<50		<50			
Fluoranthene	<50		<50			
Indeno (1,2,3-cd) pyrene	<50		<50			
Phenanthrene	<50		<50			
Acenaphthene	<50		<50			
Anthracene	<50		<50			
Benzo (a) pyrene	<50		<50			
Benzo (k) flouranthene	<50		<50			
Dibenzo (a,h) anthracene	<50		<50			
Fluorene	<50		<50			
Naphthalene	<50		<50			
Pyrene	<50		<50			
Chromium						
Iron						
Manganese	See Sedimentary					
Copper	Environment Section					
Zinc	Project II					
Nickel						
Number of samples	10		10			

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix A

Hart-Miller Exterior Monitoring Program Samples Collected for 1987-88

H.M.I. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS REQUIRED
870380	F4	8-24-87	YEAR #6 SUMMER	1644	0	EBB	9-12	HOGCHOCKER	BLACK MARSH AREA	PFITZENMEYER	METALS
870381	F3	8-24-87	"	1631	0	"	9-12	CATFISH	@ SS# XIE4715	PFITZENMEYER	METALS
870382	F3	8-24-87	"	1631	0	"	9-12	HOGCHOCKER	@ SS# XIE4715	PFITZENMEYER	METALS
870383	F1	8-24-87	"	1503	0	"	9-12	BLUE CRAB	SLUICE GATE AREA	PFITZENMEYER	ORGANICS
870384	F4	8-24-87	"	1644	0	"	9-12	HOGCHOCKER	BLACK MARSH AREA	PFITZENMEYER	ORGANICS
870385	F1	8-24-87	"	1503	0	"	9-12	BLUE CRAB	SLUICE GATE AREA	PFITZENMEYER	METALS
870386	F2	8-24-87	"	1545	0	"	9-12	BLUE CRAB	@ SS# XIE5406	PFITZENMEYER	METALS
870387	F2	8-24-87	"	1545	0	"	9-12	FLOUNDER	@ SS# XIE5406	PFITZENMEYER	METALS
870388	F2	8-24-87	"	1545	0	"	9-12	BLUE CRAB	@ SS# XIE5406	PFITZENMEYER	ORGANICS
870389	F3	8-24-87	"	1631	0	"	9-12	BLUE CRAB	@ SS# XIE4715	PFITZENMEYER	METALS
870390	F3	8-24-87	"	1631	0	"	9-12	BLUE CRAB	@ SS# XIE4715	PFITZENMEYER	ORGANICS
870391	F4	8-24-87	"	1644	0	"	9-12	FLOUNDER	BLACK MARSH AREA	PFITZENMEYER	METALS
870392	F4	8-24-87	"	1644	0	"	9-12	FLOUNDER	BLACK MARSH AREA	PFITZENMEYER	ORGANICS
870393	F4	8-24-87	"	1644	0	"	9-12	SPOT	BLACK MARSH AREA	PFITZENMEYER	ORGANICS
870394	S4	8-24-87	"	1631	0	"	9-12	RANGIA	SS# XIE4715	PFITZENMEYER	ORGANICS
870395	S4	8-24-87	"	1631	0	"	9-12	RANGIA	SS# XIE4715	PFITZENMEYER	METALS
870396	HM22	8-24-87	"	1253	0	"	9-12	RANGIA	SS# XIE6Z689	PFITZENMEYER	ORGANICS
870397	HM22	8-24-87	"	1253	0	"	9-12	RANGIA	SS# XIE6Z689	PFITZENMEYER	METALS
870398	HM7	8-24-87	"	1232	0	"	9-12	RANGIA	SS# XIE6388	PFITZENMEYER	METALS
870399	HM7	8-24-87	"	1232	0	"	9-12	RANGIA	SS# XIE6388	PFITZENMEYER	ORGANICS

* SS# = STATE STATION #

* WEATHER CODE #0 = CLEAR

* SAMPLES ARE PACKED IN PLASTIC ZIPLOC BAGS, AND HAVE BEEN FROZEN SINCE TIME OF SAMPLING
* SAMPLES FOR ORGANIC ANALYSIS HAVE BEEN WRAPPED IN ALUMINUM FOIL TO PREVENT CONTAMINATION.

SAMPLES FOR ORGANIC ANALYSIS INCLUDE ALL THOSE ANALYSIS LISTED IN TABLE #5 OF AGREEMENT
SAMPLES FOR METAL ANALYSIS INCLUDE THE FOLLOWING SIX TRACE METALS:
- CHROMIUM * IRON * MANGANESE * COPPER * ZINC * NICKEL

SAMPLES DELIVERED TO HMI LABORATORY ON: 12/7/87 0945 SAMPLES RELINQUISED BY: H.T. PFITZENMEYER
SAMPLES RECIEVED BY: J. HILGARTNER

SAMPLES DELIVERED TO WATER LABORATORY ON: 12/7/87 1500 SAMPLES RELINQUISED BY: L. FRITZ
SAMPLES RECIEVED BY: J. WOLFHILL

Appendix A
(continued)

H.M.I. SAMPLE ID	NRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS REQUIRED
870405	HM 16-1	12-7-87	YEAR #7 FALL	1034	C,S	SL	17	CYATHUNA	XIF3325	PFITZENMEYER	MET/ORG
870406	HM 16-2	12-7-87	"	1045	C,S	SBE	17	RANGIA	XIF3325	PFITZENMEYER	MET/ORG
870407	HM 16-3	12-7-87	"	1118	C,S	SBE	27	RANGIA	XIF3325	PFITZENMEYER	MET/ORG
870408	S 6-1	12-7-87	"	1200	C,S	SBE	11	CYANTHUNA	XIF4327	PFITZENMEYER	MET/ORG
870409	S 6-2	12-7-87	"	1208	C,S	SBE	11	MACOMA	XIF4327	PFITZENMEYER	MET/ORG
870410	S 6-3	12-7-87	"	1215	C,S	SBE	11	RANGIA	XIF4327	PFITZENMEYER	MET/ORG
870411	S 6-4	12-7-87	"	1225	C,S	SBE	11	RANGIA	XIF4327	PFITZENMEYER	MET/ORG
870412	S 4-1	12-7-87	"	1343	C,S	SBE	13.5	RANGIA	XIF4715	PFITZENMEYER	MET/ORG
870413	S 4-2	12-7-87	"	1350	C,S	SBE	13.5	RANGIA	XIF4715	PFITZENMEYER	MET/ORG
870414	S 4-3	12-7-87	"	1400	C,S	SBE	13.5	MACOMA	XIF4715	PFITZENMEYER	MET/ORG
870415	S 7-1	12-7-87	"	1450	C,S	SBE	13.1	RANGIA	XI65405	PFITZENMEYER	MET/ORG
870416	S 7-2	12-7-87	"	1455	C,S	SBE	13.1	RANGIA	XI65405	PFITZENMEYER	MET/ORG
870417	S 1-1	12-7-87	"	1510	1	SBE	5	RANGIA	XIF5710	PFITZENMEYER	MET/ORG
870418	S 1-2	12-7-87	"	1510	1	SBE	5	RANGIA	XIF5710	PFITZENMEYER	MET/ORG
870419	HM 22-1	12-7-87	"	1630	1	SBE	14	RANGIA	XI67689	PFITZENMEYER	MET/ORG
870420	HM 22-2	12-7-87	"	1640	1	SBE	14	RANGIA	XI67689	PFITZENMEYER	MET/ORG
870421	F -1	12-8-87	"	1215	C,O	SBE	11	Y.PERCH	NORTH SIDE/HMI	PFITZENMEYER	MET/ORG
870422	F -2	12-8-87	"	1220	C,O	SBE	11	Y.PERCH	NORTH SIDE/HMI	PFITZENMEYER	MET/ORG
870423	F 3-1	12-8-87	"	1405	C,O	SBE	16	MENHADEN	SOUTH/UNLOADER	PFITZENMEYER	MET/ORG
870424	F 3-2	12-8-87	"	1415	C,O	SBE	16	MENHADEN	SOUTH/UNLOADER	PFITZENMEYER	MET/ORG
870425	F 4-1	12-8-87	"	1500	C,O	SBE	16	MENHADEN	BLACK MARSH @	PFITZENMEYER	MET/ORG
870426	F 4-2	12-8-87	"	1500	C,O	SBE	16	W.PERCH	BLACK MARSH @	PFITZENMEYER	MET/ORG

OTHER PERTINENT INFORMATION:
* WEATHER CODES: C,S = CALM & SUNNY 1 = CLOUDY C,O = CALM & OVERCAST * TIDE CODE SBE = SLACK BEFORE EBB
* SAMPLES ARE PACKED IN 250ML GLASS JARS WITH TEFLON LINERS * SAMPLES HAVE BEEN FROZED SINCE TIME OF SAMPLING
ALL SAMPLES ARE TO BE SPLIT FOR ORGAINC ANALYSIS (ALL ANALYSIS LISTED IN TABLE #5 OF AGREEMENT)
AND FOR METAL ANALYSIS OF THE FOLLOWING SIX TRACE METALS:
* CHROMIUM * IRON * MANGANESE * COPPER * ZINC * NICKEL

SAMPLES DELIVERED TO HMI LABORATORY ON: 12/8/87 1345 SAMPLES RELINQUISED BY: H.T. PFITZENMEYER
SAMPLES RECIEVED BY: L. FRITZ

SAMPLES DELIVERED TO MARTEL LABORATORY ON: 1/21/88 1500 SAMPLES RELINQUISED BY: L. FRITZ
SAMPLES RECIEVED BY: J. WOLFKILL

H.M.I. SAMPLE ID	NRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE CODE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS TO BE DONE
870223	3	11-3-87	YEAR #7 FALL	N/A	1	N/A	15	SEDIMENT	X=27636.5/Y=42886.5	HENNESSEE	ORGANICS
870224	19	11-3-87	"	N/A	1	N/A	17	SEDIMENT	X=27632.3/Y=42889.0	HENNESSEE	ORGANICS
870225	BC-3	11-3-87	"	N/A	1	N/A	14	SEDIMENT	X=27633.3/Y=42901.9	HENNESSEE	ORGANICS
870226	24-1	11-3-87	"	N/A	1	N/A	16.5	SEDIMENT	X=27629.8/Y=42909.0	HENNESSEE	ORGANICS
870227	24-2	11-3-87	"	N/A	1	N/A	16.5	SEDIMENT	X=27629.8/Y=42909.0	HENNESSEE	ORGANICS
870228	24-3	11-3-87	"	N/A	1	N/A	16.5	SEDIMENT	X=27629.8/Y=42909.0	HENNESSEE	ORGANICS
870229	28	11-3-87	"	N/A	1	N/A	19.5	SEDIMENT	X=27629.4/Y=42915.1	HENNESSEE	ORGANICS
870230	21 B	11-3-87	"	N/A	1	N/A	13	SEDIMENT	X=27632.1/Y=42912.9	HENNESSEE	ORGANICS
870231	BC-6	11-3-87	"	N/A	1	N/A	11.5	SEDIMENT	X=27643.4/Y=42917.1	HENNESSEE	ORGANICS
870232	23	11-3-87	"	N/A	1	N/A	11	SEDIMENT	X=27646.8/Y=42900.5	HENNESSEE	ORGANICS

* LORAN READINGS

ADDITIONAL INFORMATION:

- WEATHER CODE #1 = PARTLY CLOUDY
- SAMPLES ARE IN GLASS JARS WITH ALUMINUM FOIL UNDER LID
- SAMPLES HAVE BEEN FROZEN SINCE TIME OF SAMPLING

SAMPLES DELIVERED TO HMI LABORATORY ON: 11/3/87 1430 SAMPLES RELINQUISED BY: E.L. HENNESSEE
SAMPLES RECIEVED BY: L. FRITZ

SAMPLES DELIVERED TO MARTEL LABORATORY ON: 1/21/88 1500 SAMPLES RELINQUISED BY: L. FRITZ
SAMPLES RECIEVED BY: J. WOLEKILL

ALL SAMPLES TO BE ANALYZED FOR ORGANICS LISTED IN TABLE #5

Appendix A
(continued)

