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

NINTH ANNUAL INTERPRETIVE REPORT
AUGUST 1989-AUGUST 1990

SUBMITTED TO
MARYLAND WATER RESOURCES ADMINISTRATION

PREPARED FOR
MARYLAND PORT ADMINISTRATION

BY
DEPARTMENT OF NATURAL RESOURCES
TIDEWATER ADMINISTRATION

MPA CONTRACT NO. 390004

FEBRUARY, 1992

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 (DNR) 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

EXECUTIVE SUMMARY

The Hart-Miller Island Containment (HMI) Facility was designed to receive material from channel dredging projects in Baltimore Harbor and its approaches. The projects have continued since the facility was operational in 1983. The facility itself is located northeast of Baltimore Harbor in the Chesapeake Bay. This report contains the results of the ninth year of monitoring (August 1989-August 1990) to assess the impacts on the biological and sedimentary environments. The exterior monitoring program is divided into four major projects: (1) Scientific Coordination & Data Management, (2) Sedimentary Environment (physical & chemical analyses, beach erosion study), (3) Benthic Study, (4) Analytic Services (analysis of organic & metals in biota). As in previous years, samples of sediments and the benthic population were taken at a number of sites in the vicinity of HMI during Fall 1989, Spring 1990 and Summer 1990. A second aspect of project monitoring, beach erosion study, initiated in the spring of 1984, was continued. Data collected from the previous eight years of exterior monitoring indicated that although facility construction and operation have effected the environment, none of these impacts have been significant. An enrichment of zinc in sediment was found near spillway one of the facility during the eighth year of monitoring. Stations were added during the ninth year of monitoring to determine if this zinc enrichment detected near spillway #1, during the eighth year, impacted the benthic species.

Scientific Coordination and Data Management

This HMI project maintains and updates the long term database. Ninth year data could not be added to the existing long term database due to staff limitations. 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. The tenth year contract will be used to update data from the tenth year monitoring contract only. The eleventh year contract will update the database with for both ninth year data and the most recent data collected (eleventh year).

Besides maintaining a database, this project also is responsible for coordinating additional studies as recommended by the Technical Review Committee. 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, these project are coordinated via the Scientific Coordination Committee (SCC). Dr. Jay Gooch (University of Maryland) has recently joined the HMI program and will bring to the Scientific Coordination Committee (SCC) a knowledge of biology with a strength in organic chemistry. This is necessary to interpret the laboratory analysis data of organics in biota and sediments, and metals in biota for the ninth monitoring year. Work and recommendations made by Dr. Gooch should help tie together these elements of the monitoring program.

Sedimentary Environment

Sedimentary Environment

The study scope of facility monitoring was expanded during the ninth year in response to the eight year detection of an area of zinc (Zn) enrichment near spillway #1. Additional sampling during an unscheduled cruise in January, 1990 revealed the eastward extent of this enrichment. The plume-like shape of the area further corroborated that Zn levels were increasing in response to the rate of release of effluent from the facility. Although Zn levels declined between April, 1989 and January, 1990, they rose again in the spring of 1990. Maximum Zn levels were as high in April 1990 as they had been a year earlier.

In addition to the analyses normally performed as part of this study, the concentrations of six additional metals on EPA's list of priority pollutants - arsenic (As), beryllium (Be), cadmium (Cd), lead (Pb), selenium (Se), and silver (Ag) - were measured in sediments. Archival sediment samples, collected over a period of six years (1985-1990), were delivered to an independent laboratory for analysis. After testing, the laboratory's results were deemed unreliable using a Quality Assurance/Quality Control (QA/QC) procedure. Results for As, Be, and Pb were analytically unacceptable based upon this QA/QC and could not be used. Those for Ag and Se were below detection limits and therefor QA/QC could not be determined.

Quantitative results for cadmium (Cd) indicate that, since spillway #1 discharge began, levels of that metal have also increased in bottom sediments around the facility. Cd trends follow those for Zn. Starting in April 1987, however, Cd levels began to increase around spillway #1. This increase, in both areal extent and intensity, continued through April 1990. The stations highest in Cd were the same as those highest in Zn. As Zn levels rose so did the levels of other toxic elements. This substantiates the use of Zn as an indicator element and points to the need for further analysis to quantify toxics loadings to the area.