H.M. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE	DE FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANAL. REQUIRED
880156	HM 16-1	4/11/88	YEAR #7 SPRING	0953	C	EBB	15	CYATHUNA	XIF3325	DUGUAY	MET/ORG
880157	HM 16-2	4/11/88	"	0953	C	EBB	15	MACOMA	XIF3325	DUGUAY	MET/ORG
880158	HM 16-3	4/11/88	"	0953	C	EBB	15	RANGIA	XIF3325	DUGUAY	MET/ORG
880159	S 6-1	4/11/88	"	1035	C	FLOOD	15	CYANTHUNA	XIF4327	DUGUAY	MET/ORG
880160	S 6-2	4/11/88	"	1035	C	FLOOD	15	MACOMA	XIF4327	DUGUAY	MET/ORG
880161	S 6-3	4/11/88	"	1035	C	FLOOD	15	RANGIA	XIF4327	DUGUAY	MET/ORG
880162	S 6-4	4/11/88	"	1121	C	FLOOD	15	CYANTHUNA	XIF4715	DUGUAY	MET/ORG
880163	S 4-1	4/11/88	"	1121	C	FLOOD	15	MACOMA	XIF4715	DUGUAY	MET/ORG
880164	S 4-2	4/11/88	"	1121	C	FLOOD	15	RANGIA, LG	XIF4715	DUGUAY	MET/ORG
880165	S 4-3	4/11/88	"	1121	C	FLOOD	15	RANGIA, SM	XIF4715	DUGUAY	MET/ORG
880166	S 2-1	4/11/88	"	1208	C	FLOOD	12	CYANTHUNA	XIF5406	DUGUAY	MET/ORG
880167	S 2-2	4/11/88	"	1208	C	FLOOD	12	POLYCHEATES	XIF5406	DUGUAY	MET/ORG
880168	S 2-3	4/11/88	"	1208	C	FLOOD	12	RANGIA, LG	XIF5406	DUGUAY	MET/ORG
880169	S 2-4	4/11/88	"	1208	C	FLOOD	12	RANGIA, SM	XIF5406	DUGUAY	MET/ORG
880170	S 1-1	4/11/88	"	1240	C	FLOOD	5	CYANTHUNA	XIF5710	DUGUAY	MET/ORG
880171	S 1-2	4/11/88	"	1240	C	FLOOD	5	AMPHIPODS	XIF5710	DUGUAY	MET/ORG
880172	S 1-3	4/11/88	"	1240	C	FLOOD	5	RANGIA	XIF5710	DUGUAY	MET/ORG
880173	HM 22-1	4/11/88	"	1406	C	FLOOD	12	CYANTHUNA	XIG7689	DUGUAY	MET/ORG
880174	HM 22-2	4/11/88	"	1406	C	FLOOD	12	RANGIA, LG	XIG7689	DUGUAY	MET/ORG
880175	HM 22-3	4/11/88	"	1406	C	FLOOD	12	RANGIA, SM	XIG7689	DUGUAY	MET/ORG
880176	F 4-1	4/11/88	"	1454	C	FLOOD	15	WHITE PERCH	42876.9 X 27640.1 (reference station)	DUGUAY	MET/ORG
880177	F 4-2	4/11/88	"	1454	C	FLOOD	15	WHITE PERCH	"	DUGUAY	MET/ORG
880178	F 4-3	4/11/88	"	1454	C	FLOOD	15	YELL. PERCH	"	DUGUAY	MET/ORG
880179	F 3-1	4/11/88	"	1535	C	FLOOD	15	WHITE PERCH	42916.6 x 27642.2 (south side of is.)	DUGUAY	MET/ORG
880180	F 3-2	4/11/88	"	1535	C	FLOOD	15	WHITE PERCH	"	DUGUAY	MET/ORG
880181	F 3-3	4/11/88	"	1535	C	FLOOD	15	YELL. PERCH	"	DUGUAY	MET/ORG
880182	F 3-4	4/11/88	"	1535	C	FLOOD	15	HOGCHOCKER	"	DUGUAY	MET/ORG

Appendix A
(continued)

H.M SAMPLE ID	NRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANAL REQU
880183	F 2-1	4/11/88	"	1547	C	FLOOD	17	WHITE PERCH	Buoy #1;Middle Rive	DUGUAY	MET/ORG
880184	F 2-2	4/11/88	"	1547	C	FLOOD	17	WHITE PERCH	"	DUGUAY	MET/ORG
880185	F -3	4/11/88	"	1547	C	FLOOD	17	CATFISH	"	DUGUAY	MET/ORG
880186	F 1-1	4/11/88	"	1607	C	FLOOD	10	WHITE PERCH	42916.6 x 27642.2 Hawks Cove	DUGUAY	MET/ORG
880187	F 1-2	4/11/88	"	1607	C	FLOOD	10	WHITE PERCH	"	DUGUAY	MET/ORG
880188	F 1-3	4/11/88	"	1607	C	FLOOD	10	YELL. PERCH	"	DUGUAY	MET/ORG
880189	F 1-4	4/11/88	"	1607	C	FLOOD	10	CATFISH	"	DUGUAY	MET/ORG

* WEATHER CODES: C = CLEAR
* SAMPLES ARE PACKED IN 250ML GLASS JARS WITH TEFLON LINERS * SAMPLES HAVE BEEN FROZED SINCE TIME OF SAMPLING
* ALL SAMPLES ARE TO BE SPLIT FOR ORGAINC ANALYSIS (ALL ANALYSIS LISTED IN TABLE #5 OF AGREEMENT)
AND FOR METAL ANALYSIS OF THE FOLLOWING SIX TRACE METALS:
* CHROMIUM * IRON * MANGANESE * COPPER * ZINC * NICKEL

* SAMPLES DELIVERED TO HMI LABORATORY ON: 4/12/88 SAMPLES RELINQUISED BY: H.T. FFITZENMEYER
SAMPLES RECIEVED BY: T.R. BANTA

* SAMPLES DELIVERED TO NARTEL LABORATORY ON: 4/13/88 1600 SAMPLES RELINQUISED BY: T.R. BANTA
SAMPLES RECIEVED BY: P. BELL

Appendix A
(continued)

H.M.I. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE CODE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS TO BE DONE
880190	3	4-12-88	YEAR #7 WINTER	N/A	2	N/A	16.5	SEDIMENT	XIF 3430	HENNESSEE	ORGANICS
880191	19	4-12-88	"	N/A	2	N/A	19	SEDIMENT	XIF 3620	HENNESSEE	ORGANICS
880192	BC-3	4-12-88	"	N/A	2	N/A	16	SEDIMENT	XIF 4615	HENNESSEE	ORGANICS
880193	24-1	4-12-88	"	N/A	2	N/A	18	SEDIMENT	XIF 5302	HENNESSEE	ORGANICS
880194	24-2	4-12-88	"	N/A	2	N/A	18	SEDIMENT	XIF 5302	HENNESSEE	ORGANICS
880195	24-3	4-12-88	"	N/A	2	N/A	18	SEDIMENT	XIF 5302	HENNESSEE	ORGANICS
880196	28	4-12-88	"	N/A	2	N/A	20	SEDIMENT	XIG 5699	HENNESSEE	ORGANICS
880197	21.8	4-12-88	"	N/A	2	N/A	14	SEDIMENT	XIF 5505	HENNESSEE	ORGANICS
880198	BC-6	4-12-88	"	N/A	2	N/A	13	SEDIMENT	XIF 5925	HENNESSEE	ORGANICS
880197	23	4-12-88	"	N/A	2	N/A	13	SEDIMENT	XIF 4642	HENNESSEE	ORGANICS

OTHER PERTINENT INFORMATION:

* WEATHER CODE #2 = CONTINUOUS LAYERS OF CLOUDS

* SAMPLES ARE IN GLASS JARS * SAMPLES HAVE BEEN FROZEN SINCE TIME OF SAMPLING

SAMPLES DELIVERED TO HMI LABORATORY ON: 4/12/88 SAMPLES RELINQUISED BY: E.L. HENNESSEE
SAMPLES RECIEVED BY: T.R. BANTA

SAMPLES DELIVERED TO MARTEL LABORATORY ON: 4/13/88 1600 SAMPLES RELINQUISED BY: T.R. BANTA
SAMPLES RECIEVED BY: P. NELL

ALL SAMPLES TO BE ANALYZED FOR ORGANICS LISTED IN TABLE #3

Appendix A
(continued)

MES Sample ID	NOAA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE *	TIDE	DEPTH IN FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS TO BE DONE
880525	NM 16-1	8-1-88	YEAR 88 SUMMER	10:25	1	FLOOD	18	RANGIA	STATE STA # XIF3325	PFITZENMEYER	MET/ORG
880526	NM 16-2	8-1-88	"	10:25	1	SLACK	18	MACOMA	STATE STA # XIF3325	PFITZENMEYER	MET/ORG
880527	NM 16-3	8-1-88	"	10:25	1	SLACK	18	CYATHURA	STATE STA # XIF3325	PFITZENMEYER	MET/ORG
880528	-S6-1	8-1-88	"	12:15	1	SLACK	12.5	RANGIA	STATE STA # XIF4420	PFITZENMEYER	MET/ORG
880529	-S6-2	8-1-88	"	12:15	1	SLACK	12.5	MACOMA	STATE STA # XIF4420	PFITZENMEYER	MET/ORG
880530	-S6-3	8-1-88	"	12:15	1	SLACK	12.5	CYATHURA	STATE STA # XIF4420	PFITZENMEYER	MET/ORG
880531	S4-1	8-1-88	"	13:10	1	EBB	15	RANGIA	STATE STA # XIF4715	PFITZENMEYER	MET/ORG
880532	-S4-2	8-1-88	"	13:10	1	EBB	15	CYATHURA	STATE STA # XIF4715	PFITZENMEYER	MET/ORG
880533	-S2-1	8-1-88	"	14:45	1	EBB	13	RANGIA	STATE STA # XIF5406	PFITZENMEYER	MET/ORG
880534	-S2-2	8-1-88	"	14:45	1	EBB	13	RITHROPAN OPEUS	STATE STA # XIF5406	PFITZENMEYER	MET/ORG
880535	-S2-3	8-1-88	"	14:45	1	EBB	13	CYATHURA	STATE STA # XIF5406	PFITZENMEYER	MET/ORG
880536	S1-1	8-1-88	"	15:45	1	EBB	7	RANGIA	STATE STA # XIF5710	PFITZENMEYER	MET/ORG
880537	S1-2	8-1-88	"	15:45	1	EBB	7	CYATHURA	STATE STA # XIF5710	PFITZENMEYER	MET/ORG
880538	NM 22-1	8-1-88	"	16:15	1	EBB	14	RANGIA	STATE STA # XIG7689	PFITZENMEYER	MET/ORG
880539	NM 22-2	8-1-88	"	16:15	1	EBB	14	RANGIA	STATE STA # XIG7689	PFITZENMEYER	MET/ORG
880540	NM 22-3	8-1-88	"	16:15	1	EBB	14	CYATHURA	STATE STA # XIG7689	PFITZENMEYER	MET/ORG
880541	F -1-1	8-1-88	"	17:25	1	EBB	10	YELLOW PERCH	LAT/LONG START-STOP ✓ 39 15.5' - 39 15.7' 76 23.2' - 76 22.9'	PFITZENMEYER	MET/ORG
880542	F -1-2	8-1-88	"	17:25	1	EBB	10	WHITE PERCH	39 15.5' - 39 15.7' 76 23.2' - 76 22.9'	PFITZENMEYER	MET/ORG
880543	F -1-3	8-1-88	"	17:25	1	EBB	10	WHITE PERCH	39 15.5' - 39 15.7' 76 23.2' - 76 22.9'	PFITZENMEYER	MET/ORG
880544	F -2-1	8-1-88	"	17:55	1	EBB	10-13	SPOT	39 15.8 - 39 16.1' 76 20.7 - 76 20.8'	PFITZENMEYER	MET/ORG
880545	F -2-2	8-1-88	"	17:55	1	EBB	10-13	WHITE PERCH	39 15.8 - 39 16.1' 76 20.7 - 76 20.8'	PFITZENMEYER	MET/ORG
880546	F -2-3	8-1-88	"	17:55	1	EBB	10-13	WHITE PERCH	39 15.8 - 39 16.1' 76 20.7 - 76 20.8'	PFITZENMEYER	MET/ORG
880547	F -3-1	8-1-88	"	18:20	1	EBB	10-14	SPOT	39 14.6' - 39 76 21.4' - 76	PFITZENMEYER	MET/ORG

Appendix A
(continued)

MES SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE #	TIDE	DEPTH IN FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS TO BE DONE
88-548	F (5)2	8-1-88	*	18:20	1	EBB	10-14	WHITE PERCH	39 14.6' - 39 76 21.4' - 76	PFITZENMEYER	MET/ORG
88-549	F (5)3	8-1-88	*	18:20	1	EBB	10-14	WHITE PERCH	39 14.6' - 39 76 21.4' - 76	PFITZENMEYER	MET/ORG
88-550	F (5)4	8-1-88	*	18:40	1	EBB	15	SPOT	39 12.3' - 39 12.5' 76 24.1' - 76 24.4'		

Concentrations (ug/kg) of Selected Organic Contaiminants in Rangia at Station HM-14.

COMPOUND	FEB 1982
alpha-BHC	<3.4
lindane	<3.4
beta-BHC	<3.4
aldrin	4.3
heptachlor	12.5
heptachlor epoxide	<3.4
dieldrin	176
naphthalene	<3.4
fluorene	3.4
phenanthrene	8.0
anthracene	9.8
fluoranthene	8.0
pyrene	8.0
benzo(a)pyrene	5.4
benzo(a)anthracene	<3.4
benzo(k)fluoranthrene	<3.4
3,4 benzofluoranthene	<3.4
chrysene	3.4
acenaphthylene	<3.4
benzo(ghi)perylene	<3.4
dibenz(a,h)anthracene	<3.4
indeno(1,2,3-cd)pyrene	<3.4
acenaphthene	<3.4
PCBs, total	195
kepone	<3.4
dimethyl phthalate	5.4
diethyl phthalate	228
dibutyl phthalate	275
di-2-ethyl hexyl phthalate	262
di octyl phthalate	39.3
atrazine	<3.4
simazine	<3.4
trifluraline	<3.4
chlordane	155
diazinon	<3.4
DDE	5.4
DDD	3.4
DDT	3.4
linuron	<3.4
butyl benzyl phthalate	76.8
endrin	<3.4
malathion	<3.4
methyl parathion	<3.4
ethyl parathion	<3.4

Ranges (ppb) of concentrations for 44 compounds in Macoma.

COMPOUND	RANGE OBSERVED AUG 1981	MAY 1982
alpha-BHC	N.D.	N.D.
lindane	<141 - 251	N.D.
beta-BHC	N.D.	N.D.
aldrin	1006 - 4780	318 - 1216
heptachlor	141 - 2012	N.D.
heptachlor epoxide	N.D.	N.D.
dieldrin	755 - 1260	<79 - 676
naphthalene	N.D.	<135 - 397
fluorene	<141 - 251	N.D.
phenanthrene	<141 - 377	N.D.
anthracene	<141 - 377	N.D.
fluoranthene	<251 - 9560	954 - 1890
pyrene	<251 - 9980	1030 - 2290
benzo(a)pyrene	N.D.	N.D.
benzo(a)anthracene	N.D.	N.D.
benzo(k)fluoranthrene	N.D.	N.D.
3,4 benzofluoranthene	N.D	N.D.
chrysene	N.D.	N.D.
acenaphthylene	N.D.	N.D.
benzo(ghi)perylene	N.D.	N.D.
dibenz(a,h)anthracene	N.D.	N.D.
indeno(1,2,3-cd)pyrene	N.D.	N.D.
acenaphthene	N.D.	N.D.
PCBs, total	1509 - 8580	3260 - 6620
kepone	N.D.	N.D.
dimethyl phthalate	141 - 1257	N.D.
diethyl phthalate	<141 -16300	2150 - 5135
dibutyl phthalate	8800 -64200	8268 -29300
di-2-ethyl hexyl phthalate	141 - 1760	477 - 540
di octyl phthalate	141 - 251	<135 - 159
atrazine	N.D.	N.D.
simazine	N.D.	N.D.
trifluraline	N.D.	N.D.
chlordane	2260 - 6050	318 - 2570
diazinon	N.D.	N.D.
DDE	<141 - 251	N.D.
DDD	<141 - 377	N.D.
DDT	N.D.	N.D.
linuron	N.D.	N.D.
butyl benzyl phthalate	421 - 2515	N.D.
endrin	N.D.	N.D.
malathion	N.D.	N.D.
methyl parathion	N.D.	N.D.
ethyl parathion	N.D.	N.D.

N.D. - not detected.

Concentrations of Selected Organic Contaiminants in Cyathura at Stations HM6, HM10, May 1983.

COMPOUND	HM6 CONCENTRATION, ug/kg	HM10
alpha-BHC	3510	4240
lindane	4210	4860
beta-BHC	3930	3650
aldrin	3700	2630
heptachlor	2650	6000
heptachlor epoxide	<2800	<1660
dieldrin	2915	3070
naphthalene	<2800	<1660
fluorene	<2800	<1660
phenanthrene	<2800	<1660
anthracene	<2800	<1660
fluoranthene	<2800	<1660
pyrene	<2800	<1660
benzo(a)pyrene	<2800	<1660
benzo(a)anthracene	<2800	<1660
benzo(k)fluoranthrene	<2800	<1660
3,4 benzofluoranthene	<2800	<1660
chrysene	<2800	<1660
acenaphthylene	<2800	<1660
benzo(ghi)perylene	<2800	<1660
dibenz(a,h)anthracene	<2800	<1660
indeno(1,2,3-cd)pyrene	<2800	<1660
acenaphthene	<2800	<1660
PCBs, total	2830	2630
kepone	<2800	<1660
dimethyl phthalate	<2800	<1660
diethyl phthalate	<2800	<1660
dibutyl phthalate	<2800	<1660
di-2-ethyl hexyl phthalate	27000	24000
di octyl phthalate	<2800	<1660
atrazine	<2800	<1660
simazine	<2800	<1660
trifluraline	<2800	<1660
chlordane	5980	5460
diazinon	<2800	<1660
DDE	<2800	5540
DDD	45000	1660
DDT	<2800	<1660
linuron	<2800	<1660
butyl benzyl phthalate	7400000	<1660
endrin	<2800	<1660
malathion	<2800	<1660
methyl parathion	<2800	<1660
ethyl parathion	<2800	<1660

Ranges (ppb) of concentrations for 44 compounds in Macoma.

COMPOUND	May[1] 1983	July[1] 1983
alpha-BHC	ND	ND
lindane	685-14900	828-5280
beta-BHC	ND	ND
aldrin	127-37100	81-300
heptachlor	<120-<1680	ND
heptachlor epoxide	ND	ND
dieldrin	820-5270	330-1990
napthalene	<200-6400	ND
fluorene	ND	ND
phenanthrene	<120-1800	ND
anthracene	<120-<1680	ND
fluoranthene	<1680-140	<81-1710
pyrene	<200-<1680	<81-1710
benzo(a)pyrene	<200-<1680	ND
benzo(a)anthracene	200-<1680	ND
benzo(k)fluoranthrene	ND	ND
3,4 benzofluoranthene	<1680-200	ND
chrysene	ND	ND
acenaphthylene	ND	ND
benzo(ghi)perylene	ND	ND
dibenz(a,h)anthracene	ND	ND
indeno(1,2,3-cd)pyrene	ND	ND
acenaphthene	ND	ND
PCBs, total	<120-6700	1500-2730
kepone	ND	ND
dimethyl phthalate	ND	ND
diethyl phthalate	<321-80000	<81-18000
dibutyl phthalate	<1250-860000	2300-335000
di-2-ethyl hexyl phthalate	7700-1500000	32000-1400000
di octyl phthalate	<120-520000	<171-140000
atrazine	ND	ND
simazine	ND	ND
trifluraline	ND	ND
chlordane	1762-7020	388-1510
diazinon	ND	ND
DDE	<120-8760	<81-<300
DDD	<120-48300	<81-1240
DDT	ND	ND
linuron	ND	ND
butyl benzyl phthalate	470-6200000	<300-17100
endrin	ND	ND
malathion	ND	ND
methyl parathion	ND	ND
ethyl parathion	ND	ND

ND = not detected.

[1] N = 6
[2] N = 3

(1987-1988).

Concentrations in Catfish	sample date		sample date		sample date	
Contaminant	range	median	range	median	range	median
Sample Date			04/11/88			
Aldrin			<5			
α - BHC			<5			
Atrazine			<10			
β - BHC			<5			
γ - BHC (Lindane)			<5			
Chlordane			<200			
4,4' - DDD			<5			
4,4' - DDE			<5			
4,4' - DDT			<5			
Diazinon			<10			
Dieldrin			<5			
Endrin			<5			
Ethyl parathion			<10			
Heptachlor			<5			
Heptachlor epoxide			<5			
Linuron			<10			
Malathion			<10			
Methyl parathion			<10			
Toxaphene			<50			
Trifluraline			<10			
PCB's (total)			240-1100 670			
Butyl benzyl phthalate			<100			
Dis-n-octyl phthalate			<500			
Bis (2-ethylhexyl) phthalate			<500			
Di-n-butyl phthalate			<100			
Diethyl phthalate			<50			
Dimethyl phthalate			<50			
Benzo (b) fluoranthene			<50			
Acenaphthylene			<50			
Benzo (a) anthracene			<50			
Benzo (g,h,i) perylene			<100			
Chrysene			<50			
Fluoranthene			<50			
Indeno (1,2,3-cd) pyrene			<100			
Phenanthrene			<50			
Acenaphthene			<50			
Anthracene			<50			
Benzo (a) pyrene			<50			
Benzo (k) flouranthene			<100			
Dibenzo (a,h) anthracene			<100			
Fluorene			<50			
Naphthalene			<50			
Pyrene			<50			
Chromium			<2			
Iron			9			
Manganese			<2			
Copper			<1-2			
Zinc			11-12			
Nickel			<5			
Number of samples			2			

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix C: (cont.)

Concentrations of contaminants in Flounder

Contaminant	sample date		sample date		sample date	
Sample Date	range	median	range	median	range	median
	8/24/87					
Aldrin	<5					
α - BHC	<5					
Atrazine	<10					
β - BHC	<5					
γ - BHC (Lindane)	<5					
Chlordane	360					
4,4' - DDD	<5					
4,4' - DDE	<5					
4,4' - DDT	<5					
Diazinon	<10					
Dieldrin	<5					
Endrin	<5					
Ethyl parathion	<10					
Heptachlor	<5					
Heptachlor epoxide	<5					
Linuron	<10					
Malathion	<10					
Methyl parathion	<10					
Toxaphene	<50					
Trifluraline	<10					
PCB's (total)	500					
Butyl benzyl phthalate	<100					
Dis-n-octyl phthalate	<500					
Bis (2-ethylhexyl) phthalate	<500					
Di-n-butyl phthalate	<100					
Diethyl phthalate	<50					
Dimethyl phthalate	<50					
Benzo (b) fluoranthene	<50					
Acenaphthylene	<50					
Benzo (a) anthracene	<50					
Benzo (g,h,i) perylene	<100					
Chrysene	<50					
Fluoranthene	<50					
Indeno (1,2,3-cd) pyrene	<100					
Phenanthrene	<50					
Acenaphthene	<50					
Anthracene	<50					
Benzo (a) pyrene	<50					
Benzo (k) flouranthene	<50					
Dibenzo (a,h) anthracene	<100					
Fluorene	<50					
Naphthalene	<50					
Pyrene	<50					
Chromium	<5					
Iron	5-7	6				
Manganese	<2-3	2.5				
Copper						
Zinc	5-7	6				
Nickel						
Number of samples	2 metals samples, 1 organic sample					

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Spot

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date					08/01/88	
Aldrin					<1	
α - BHC					<1	
Atrazine					<10	
ɣ - BHC					<1	
ɣ - BHC (Lindane)					<3-<1	
Chlordane					<10	
4,4' - DDD					<1	
4,4' - DDE					<1	
4,4' - DDT					<1	
Diazinon					<10	
Dieldrin					<1	
Endrin					<1	
Ethyl parathion					<10	
Heptachlor					<3-<1	<1
Heptachlor epoxide					<1	
Linuron					<10	
Malathion					<10	
Methyl parathion					<10	
Toxaphene					<10	
Trifluraline					<10	
PCB's (total)					<100-217	82
Butyl benzyl phthalate					<1	
Dis-n-octyl phthalate					<1	
Bis (2-ethylhexyl) phthalate					<10	
Di-n-butyl phthalate					<1	
Diethyl phthalate					<1	
Dimethyl phthalate					<1	
Benzo (b) fluoranthene					<1	
Acenaphthylene					<1	
Benzo (a) anthracene					<1	
Benzo (g,h,i) perylene					<2	
Chrysene					<1	
Fluoranthene					<1	
Indeno (1,2,3-cd) pyrene					<2	
Phenanthrene					<1	
Acenaphthene					<1	
Anthracene					<1	
Benzo (a) pyrene					<1	
Benzo (k) flouranthene					<1	
Dibenzo (a,h) anthracene					<2	
Fluorene					<1	
Naphthalene					<1	
Pyrene					<1	
Chromium					<2	
Iron					13-22	15
Manganese					12-15	12
Copper					<1-5	1
Zinc					9-15	13
Nickel					<2	

* Values display in parts per billion (PPb)
** Metals in parts per million

Appendix C: (cont.)