Data related to grain size data from all of the post-construction cruises were re-analyzed in terms of % sand and clay:mud ratios. Pre- and post-discharge cruises differed on both variables. Northeast of the facility, the distribution of the sand fraction reversed when the facility started discharging. Since November of 1988, the sand content of sediments has systematically decreased with distance from the facility. Finer grain sands were now found further offshore from the facility. Clay:mud ratios show the development of a seasonal trend in the distribution of the fine fraction. The clay component of mud varies over a smaller range in the fall than in the spring. Both of these effects may be related to the release of effluent from spillways #1 and #2. Flow from the facility probably scours or dispenses fines from the area immediately adjacent to the dike side of the facility. This alters the hydrodynamic conditions that control the sedimentation of fine particles in the vicinity of the facility.

With the exception of one station in Hawk Cove, sediment composition during the ninth year of exterior monitoring was consistent with eighth year findings. The comparatively coarser grain size composition (higher sand content and lower clay:mud ratio) at station 16 may be related to the release of effluent from spillway #2. This seems likely, given the higher than normal Zn levels at that location.

Beach erosion study

A second part of this study investigates erosion of the recreation beach established as part of the HMI facility. Despite stabilization of the recreational beach in August 1988, erosion continued along the lower dike face and foreshore. Net losses totaled 3081 yd^3 (2356 m^3) during the study period (May 1989 - May 1990). These losses were nearly as severe as they had been just prior to reconstruction of the beach. Erosion, due primarily by wave attack, occurred along the entire stretch of beach north of station 24+00. The problem was aggravated by increasingly steeper beach slopes.

Benthic Study

Benthic invertebrate populations in the vicinity of the HMI Containment Facility were monitored for the ninth successive year. This monitoring is undertaken in order to assess any possible effects on these bottom-dwelling organisms from operation of the facility. Organisms living within the sediments (infaunal) or upon the concrete and wooden pilings (epifaunal) around the facility were collected. Along with these samples, organisms living at some distance from the containment facility (referred to as reference stations) in December 1989 and April and August 1990 were also collected.

A total of 26 benthic infaunal species were collected from these seventeen stations. The most abundant species were the worms, *Scolecolepides viridi*, *Tubificoides gabriellae*, and *Streblospio benedicti*; the crustaceans, *Leptocheirus plumulosus*, *Cyathura polita*, and *Corophium lacustrae*; and the clam *Rangia cuneata*.

Species diversity values were evaluated at each of the infaunal stations at the three sampling periods. The highest diversity value was determined for one of the zinc enriched stations, G25, in August 1990. The lowest diversity value occurred at another zinc enriched station, this time at station G84 in April 1990. This monitoring year was similar to last years monitoring. Highest diversity values occurred in December and the lowest overall diversity values (seven stations under 1.0) occurring in April 1990.

The length-frequency distributions of the benthic clams are used as one indicator of the potential impacts to an area. The length-frequency distributions of the benthic clams, *Rangia cuneata*, *Macoma balthica*, and *Macoma mitchelli* were examined at the nearfield, reference, and zinc enrichment stations. There was a significant relationship in terms of numbers of clams present and the relative size groupings for the three sampling dates. *Rangia cuneata* continues to be the most abundant species for all three groups of stations, followed by *Macoma balthica*. *Macoma mitchelli* remains for the most part the least abundant clam species.

Cluster analysis tests correlate sampling stations with bottom habitats. This project used three sampling periods. Variations in recruitment at the different stations explain why some specific stations did not form tight groupings. The clusters were again consistent with studies from previous years and did not indicate any unusual groupings resulting directly from the containment facility. Rank analysis of differences in the mean abundances of ten selected species at stations with silt/clay substrates indicated significant differences only for the reference stations in December and August. No significant differences in means for the combined silt/clay nearfield and reference stations or for the combined silt/clay zinc-enriched and reference stations occurred for any of the sampling periods.