Concentrations of contaminants in Hogchoker

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date			04/11/88			
Aldrin			<5			
α - BHC			<5			
Atrazine			<10			
β - BHC			<5			
γ - BHC (Lindane)			<5			
Chlordane			<50			
4,4' - DDD			<5			
4,4' - DDE			<5			
4,4' - DDT			<5			
Diazinon			<10			
Dieldrin			<5			
Endrin			<5			
Ethyl parathion			<10			
Heptachlor			<5			
Heptachlor epoxide			<5			
Linuron			<10			
Malathion			<10			
Methyl parathion			<10			
Toxaphene			<50			
Trifluraline			<10			
PCB's (total)			170			
Butyl benzyl phthalate			<100			
Dis-n-octyl phthalate			<500			
Bis (2-ethylhexyl) phthalate			<500			
Di-n-butyl phthalate			<100			
Diethyl phthalate			<50			
Dimethyl phthalate			<50			
Benzo (b) fluoranthene			<50			
Acenaphthylene			<50			
Benzo (a) anthracene			<50			
Benzo (g,h,i) perylene			<100			
Chrysene			<50			
Fluoranthene			<50			
Indeno (1,2,3-cd) pyrene			<100			
Phenanthrene			<50			
Acenaphthene			<50			
Anthracene			<50			
Benzo (a) pyrene			<50			
Benzo (k) flouranthene			<100			
Dibenzo (a,h) anthracene			<100			
Fluorene			<50			
Naphthalene			<50			
Pyrene			<50			
Chromium			<2			
Iron			19			
Manganese			57			
Copper			2			
Zinc			26			
Nickel			<2			
Number of samples			1			

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Verhaden

Contaminant	sample date range	median	sample date range	median	sample date range	median
Sample Date	12/08/87					
Aldrin	<5					
α - BHC	<5					
Atrazine	<10					
β - BHC	<5					
γ - BHC (Lindane)	<5					
Chlordane	46-400	72				
4,4' - DDD	<5					
4,4' - DDE	<5					
4,4' - DDT	<5					
Diazinon	<10					
Dieldrin	<5					
Endrin	<5					
Ethyl parathion	<10					
Heptachlor	<5					
Heptachlor epoxide	<5					
Linuron	<10					
Malathion	<10					
Methyl parathion	<10					
Toxaphene	<50					
Trifluraline	<10					
PCB's (total)	94-680	98				
Butyl benzyl phthalate	<100					
Dis-n-octyl phthalate	<500					
Bis (2-ethylhexyl) phthalate	<500					
Di-n-butyl phthalate	<100					
Diethyl phthalate	<50					
Dimethyl phthalate	<50					
Benzo (b) fluoranthene	<50					
Acenaphthylene	<50					
Benzo (a) anthracene	<50					
Benzo (g,h,i) perylene	<100					
Chrysene	<50					
Fluoranthene	<50					
Indeno (1,2,3-cd) pyrene	<100					
Phenanthrene	<50					
Acenaphthene	<50					
Anthracene	<50					
Benzo (a) pyrene	<50					
Benzo (k) flouranthene	<50					
Dibenzo (a,h) anthracene	<100					
Fluorene	<50					
Napnthalene	<50					
Pyrene	<50					
Chromium	<5					
Iron	9-11	11				
Manganese	<2-4	2				
Copper	<1					
Zinc	4-6					
Nickel	<5	5				
Number of samples						

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in White perch

Contaminant	sample date range	median	sample date range	median	sample date range	median
Aldrin	<5		<5		<1	
α - BHC	<5		<5		<1	
Atrazine	<10		<10		<10	
β - BHC	<5		<5		<1	
γ - BHC (Lindane)	<5		<5		<1	
Chlordane	290	290	<500-<50	<200	<10-295	117
4,4' - DDD	<5		<5		<1	
4,4' - DDE	<5		<5		<1	
4,4' - DDT	<5		<5		<1	
Diazinon	<10		<10		<10	
Dieldrin	<5		<5		<1	
Endrin	<5		<5		<1	
Ethyl parathion	<10		<10		<10	
Heptachlor	<5		<5		<1	
Heptachlor epoxide	<5		<5		<1	
Linuron	<10		<10		<10	
Malathion	<10		<10		<10	
Methyl parathion	<10		<10		<10	
Toxaphene	<50		<50		<10	
Trifluralina	<10		<10		<10	
PCB's (total)	720	720	<50-940	440	208-708	255
Butyl benzyl phthalate	<100		<100		<1	
Dis-n-octyl phthalate	<500		<500		<1	
Bis (2-ethylhexyl) phthalate	<500		<500		<10	
Di-n-butyl phthalate	<100		<100		<1	
Diethyl phthalate	<50		<50		<1	
Dimethyl phthalate	<50		<50		<1	
Benzo (b) fluoranthene	<50		<50		<1	
Acenaphthylene	<50		<50		<1	
Benzo (a) anthracene	<50		<50		<1	
Benzo (g,h,i) perylene	<100		<100		<2	
Chrysene	<50		<50		<1	
Fluoranthene	<50		<50		<1	
Indeno (1,2,3-cd) pyrene	<100		<100		<2	
Phenanthrene	<50		<50		<1	
Acenaphthene	<50		<50		<1	
Anthracene	<50		<50		<1	
Benzo (a) pyrene	<50		<50		<1	
Benzo (k) flouranthene	<50		<100		<1	
Dibenzo (a,h) anthracene	<100		<100		<2	
Fluorene	<50		<50		<1	
Naphthalene	<50		<50		<1	
Pyrene	<50		<50		<1	
Chromium	<5		<2		<2	
Iron	9		10-58	14	8-19	16.5
Manganese	<2		<2-78	12.5	3-9	3.5
Copper	<1		2-12	2.5	1-2	1
Zinc	6		10-45	21.5	12-21	16.5
Nickel	<5		<5-6	5	<2	
Number of samples	1		8		6	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Yellow Perch

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	12/08/87		04/11/88		08/01/88	
Aldrin	<5		<5		<1	
α - BHC	<5		<5		<1	
Atrazine	<10		<10		<10	
β - BHC	<5		<5		<1	
γ - BHC (Lindane)	<5		<5		<1	
Chlordane	81-89	85	<200-<50	<100	95	
4,4' - DDD	<5		<5		<1	
4,4' - DDE	<5		<5		<1	
4,4' - DDT	<5		<5		<1	
Diazinon	<10		<10		<10	
Dieldrin	<5		<5		<1	
Endrin	<5		<5		<1	
Ethyl parathion	<10		<10		<10	
Heptachlor	<5		<5		<1	
Heptachlor epoxide	<5		<5		<1	
Linuron	<10		<10		<10	
Malathion	<10		<10		<10	
Methyl parathion	<10		<10		<10	
Toxaphene	<50		<50		<10	
Trifluraline	<10		<10		<10	
PCB's (total)	310-860	335	<50-450	310	183	
Butyl benzyl phthalate	<100		<100		<1	
Dis- n-octyl phthalate	<500		<500		<1	
Bis (2-ethylhexyl) phthalate	<500		<500		<10	
Di-n-butyl phthalate	<100		<100		<1	
Diethyl phthalate	<50		<50		<1	
Dimethyl phthalate	<50		<50		<1	
Benzo (b) fluoranthene	<50		<50		<1	
Acenaphthylene	<50		<50		<1	
Benzo (a) anthracene	<50		<50		<1	
Benzo (g,h,i) perylene	<100		<100		<2	
Chrysene	<50		<50		<1	
Fluoranthene	<50		<50		<1	
Indeno (1,2,3-cd) pyrene	<100		<100		<2	
Phenanthrene	<50		<50		<1	
Acenaphthene	<50		<50		<1	
Anthracene	<50		<50		<1	
Benzo (a) pyrene	<50		<50		<1	
Benzo (k) flouranthene	<50		<50		<1	
Dibenzo (a,h) anthracene	<100		<100		<2	
Fluorene	<50		<50		<1	
Naphthalene	<50		<50		<1	
Pyrene	<50		<50		<1	
Chromium	<5		<2		<2	
Iron	6-8	7	10-31	11	57	
Manganese	<2		<2-35	6	4-8	
Copper	<1		2-5	3	<1	
Zinc	5-7	6	11-30	13	10	
Nickel	<5		<5		<2	
Number of samples	2		3		1	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in blue crab

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	8/24/87					
Aldrin	<5					
α - BHC	<5					
Atrazine	<10					
β - BHC	<5					
γ - BHC (Lindane)	<5					
Chlordane	<50-160	<50				
4,4' - DDD	<5					
4,4' - DDE	<5					
4,4' - DDT	<5					
Diazinon	<10					
Dieldrin	<5					
Endrin	<5					
Ethyl parathion	<10					
Heptachlor	<5					
Heptachlor epoxide	<5					
Linuron	<10					
Malathion	<10					
Methyl parathion	<10					
Toxaphene	<50					
Trifluraline	<10					
PCB's (total)	<10-200	30				
Butyl benzyl phthalate	<100					
Di-n-octyl phthalate	<500					
Bis (2-ethylhexyl) phthalate	<500					
Di-n-butyl phthalate	<100					
Diethyl phthalate	<50					
Dimethyl phthalate	<50					
Benzo (b) fluoranthene	<50					
Acenaphthylene	<50					
Benzo (a) anthracene	<50					
Benzo (g,h,i) perylene	<100					
Chrysene	<50					
Fluoranthene	<50					
Indeno (1,2,3-cd) pyrene	<100					
Phenanthrene	<50					
Acenaphthene	<50					
Anthracene	<50					
Benzo (a) pyrene	<50					
Benzo (k) flouranthene	<50					
Dibenzo (a,h) anthracene	<100					
Fluorene	<50					
Naphthalene	<50					
Pyrene	<50					
Chromium	<5					
Iron	11-22	12				
Manganese	92-214	162				
Copper	8-13	9				
Zinc	29-60	49				
Nickel	<5					
Number of samples	3					

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Appendix C: (cont.)

Concentrations of contaminants in Polychaetes

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	04/11/88					
Aldrin	<5					
α - BHC	<5					
Atrazine	<10					
β - BHC	<5					
γ - BHC (Lindane)	<5					
Chlordane	<50					
4,4' - DDD	<5					
4,4' - DDE	<5					
4,4' - DDT	<5					
Diazinon	<10					
Dieldrin	<5					
Endrin	<5					
Ethyl parathion	<10					
Heptachlor	<5					
Heptachlor epoxide	<5					
Linuron	<10					
Malathion	<10					
Methyl parathion	<10					
Toxaphene	<50					
Trifluraline	<10					
PCB's (total)	<10					
Butyl benzyl phthalate	<100					
Dis-n-octyl phthalate	<500					
Bis (2-ethylhexyl) phthalate	<500					
Di-n-butyl phthalate	<100					
Diethyl phthalate	<50					
Dimethyl phthalate	<50					
Benzo (b) fluoranthene	<50					
Acenaphthylene	<50					
Benzo (a) anthracene	<50					
Benzo (g,h,i) perylene	<100					
Chrysene	<50					
Fluoranthene	<50					
Indeno (1,2,3-cd) pyrene	<100					
Phenanthrene	<50					
Acenaphthene	<50					
Anthracene	<50					
Benzo (a) pyrene	<50					
Benzo (k) flouranthene	<100					
Dibenzo (a,h) anthracene	<100					
Fluorene	<50					
Naphthalene	<50					
Pyrene	<50					
Chromium	<2					
Iron	128					
Manganese	32					
Copper	6					
Zinc	35					
Nickel	<10					
Number of samples	1					

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Mudcrab

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date					08/01/88	
Aldrin					<1	
α - BHC					<1	
Atrazine					<10	
β - BHC					<1	
γ - BHC (Lindane)					<1	
Chlordane					<10	
4,4' - DDD					<1	
4,4' - DDE					<1	
4,4' - DDT					<1	
Diazinon					<10	
Dieldrin					<1	
Endrin					<1	
Ethyl parathion					<10	
Heptachlor					<1	
Heptachlor epoxide					<1	
Linuron					<10	
Malathion					<10	
Methyl parathion					<10	
Toxaphene					<10	
Trifluraline					<10	
PCB's (total)					<10	
Butyl benzyl phthalate					<1	
Dis-n-octyl phthalate					<1	
Bis (2-ethylhexyl) phthalate					<10	
Di-n-butyl phthalate					<1	
Diethyl phthalate					<1	
Dimethyl phthalate					<1	
Benzo (b) fluoranthene					<1	
Acenaphthylene					<1	
Benzo (a) anthracene					<1	
Benzo (g,h,i) perylene					<2	
Chrysene					<1	
Fluoranthene					<1	
Indeno (1,2,3-cd) pyrene					<2	
Phenanthrene					<1	
Acenaphthene					<1	
Anthracene					<1	
Benzo (a) pyrene					<1	
Benzo (k) flouranthene					<1	
Dibenzo (a,h) anthracene					<2	
Fluorene					<1	
Naphthalene					<1	
Pyrene					<1	
Chromium					<5	
Iron					715	
Manganese					2000	
Copper					33	
Zinc					49	
Nickel					<5	
Number of samples					1	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Haccine

Contaminant	sample date range	median	sample date range	median	sample date range	median
Sample Date	12/7/87		4/11/88		8/1/88	
Aldrin	<5		<5		<1	
α - BHC	<5		<5		<1	
Atrazine	<10		<10		<10	
β - BHC	<5		<5		<1	
γ - BHC (Lindane)	<5		<5		<1	
Chlordane	<50		<50-62	<50	23-28	25.5
4,4' - DDD	<5		<5		<1	
4,4' - DDE	<5		<5		<1	
4,4' - DDT	<5		<5		<1	
Diazinon	<10		<10		<10	
Dieldrin	<5		<5		<1	
Endrin	<5		<5		<1	
Ethyl parathion	<10		<10		<10	
Heptachlor	<5		<5		<1	
Heptachlor epoxide	<5		<5		<1	
Linuron	<10		<10		<10	
Malathion	<10		<10		<10	
Methyl parathion	<10		<10		<10	
Toxaphene	<50		<50		<10	
Trifluraline	<10		<10		<10	
PCB's (total)	<10-81	45.5	<10		<10	
Butyl benzyl phthalate	<100		<100		<1	
Dis-n-octyl phthalate	<500		<500		<1	
Bis (2-ethylhexyl) phthalate	<500		<500		<10	
Di-n-butyl phthalate	<100		<100		<1	
Diethyl phthalate	<50		<50		<1	
Dimethyl phthalate	<50		<50		<1	
Benzo (b) fluoranthene	<50		<50		<1	
Acenaphthylene	<50		<50		<1	
Benzo (a) anthracene	<50		<50		<1	
Benzo (g,h,i) perylene	<100		<100		<2	
Chrysene	<50		<50		<1	
Fluoranthene	<50		<50		<1	
Indeno (1,2,3-cd) pyrene	<100		<100		<2	
Phenanthrene	<50		<50		<1	
Acenaphthene	<50		<50		<1	
Anthracene	<50		<50		<1	
Benzo (a) pyrene	<50		<50		<1	
Benzo (k) flouranthene	<50		<100		<1	
Dibenzo (a,h) anthracene	<100		<100		<2	
Fluorene	<50		<50		<1	
Naphthalene	<50		<50		<1	
Pyrene	<50		<50		<1	
Chromium	<5-6	5.5	3	3	<2	
Iron	1025.5	681-1220	466-550	795	460-560	
Manganese	121-133		101-132	115	145-206	
Copper	6-7	6.5	8	8	6-8	
Zinc	27-38	32.5	44-70	46	29-59	
Nickel	<5		<5-18	5	<2	
Number of samples	2		2		2	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Rang La

Contaminant	sample date range	median	sample date range	median	sample date range	median
Sample Date	12/7/87		4/11/88		8/1/88	
Aldrin	<5		<5		<1	
α - BHC	<5		<5		<1	
Atrazine	<10		<10		<10	
β - BHC	<5		<5		<1	-5 <1
γ - BHC (Lindane)	<5		<5		<1	
Chlordane	<50		<500-5	<50	<10-2000	<10
4,4' - DDD	<5		<5		<1	
4,4' - DDE	<5		<5		<1	
4,4' - DDT	<5		<5		<1	
Diazinon	<10		<10		<10	
Dieldrin	<5		<5		<1	
Endrin	<5		<5		<1	
Ethyl parathion	<10		<10		<10	
Heptachlor	<5		<5		<1	
Heptachlor epoxide	<5		<5		<1	
Linuron	<10		<10		<10	
Malathion	<10		<10		<10	
Methyl parathion	<10		<10		<10	
Toxaphene	<50		<50		<10	
Trifluraline	<10		<10		<10	
PCB's (total)	<10-100	<10	<10		<10	
Butyl benzyl phthalate	<100		<100		<1	
Dis-n-octyl phthalate	<500		<500		<1	
Bis (2-ethylhexyl) phthalate	<500		<500		<10	
Di-n-butyl phthalate	<100		<100		<1	
Diethyl phthalate	<50		<50		<1	
Dimethyl phthalate	<50		<50		<1	
Benzo (b) fluoranthene	<50		<50		<1	
Acenaphthylene	<50		<50		<1	
Benzo (a) anthracene	<50		<50		<1	
Benzo (g,h,i) perylene	<100		<100		<2	
Chrysene	<50		<50		<1	
Fluoranthene	<50		<50		<1	
Indeno (1,2,3-cd) pyrene	<100		<100		<2	
Phenanthrene	<50		<50		<1	
Acenaphthene	<50		<50		<1	
Anthracene	<50		<50		<1	
Benzo (a) pyrene	<50		<50		<1	
Benzo (k) flouranthene	<50		<100		<1	
Dibenzo (a,h) anthracene	<100		<100		<2	
Fluorene	<50		<50		<1	
Naphthalene	<50		<50		<1	
Pyrene	<50		<50		<1	
Chromium	<5-12	6 5	<2-8	3	<2	
Iron	33-290	124	48-132	82	48-400	328
Manganese	3-123	17	19-116	44	8- 49	21
Copper	<1-3	1.5	3-25	5	2- 6	3
Zinc	4-16	9	2-20	9	15-25	19
Nickel	<3-9	6 5	<3-10	5	<2-11	3
Number of samples	12		9		7	

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Amphipods

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	12/07/87		04/11/88		08/01/88	
Aldrin			<5			
α - BHC			<5			
Atrazine			<10			
β - BHC			<5			
γ - BHC (Lindane)			<5			
Chlordane			<50			
4,4' - DDD			<5			
4,4' - DDE			<5			
4,4' - DDT			<5			
Diazinon			<10			
Dieldrin			<5			
Endrin			<5			
Ethyl parathion			<10			
Heptachlor			<5			
Heptachlor epoxide			<5			
Linuron			<10			
Malathion			<10			
Methyl parathion			<10			
Toxaphene			<50			
Trifluralina			<10			
PCB's (total)			<10			
Butyl benzyl phthalate			<100			
Dis-n-octyl phthalate			<500			
Bis (2-ethylhexyl) phthalate			<500			
Di-n-butyl phthalate			<100			
Diethyl phthalate			<50			
Dimethyl phthalate			<50			
Benzo (b) fluoranthene			<50			
Acenaphthylene			<50			
Benzo (a) anthracene			<50			
Benzo (g,h,i) perylene			<100			
Chrysene			<50			
Fluoranthene			<50			
Indeno (1,2,3-cd) pyrene			<100			
Phenanthrene			<50			
Acenaphthene			<50			
Anthracene			<50			
Benzo (a) pyrene			<50			
Benzo (k) flouranthene			<100			
Dibenzo (a,h) anthracene			<100			
Fluorene			<50			
Naphthalene			<50			
Pyrene			<50			
Chromium	N/A		<4		N/A	
Iron	N/A		146		N/A	
Manganese	N/A		14		N/A	
Copper	N/A		9		N/A	
Zinc	N/A		9		N/A	
Nickel	N/A		<10		N/A	
Number of samples			1			

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Cyanthura

Contaminant	sample date range	median	sample date range	median	sample date range	median	
Sample Date	12/7/87		4/11/88		8/1/88		
Aldrin	<5		<5		<1-197		
α - BHC	<5		<5		<1		
Atrazine	<10		<10		<10		
β - BHC	<5		<5		<1		
γ - BHC (Lindane)	<5		<5		<1		
Chlordane	<50		<100-110	65	<10-83000		966.5
4,4' - DDD	<5		<5		<1		
4,4' - DDE	<5		<5		<1		
4,4' - DDT	<5		<5		<1		
Diazinon	<10		<10		<10		
Dieldrin	<5		<5		<1		
Endrin	<5		<5		<1		
Ethyl parathion	<10		<10		<10		
Heptachlor	<5		<5		<1		
Heptachlor epoxide	<5	<5	<5		<1		
Linuron	<10		<10		<10		
Malathion	<10		<10		<10		
Methyl parathion	<10		<10		<10		
Toxaphene	<50		<50		<10		
Trifluraline	<10		<10		<10		
PCB's (total)	<10		<10		<10		
Butyl benzyl phthalate	<100		<100		<1		
Dis-n-octyl phthalate	<500		<500		<1		
Bis (2-ethylhexyl) phthalate	<500		<500		<10		
Di-n-butyl phthalate	<100		<100		<1		
Diethyl phthalate	<50		<50		<1		
Dimethyl phthalate	<50		<50		<1		
Benzo (b) fluoranthene	<50		<50		<1		
Acenaphthylene	<50		<50		<1		
Benzo (a) anthracene	<50		<50		<1		
Benzo (g,h,i) perylene	<100		<100		<2		
Chrysene	<50		<50		<1		
Fluoranthene	<50		<50		<1		
Indeno (1,2,3-cd) pyrene	<100		<100		<2		
Phenanthrene	<50		<50		<1		
Acenaphthene	<50		<50		<1		
Anthracene	<50		<50		<1		
Benzo (a) pyrene	<50		<50		<1		
Benzo (k) flouranthene	<50		<100		<1		
Dibenzo (a,h) anthracene	<100		<100		<2		
Fluorene	<50		<50		<1		
Naphthalene	<50		<50		<1		
Pyrene	<50		<50		<1		
Chromium	<5		<2-<20		10- 20	15	
Iron	96-133	64.5	67-380		306-720	498	
Manganese	28-47	37.5	25-380		222-920	382	
Copper	18-19	18.9	17-90		20- 44	285	
Zinc	23-26	24.5	23-140		59-240	93.5	
Nickel	5		<5-<50		10- 20	15	
Number of samples	2		6		6		

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

Concentrations of contaminants in Sediment

Contaminant	sample date range	sample date median	sample date range	sample date median	sample date range	sample date median
Sample Date	11/03/87		04/12/88			
Aldrin	<1		<1			
α - BHC	<1		<1			
Atrazine	<1		<10			
β - BHC	<1		<1			
γ - BHC (Lindane)	<1		<1			
Chlordane	<10		<10			
4,4' - DDD	<1		<1			
4,4' - DDE	<1		<1			
4,4' - DDT	<1		<1			
Diazinon	<10		<10			
Dieldrin	<1		<1			
Endrin	<1		<1			
Ethyl parathion	<10		<10			
Heptachlor	<1		<1			
Heptachlor epoxide	<1		<1			
Linuron	<10		<10			
Malathion	<10		<10			
Methyl parathion	<10		<10			
Toxaphene	<10		<10			
Trifluraline	<10		<10			
PCB's (total)	<10		<10			
Butyl benzyl phthalate	<50		<50			
Dis-n-octyl phthalate	<50		<50			
Bis (2-ethylhexyl) phthalate	<50		<50			
Di-n-butyl phthalate	<50		<50			
Diethyl phthalate	<50		<50			
Dimethyl phthalate	<50		<50			
Benzo (b) fluoranthene	<50		<50			
Acenaphthylene	<50		<50			
Benzo (a) anthracene	<50		<50			
Benzo (g,h,i) perylene	<50		<50			
Chrysene	<50		<50			
Fluoranthene	<50		<50			
Indeno (1,2,3-cd) pyrene	<50		<50			
Phenanthrene	<50		<50			
Acenaphthene	<50		<50			
Anthracene	<50		<50			
Benzo (a) pyrene	<50		<50			
Benzo (k) flouranthene	<50		<50			
Dibenzo (a,h) anthracene	<50		<50			
Fluorene	<50		<50			
Naphthalene	<50		<50			
Pyrene	<50		<50			
Chromium						
Iron						
Manganese	See Sedimentary					
Copper	Environment Section					
Zinc	Project II					
Nickel						
Number of samples	10		10			

* ranges and medians for organics are in parts per billion (ppb)
** ranges and medians for metals are in parts per million (ppm)

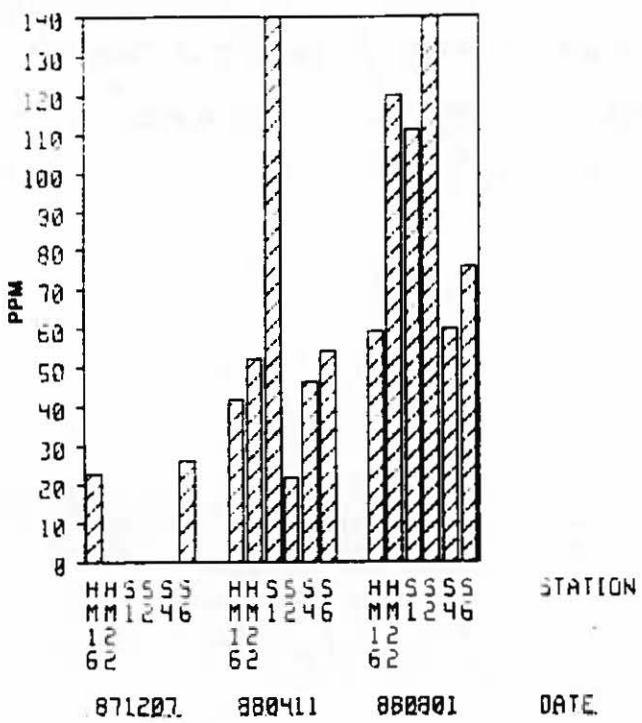
Appendix D: Graphics of Contaminants in Selected Species