Epifaunal populations were similar to those observed in previous years. Samples were collected at two depths. The lower depth is well below the winter ice scour zone. Epifaunal populations persisted throughout the year at all of the locations on the pilings. The epifaunal populations at both the nearfield and reference stations were very similar over all three sampling periods. As previously reported, the amphipod, *Corophium lacustre*, was one of the most abundant organisms present at both the reference and nearfield stations at all sampling periods. This year the hydroid, *Cordylophora caspia*, replaced the colonial bryozoan, *Victorella pavida,* as the second most frequently observed species on the pilings. *Cordylophora* was likewise present at both reference and nearfield stations all sampling periods.

The results of the current monitoring effort once again suggest that only localized and temporary effects on the benthic organisms result from the containment facility. These effects are limited mainly to the area where dredged materials are brought in by the barges to the facility and this could be caused by some scouring of the bottom by the activity of the barges and tug boats. Discharge of effluent from the facility has occurred over the past few sampling years and, to date, no adverse effects on the benthic populations have been observed. The four benthic infaunal stations added this year in the zinc enriched areas do not appear to differ in any distinct manner from the original nearfield and reference epifaunal stations.

<u>Analytic services (Contaminant studies)</u>

Since 1981, metals and organic chemicals have been analyzed in sediments and biota as part of the HMI exterior monitoring program. Yearly seasonal sampling has been conducted in the region of the facility to determine status and trends in contaminant concentrations. In the present monitoring year, samples of sediment and biota were collected to determine the concentrations of 43 individual trace organic contaminant compounds in benthos and sediment. Biological samples (benthos) were also analyzed for concentrations of six metals: chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), and zinc (Zn).

Concentrations of trace metals in benthic samples were highly variable and did not show any distinct differences based on station type (nearfield, reference and Zn-enriched). One sample of *Rangia* from nearfield station S6 had high concentrations of Fe and Mn. Cr, Cu and Zn concentrations were higher in *Macoma* than in *Rangia*, with the Cr concentrations generally higher than other bivalve populations in the Chesapeake and the Coastal U.S.. Cu and Zn concentrations were highest in *Cyathura*. Concentrations of Cu in *Rangia* and *Macoma* were similar to levels found previously in soft shell clams from around the Chesapeake and were also similar to the highest levels found in a nationwide survey of the blue mussel, *Mytilus edulis*. Ni concentrations were highest in *Rangia* and were two to ten times higher than the nationwide survey of blue mussels. There were no distinct differences in Zn concentrations in samples from the Zn enriched stations in comparison to other stations. Trace metal concentrations in white perch and yellow perch samples were not unusually high, though the frequency of detection was somewhat higher than in the study's eighth year. Concentrations of trace metals in fish were similar among transects.

As in past years, the frequency of detection of organic contaminants was quite low. A strong caution should be noted, because the detection limits for many of the analytes in these samples were extraordinarily high. In several cases the detection limits were well above FDA action levels and Practical Quantitation Limits (PQLs) given in EPA procedures. It appears as though these high detection limits are partially the result of inadequate sample sizes. In addition, organismal size data are not standardized or provided and it is difficult to determine the influence this may have had on the detection of contaminants.

In general, there were no obvious trends in differences in contaminant concentrations among stations or from year eight to year nine. The small sample sizes, however, do not facilitate rigorous statistical analyses of these data.

RECOMMENDATIONS

The Hart Miller Island (HMI) exterior monitoring program should be continued. The HMI SCC should continue so it can provide the expertise and coordination necessary for appropriate monitoring of this facility. It is imperative that good lines of communication be maintained between the monitoring researchers and the managers of HMI. It is further recommended that the SCC continue to meet with the Technical Advisory Committee. Maintenance and updating the long-term database are necessary.

1. It has been recommended that an additional study be added under Project III-Benthic Studies to conduct a sediment bioassay on Zn-enriched sediments.

2. Consider including bioassay work in the scope of exterior monitoring.

3. Consider quantifying toxics loadings to the area around the facility.

4. Adding approximately 30,500 yd^3 (23,320 m^3) of clean, medium-sized sand to the beach is recommended to reduce the average slope of the beach to 3.8° and provide an adequate recreational area to the public.

5. Continued monitoring of the benthic populations in the area.

6. Standardize sampling protocols so that there is better concordance between the sediment sampling effort and the benthos monitoring effort.

7. Addition of a sediment toxicity component would complete the sediment quality triad concept.

8. Re-evaluate the sampling locations.

9. Drop the analysis of Fe and Mn in tissues.

10. Decrease the number of target organic analytes.

11. Standardize sampling of biota with respect to size and/or age of the organisms in an attempt to reduce variability and facilitate the detection of interstation differences in contaminant burdens. Normalization of organic contaminant burdens to lipid weight would also be desirable.

12. Investigate the problem of high detection limits with the contractor in order to insure that the HMI sampling protocol is providing samples of sufficient size for the contractor to meet lower detection limits.

13. Separate samples of *Rangia* and *Macoma* should be collected, with one set being allowed to purge gut contents before analysis and one set analyzed as collected.

TABLE OF CONTENTS

LIST OF TABLES

SEDIMENTARY ENVIRONMENT

ANALYTICAL SERVICES

LIST OF FIGURES

SEDIMENTARY ENVIRONMENT

PART 1: SEDIMENTARY ENVIRONMENT

PART 2: BEACH EROSION STUDY

BENTHIC STUDIES

ANALYTICAL SERVICES

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.

Enrichment factor - A method of normalizing geochemical data to a reference material, which partially corrects for variation due to grain size.

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

Flocculate - A cluster 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.

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 outflow 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 (HMI) Containment Facility was established in 1983 to receive dredged material from the inner harbor and its approach channels. The HMI monitoring program was established to determine the effects of construction and operation of the facility on the surrounding environment. The program has involved both pre-construction and operational monitoring conditions. The *Ninth Annual Interpretive Report* presents the results of monitoring from August 1989 through August 1990.

DESCRIPTION OF THE CONTAINMENT FACILITY

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 originally designed to receive 52 million cubic yards (mcy) of material, most of which are bottom sediments produced by deepening the Baltimore Harbor and its approach channels to 50 feet (ft). Once the facility is filled, it will be converted to a permanent wildlife and recreational area.

The facility is currently 28 ft (18 ft + a 10 ft 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 would 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 on the exposed outside face, 5:1 on the inside and 20:1 along the recreational beach on the western side. The completed perimeter of the facility is approximately 29,000 ft 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 ft long.

DREDGED MATERIAL OPERATIONS

The breakdown of dredged material placed in this facility is found in Table 1. The 3.9 mcy material dredged in 1983 and 1984 and placed in the facility was composed of mostly 42 ft channel maintenance and facility maintenance (188,000 yd^3). Material from one additional project was also deposited in the facility in 1984, that from Dundalk Marine Terminal (500,000 yd^3).

Material dredged in 1985 totaled of 3.7 mcy and was deposited into the North Cell. Of the 7.9 mcy of dredged material deposited in 1986, 3.7 mcy was placed into the North Cell and 3.8 mcy into the South Cell. The material 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 ft. The other projects for that year were primarily to remove dredged material allowing shipping companies to have easier access to the 42 ft deep channel. The addition of the dredged material from these projects produced sufficient quantity of supernatant to require a discharge from spillway #1 during the seventh monitoring year, beginning on October 25, 1986. Monitoring of the discharge is required to fulfill the State Discharge Permit #86-DP-2294.

The 1987 dredging operations included projects from the Inner Harbor area including the following: Seagirt Marine terminal, Amstar, and the Bethlehem Steel Shipyard. The operations also included 125,000 yd^3 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 ft channel project. Since the beginning of the project to deepen the channel to 50 ft, shipping companies have been dredging their access channels deeper to make better use of the 50 ft channel depth. The 50 ft contract #1 represents the first of two contracts to increase the Maryland shipping channel to a depth of 50 ft. The first contract of the 50 ft channel project totaled 9.9 mcy and 54,000 yd^3 of material that was used to relocate utilities related to the 50 ft channel.

The 1988 dredging operations included dredging projects from the inner harbor area including Baltimore Gas & Electric Company, Canton waterfront, CSX coal pier, and Toyota. The operations included dredgings from the maintenance of the 42 ft channel in addition to 6.2 mcy of material from the 50 ft channel project.

The 1989 operations included dredgings from CSX, Consolidated Coal, and Seagirt marine terminal dredging. These operations also included 6.3 mcy of dredged material from the 50 ft channel project contract No. 2.