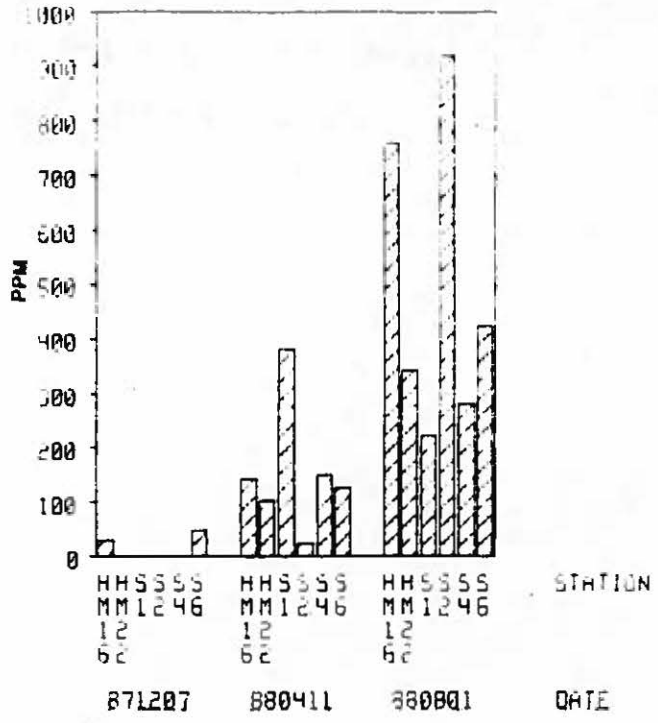
Hart-Miller Island Exterior Monitoring Program

1987-1988

Legend: Contaminant graphs

spcode = species sampled
param = parameter tested
@ = below detection limit
* = values greater than 1000
dates are displayed in the format YYMMDD





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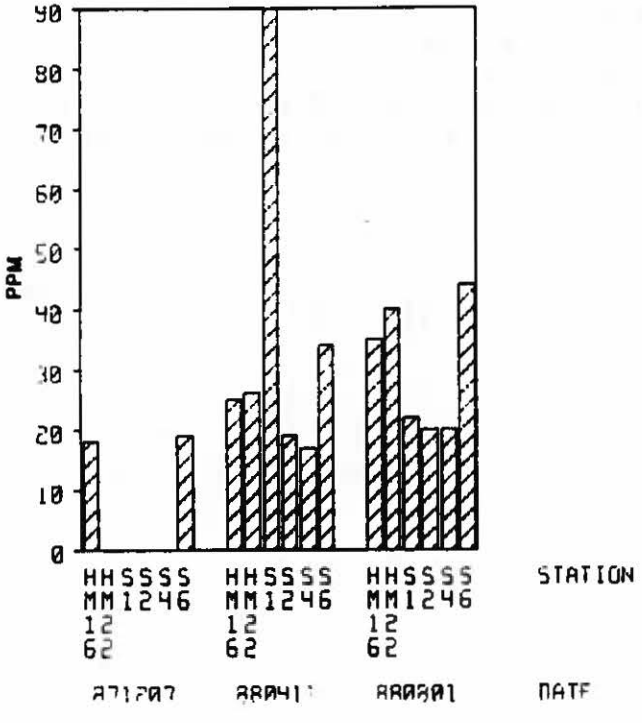

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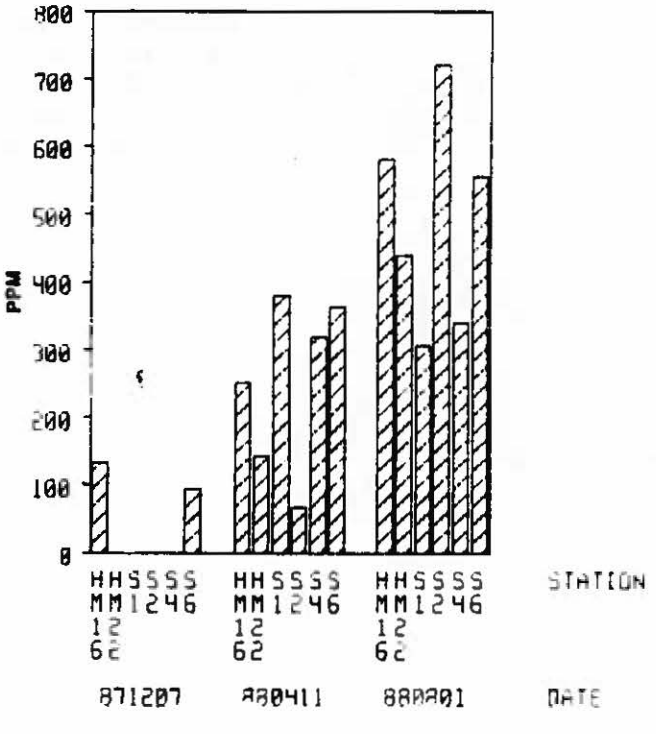

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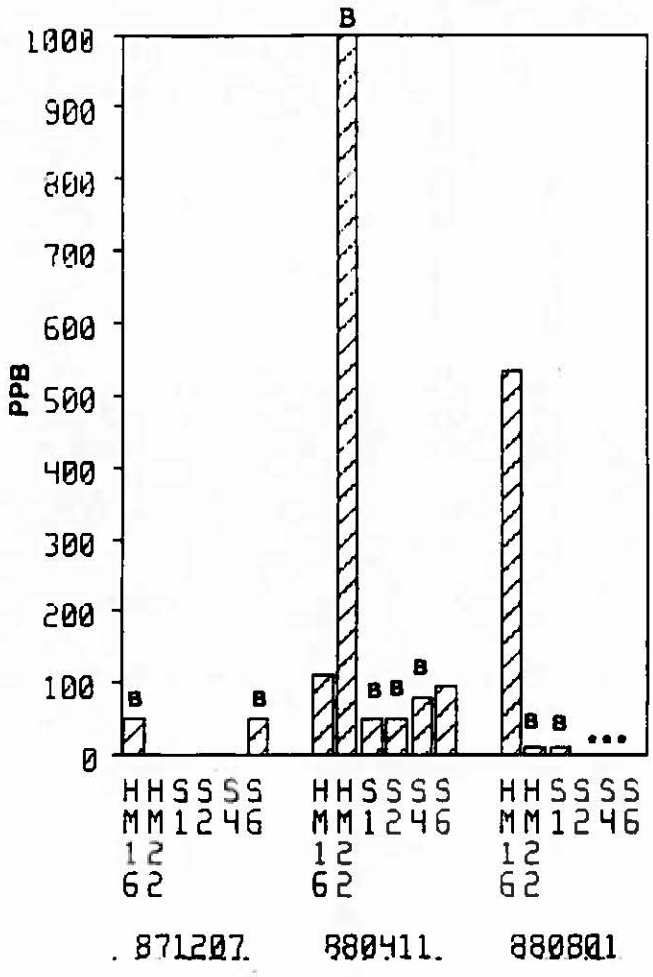

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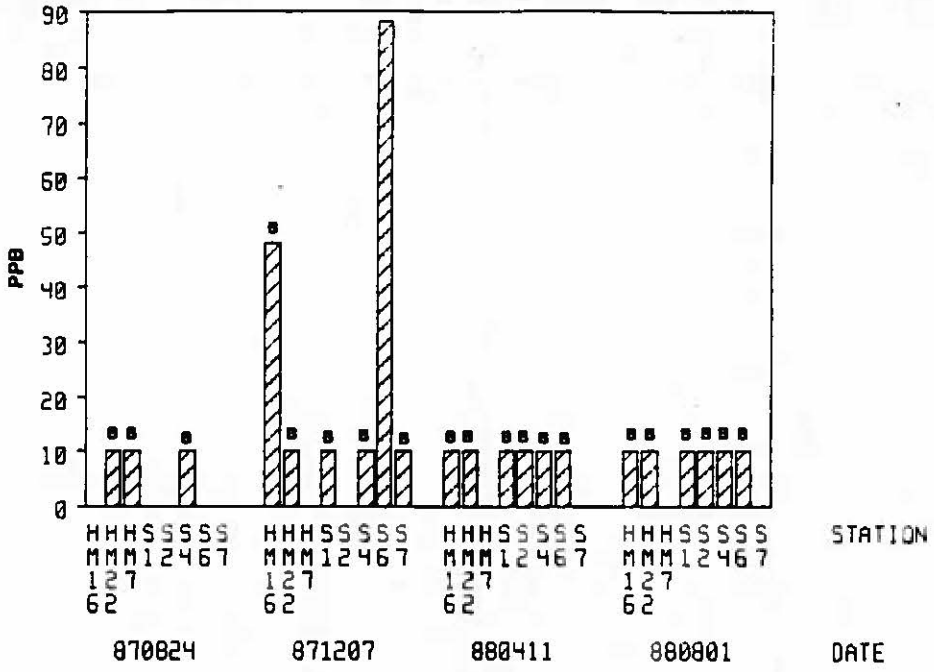
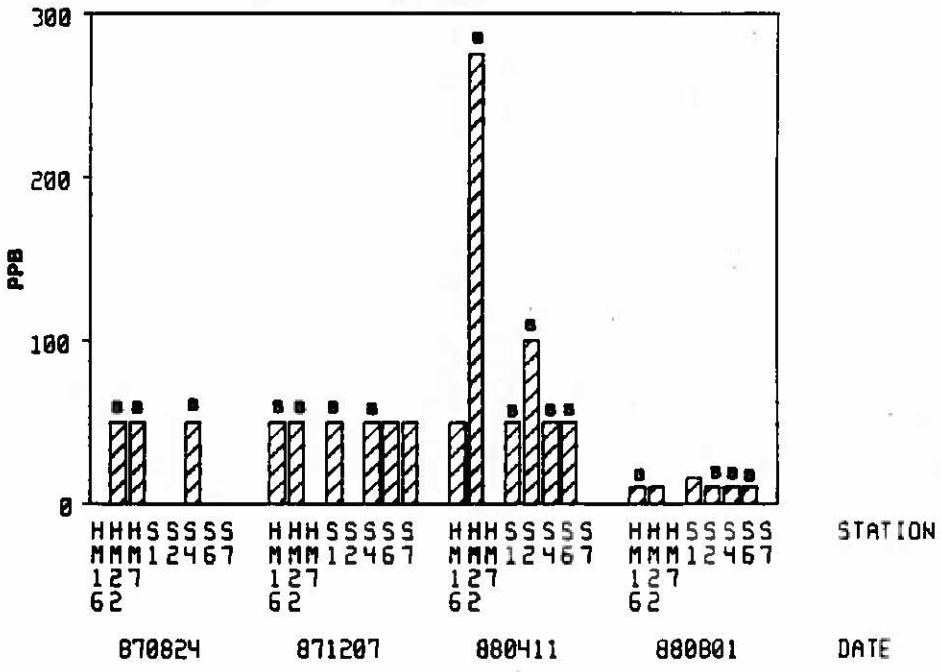


SPCODE=BRACKISH WATER CLAM PARAM=TCHLDANE



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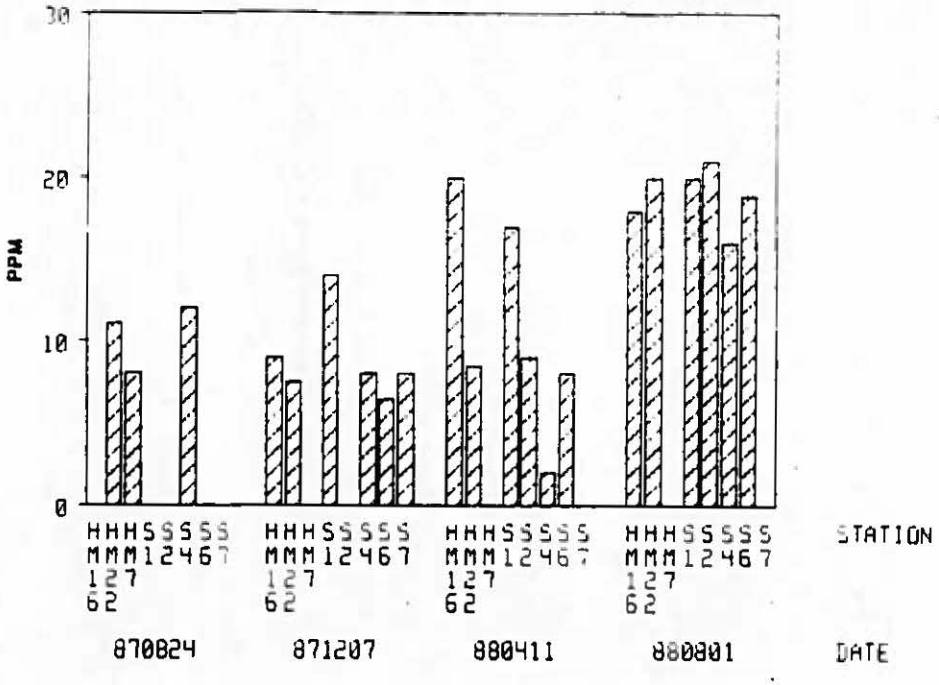