The 1990 dredging operations included dredging projects from the inner harbor including Seagirt Marine terminal, Curtis Bay Coal and Allied Signal in addition to 6,500 yd^3 from Baltimore County dredging projects. The Allied Signal project was considered to be rich in Cr content. This year's dredging activities also included 9.5 mcy from the 50 ft channel project, contract no. 2.

TABLE 1

Dredging OPERATIONS

YEAR DISPOSED	PROJECT NAME	CUT QUANTITY (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 ft Channel Maintenance and Brewerton Eastern Extension	3,908,000
	TOTAL 1984	4,596,000
1985	42 ft Channel Maintenance	3,145,000
1985	Bethlehem Steel	596,000
	TOTAL 1985	3,741,000
1986	42 ft 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	166,632
	TOTAL 1986	7,882,082
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

TABLE 1 (cont.)

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 Brewerton, Swann Point	125,000
	Total 1988	8,342,724
1989	50 ft Channel Contract No. 2	6,300,000
1989	CSX	25,000
1989	Consolidation Coal Sales	235,000
1989	MPA Seagirt	43,000
	Total 1989	6,603,000
1990	50 ft Channel Contract No. 2	9,500,000
1990	MPA Seagirt	40,000
1990	Curtis Bay Coal	63,650
1990	Allied Signal	140,000
1990	Baltimore County	6,500
	Total 1990*	9,750,150
	Grand Total* (cubic yards)	54,045,350

* through December 31, 1990

SUMMARY OF MONITORING PROGRAMS

The State permits require the facility, that there was a need for "a comprehensive environmental monitoring program for the Hart-Miller Island (HMI) Containment Facility prior, during and following commencement of operations." The responsibility for the monitoring was assigned to the Water Resources Administration (WRA). The monitoring program is divided into two complementary portions: (a) monitoring to ensure compliance with federal and state laws; and (b) monitoring for possible environmental impacts. The operational permits requiring monitoring were issued by the Maryland Department of the Environment (MDE) and the WRA of the Department of Natural Resources (DNR). MPA is the coordinating for HMI. The Maryland Environmental Service (MES) is responsible for monitoring water quality within the diked area.

This report describes continuing studies designed to assess any impacts to the environment, specifically biota and sediments exterior to the facility. This assessment is performed under a separate agreement between the DNR and the MPA. Liaison and coordination between all agencies having roles in site management, operations, monitoring, sampling and oversight programs related to the HMI Facility, is maintained 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 and are coordinated through periodic meetings with the Scientific Coordination Committee (SCC).

PROJECT I: SCIENTIFIC COORDINATION AND DATA MANAGEMENT

The Tidewater Administration (TWA) is responsible for maintaining a database on the exterior monitoring program. Data stored include fish, benthos, water quality, climate, sediments and hydrography. The agency 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 seven years of the HMI environmental assessment program, data collected by the DNR and research institutions were stored in the TWA'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 data is currently stored on the Annapolis Data center IBM computer and the EPA VAX computer in Annapolis.

The TWA provides overall scientific planning, review and coordination of the exterior monitoring activities for the HMI Facility, as well as compiling and distributing the annual Interpretive and Data Reports. This also includes the analysis 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 (MGS) has been involved in monitoring the physical and chemical attributes of the sediments around the HMI Containment Facility since 1981. This monitoring 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 facility. Improper handling or leakage of these dredged materials from the facility 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, no major changes had been detected within the sedimentary environment as a result of construction or operation of the facility. During the eighth monitoring year a Zn enrichment was detected near spillway number one. In response to this detection additional monitoring stations were added to the program.However, monitoring did reveal a fluid mud layer that was deposited during facility 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 which include organic contaminants, trace metals, textural and radiographic analyses.

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 appears 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 has been planted to prevent erosion from aeolian processes.

PROJECT III: BIOTA

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 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 whether 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 change. Changes, for examples, include salinity, wind-related wave action, high summer water temperatures and ice formation in winter. As a result, the benthic populations undergo large seasonal and annual variations in abundance. Also, it is important to protect estuarine areas with wide seasonal salinity changes and vast shallow soft-bottom shoals, such as the HMI site. These sites 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, 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. These effects, 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 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.

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 and then returned to the MES staff at HMI for transfer to Martel. Martel then performed the chemical analyses.

This process reduced the time required for data analysis to as little as three months. Project III - Benthic Studies currently collects 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. Beginning with this monitoring year the laboratory data analyzed by Martel Laboratories was interpreted by University of Maryland's, Chesapeake Biological Laboratory.

PROJECT I

SCIENTIFIC COORDINATION AND DATA MANAGEMENT
NINTH YEAR INTERPRETIVE REPORT

BY
Fred Schenerman
DEPARTMENT OF NATURAL RESOURCES
TIDEWATER ADMINISTRATION
580 TAYLOR AVENUE
TAWES STATE OFFICE BLDG., B-3
ANNAPOLIS, MD 21401

February 1992

Development and implementation of an exterior monitoring program sufficiently sensitive to the environmental effects of dredged material containment at Hart-Miller Island (HMI) continues to be a complex and difficult undertaking. Environmental monitoring activities have been evolving in the nine years of the project's life. The ongoing and primary activities have included physical and chemical characterization of sediments and population studies of benthos and finfish.

Not all activities related to project monitoring have continued. Baseline data on water column nutrients and productivity, submerged aquatic vegetation, trace metals and organic contaminants were included only in the first and second year monitoring activities. Bathymetric studies were completed in the first three contract monitoring years to identify pre- and post-construction changes in currents and erosion. Fish population studies were conducted in the first five monitoring years of the project but were discontinued thereafter. An additional investigator was added to the monitoring program during the ninth year to interpret the of the benthos and sediment that was analyzed by Martel Laboratories.

Scientific planning, review and coordination of these monitoring activities is provided by Tidewater Administration (TWA). Sampling and data analysis are done contractually by outside contractual investigators (Maryland Geological Survey, University of Maryland, and a contractual laboratory). Administrative technical needs related to monitoring activities are discussed with principal investigators at quarterly meetings of the Scientific Coordination Committee (SCC). The compilation, editing, technical review, and printing of the overall report are the responsibilities of TWA. Storage of the data providing the foundation for these reports is also TWA's responsibility.

During the first eight years of the environmental monitoring program, data collected by the Department of Natural Resources (DNR) and contractual research institutions were stored in the TWA's "Resource Monitoring Data Storage System. (RMDSS)" An IBM-OS File/SAS Data Base is used for computer storage and analysis of data. Data are also stored on a VAX 8600 computer in a SAS file format.

Ninth year data could not be added to the existing long term database due to staff limitations. The ninth year data will be added under the eleventh year contract. 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.

In completion of the program objectives, two separate reports are produced annually, a data report and an interpretive report.

Data from the 1989-1990 monitoring year are included in the *Ninth Year Data Report*. Historic data are standardized using RMDSS formats. Codes are documented in the manual for the RMDSS produced by the TWA, Chesapeake Bay Research and Monitoring Division.

Two committees coordinate management, operation and monitoring of the facility. The SCC meets quarterly with the principal investigators, Water Resources Administration (WRA), and Maryland Port Administration (MPA) to discuss issues related to the exterior monitoring program. These members are also present at the quarterly Technical Review Committee (TRC) meetings to provide detailed and recommendations information about the exterior monitoring program. The TRC suggests modifications to be made to the monitoring and operational programs related to the facility and there approval is required before changes can be made to the monitoring program. The TWA also briefs the Hart-Miller Citizens oversight committee.

The addition of Dr. Jay Gooch from the University of Maryland to the SCC will provide the knowledge of a biologist with an organic chemistry background to interpret the laboratory analysis data analyzed by Martel Laboratories for the ninth monitoring year. Work and recommendations made by this additional investigator should fill a void in the monitoring program.

Conclusion and Recommendations

The HMI exterior monitoring program should be continued. The HMI SCC should continue so it can provide the expertise and coordination necessary for appropriate monitoring of this facility. It is imperative that good lines of communication be maintained between the monitoring researchers and the managers of HMI. Both groups can benefit from shared information acquired through the research conducted. It is recommended that the SCC continue to meet with the Technical Advisory Committee. Use of contractual agreements are necessary to maintain and update the long-term database. This data can be used to determine long term trends.