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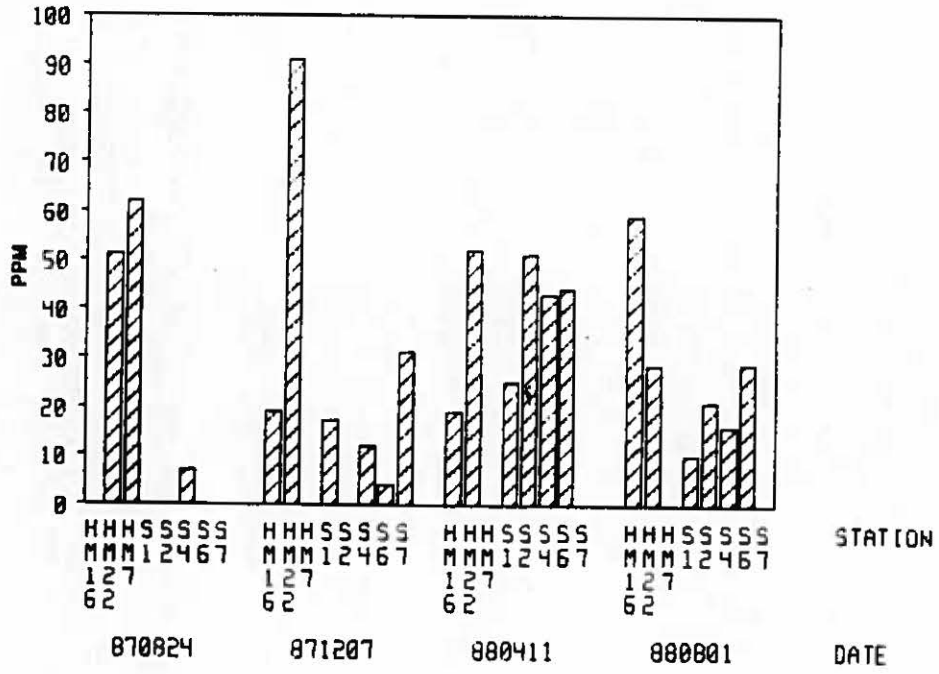

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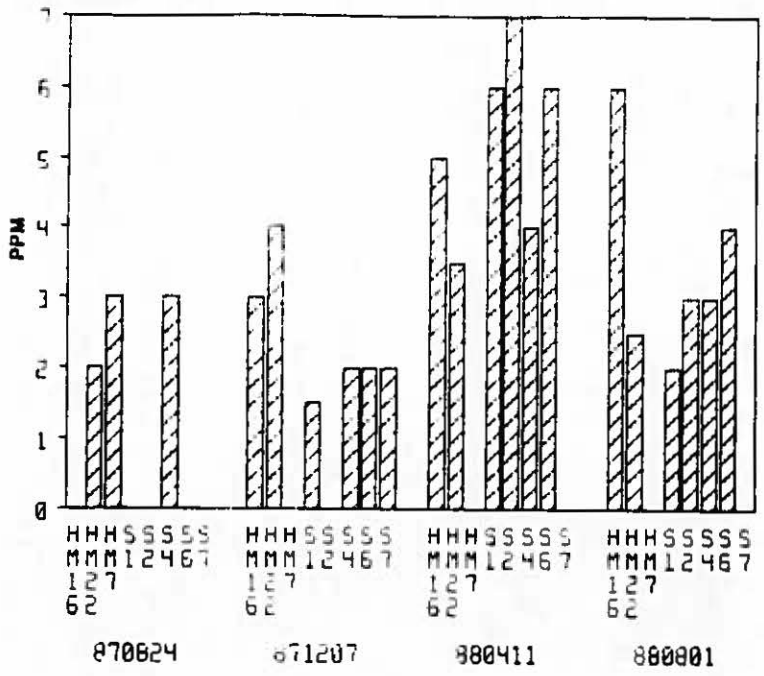

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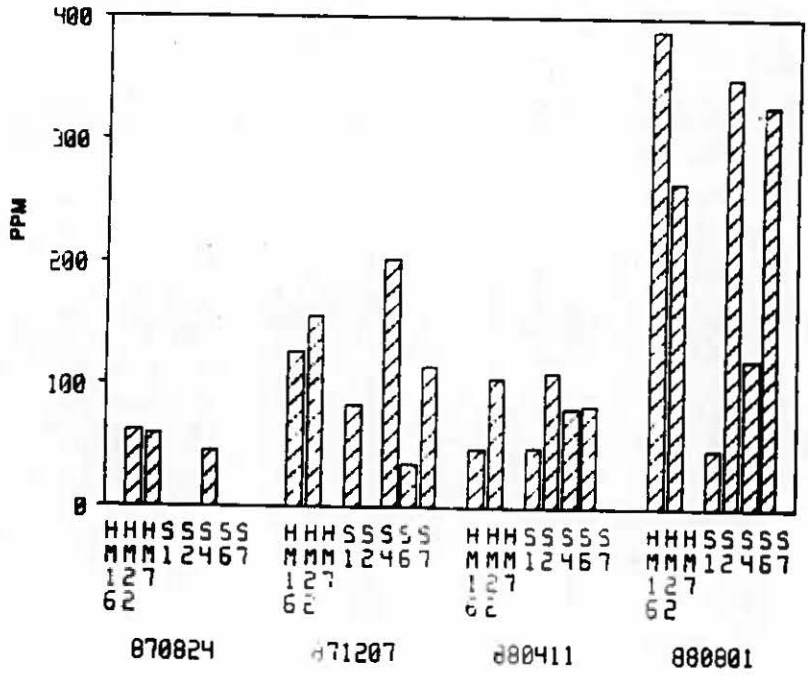

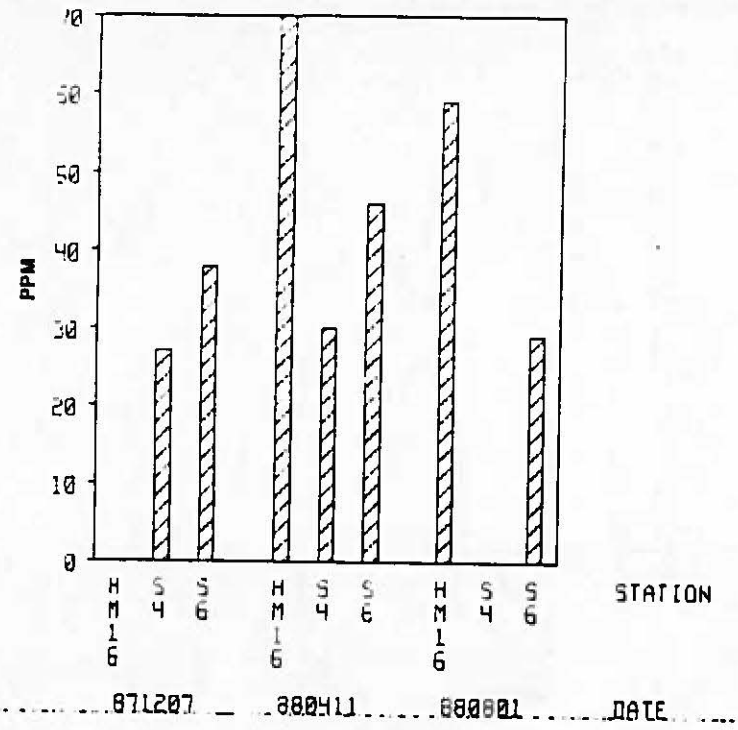
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30
40
50
60
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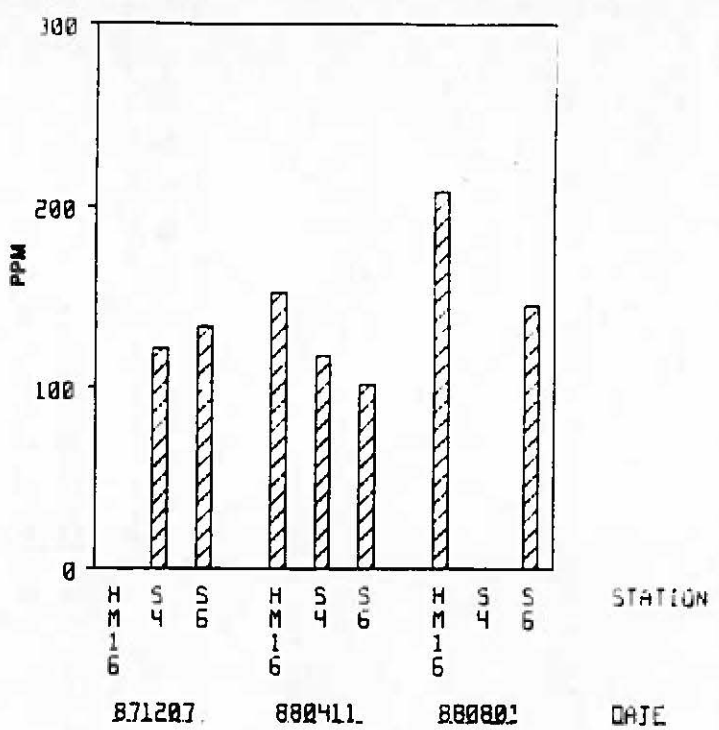
DATE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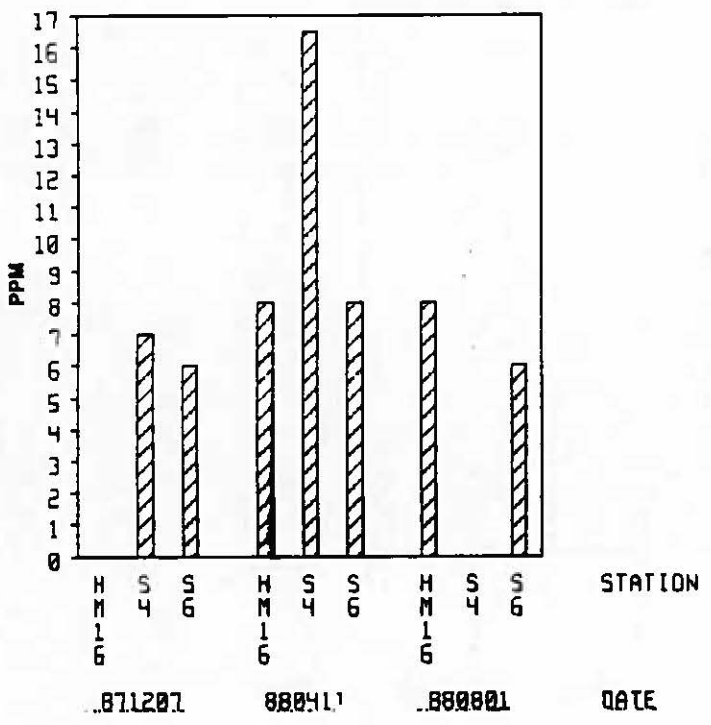
DATE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17
HM16 S4 S6 HM16 S4 S6 HM16 S4 S6
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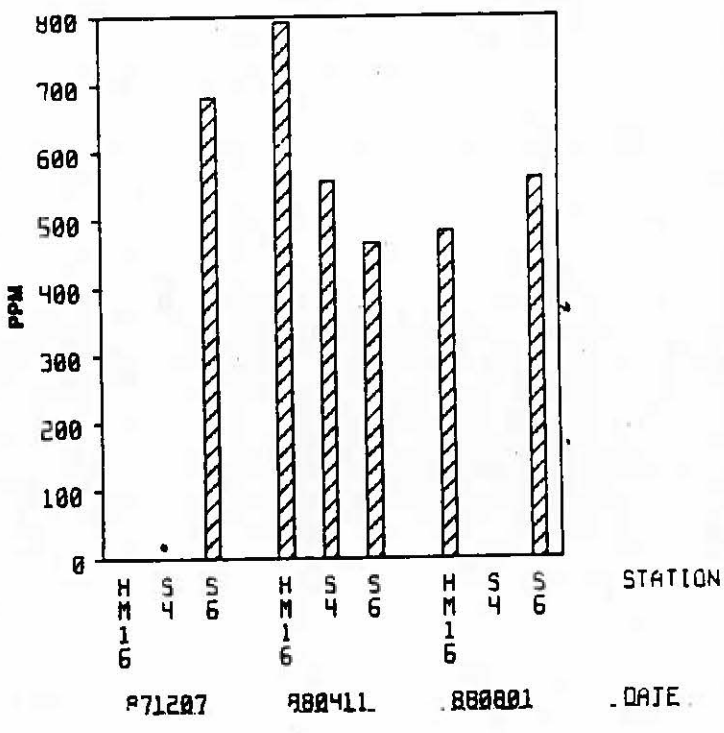
DATE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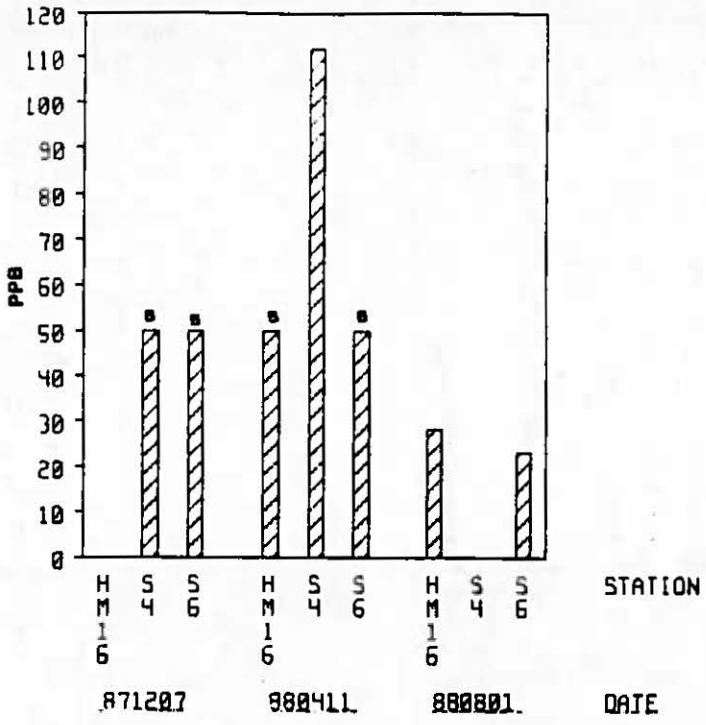

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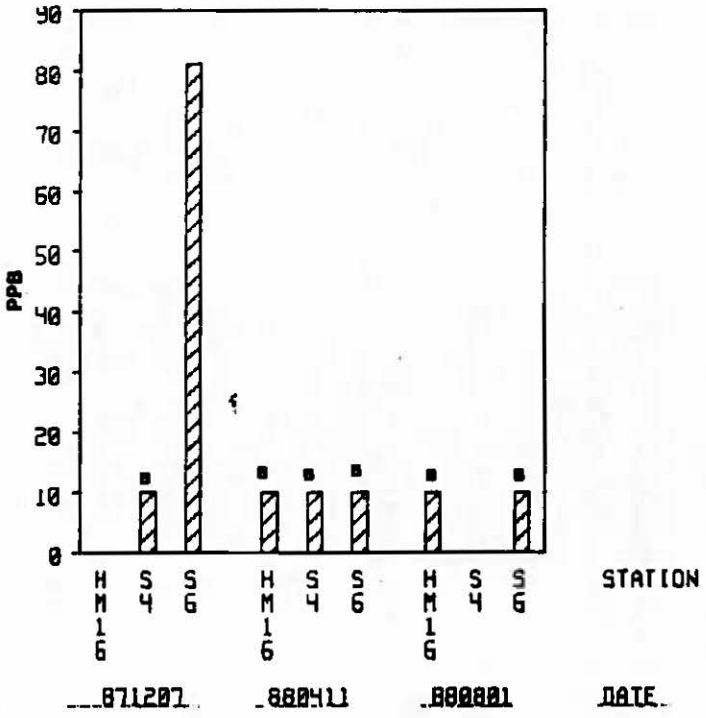

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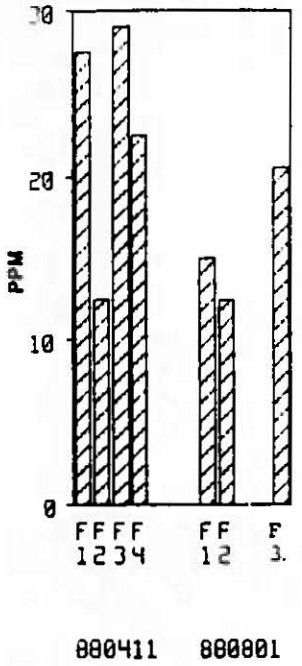

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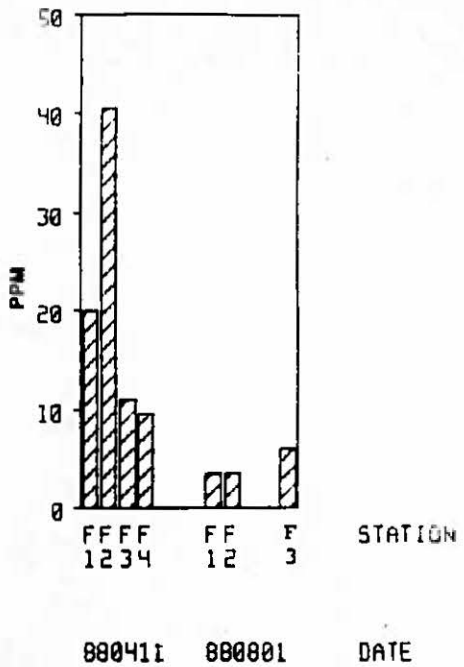

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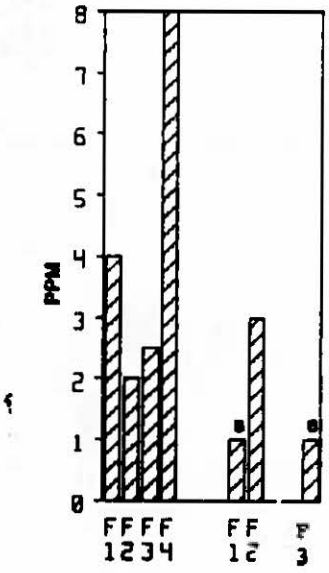

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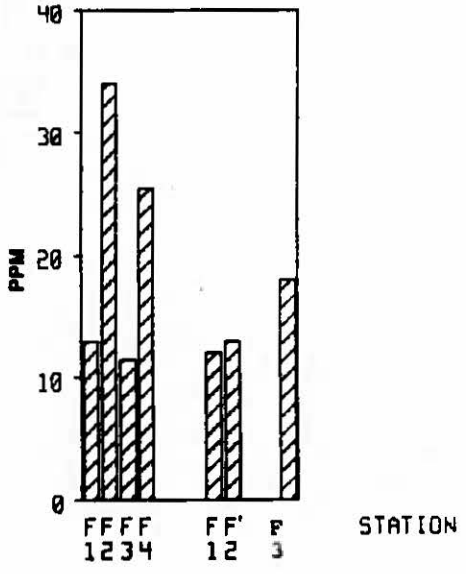

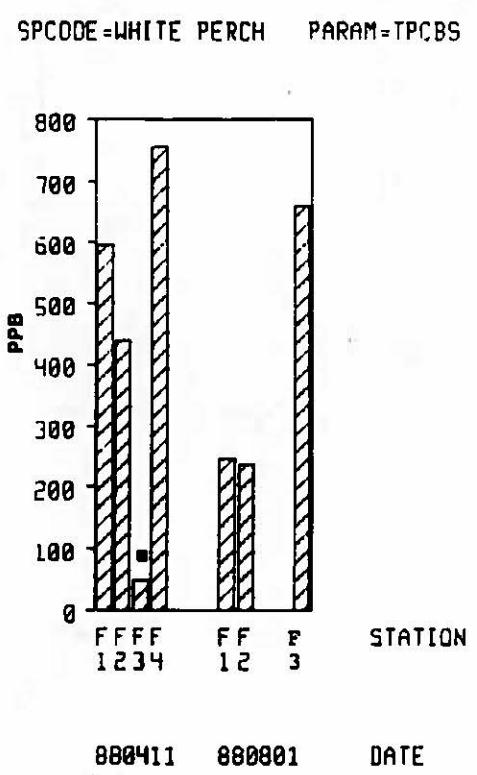
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1 2
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STATION
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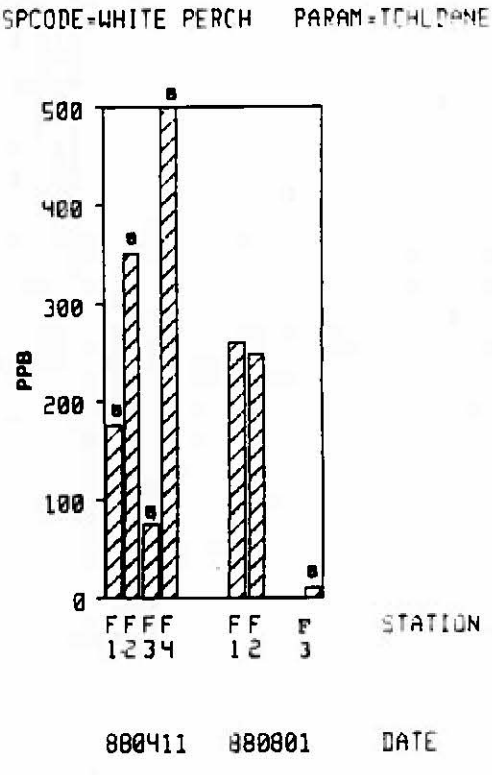
DATE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100
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F F F F
1 2 3 4
F F
1 2
F
3
STATION
880411 880801
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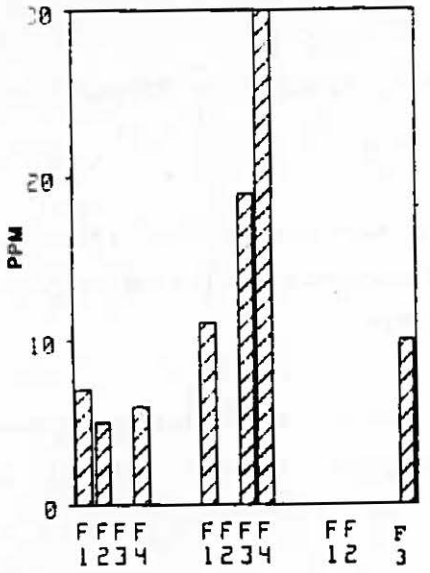

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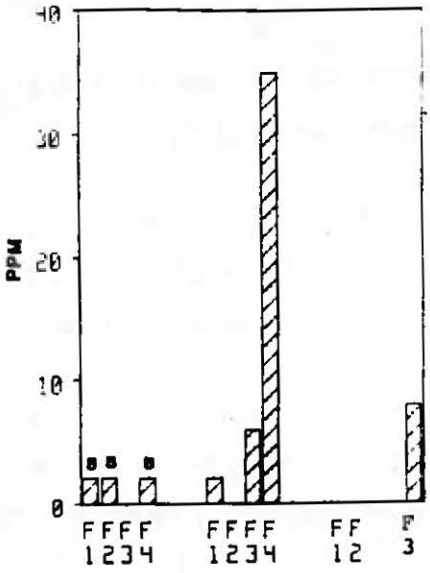

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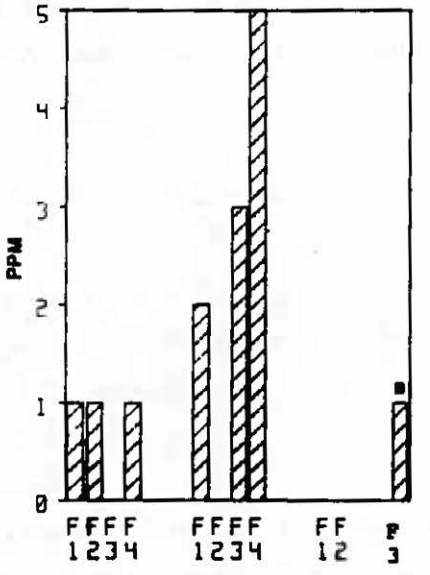

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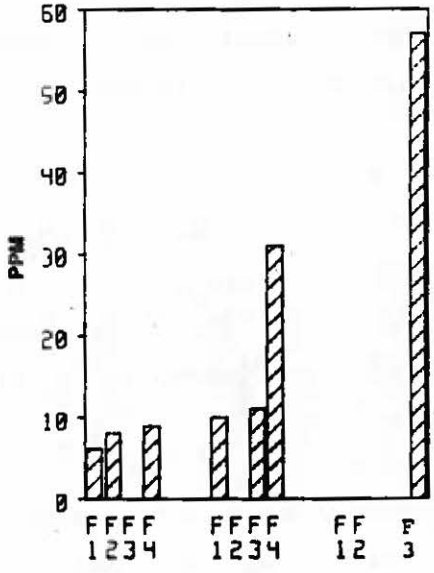

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