It has been recommended that an additional study be added under Project III-Benthic Studies to conduct a sediment bioassay on sediments surrounding the facility. The study was recommended for introduction as soon as the procedure became accepted by the scientific community as reliable. Investigators therefor waited until the eleventh year contract before instituting this sediment bioassay which will be done by the Maryland Department of the Environment (MDE).

Acknowledgements

The completion of this report could not have been possible without the assistance of the many scientists and project administrators involved. I would especially like to thank the following: Dave Bibo and Tony Serio (MPA) and George Herlth (WRA) for their patience and assistance in coordinating the monitoring contract, Dr. Linda Duguay for providing assistance in obtaining the services of Dr. Jay Gooch, Lamere Hennessee and Jim Hill (MGS) and Cecelia Donovan (Maryland Environmental Service) for coordinating the laboratory analyses of the additional sediment samples and Larry Lubbers for providing administrative assistance with some complicated communications. I would especially like to thank Dr. James Ahl for providing technical assistance and editing of this report.

The Continuing State Assessment of the Environmental Impacts of Construction and Operation of the Hart-Miller Island Containment Facility

Project II

SEDIMENTARY ENVIRONMENT
NINTH YEAR INTERPRETIVE REPORT
(November 1989 - October 1990)

Part 1: Sedimentary Environment
Lamere Hennessee and Jim Hill

Part 2: Beach Erosion Study
Robert Cuthbertson

Coastal and Estuarine Geology Program
Maryland Geological Survey
2300 St. Paul St.
Baltimore, MD 21218

File Report No. 64

submitted to

Tidewater Administration
Maryland Department of Natural Resources
Tawes State Office Building
Annapolis, MD 21041

October 1991

ABSTRACT

SEDIMENTARY ENVIRONMENT

The scope of monitoring was expanded during the ninth year in response to eighth detection of an area of Zn enrichment near spillway #1. Additional sampling during an unscheduled cruise in January 1990 revealed the eastward extent of the enriched area. The plume-like shape of the area further corroborated the suspicion that Zn levels were increasing in response to the rate of release of effluent from the dike. Although Zn levels declined between April 1989 and January 1990, they rose again in the spring of 1990. Maximum Zn levels were as high in April 1990 as they had been a year earlier.

In addition to the analyses normally performed as part of this study, the concentrations of six additional metals on EPA's list of priority pollutants - arsenic (As), beryllium (Be), cadmium (Cd), lead (Pb), selenium (Se), and silver (Ag) - were measured. Archival sediment samples, collected over a period of six years (1985-1990), were delivered to an independent laboratory for analysis. After testing, the laboratory's performance was deemed unreliable. Results for As, Be, and Pb were analytically unacceptable. Those for Ag and Se were below detection limits.

Semi-quantitative results for cadmium (Cd) indicate that, since discharge began, levels of that metal have also increased in bottom sediments around the facility. Cd trends follow those for Zn. Initially, the primary source of Cd appears to have been Back River. Starting in April 1987, however, Cd levels began to increase around spillway #1. This increase, in both areal extent and intensity, continued through April 1990. The stations highest in Cd were the same as those highest in Zn. This substantiates the use of Zn as an indicator element and points to the need for further analysis to quantify toxics loadings to the area. Zn was used as an indicator of other potential toxics within the sediment.

Grain size data from all of the post-construction cruises were re-analyzed in terms of % sand and clay:mud ratios. Pre- and post-discharge cruises differed on both variables. Northeast of the dike, the pre-release distribution of the sand fraction - coarsening offshore - reversed with the onset of discharging. Since November 1988, sand content has systematically decreased with distance from the dike (fining offshore). Clay:mud ratios show the development of a seasonal trend in the distribution of the fine fraction. The clay component of mud varies over a smaller range in the fall than in the spring. Both of these effects may be related to the release of effluent from spillways #1 and #2. Flow from the dike probably scours or winnows fines from the area immediately adjacent to the dike and alters the hydrodynamic conditions that control the sedimentation of fine particles in the vicinity of the facility.

With the exception of one station in Hawk Cove, sediment composition during the ninth year of exterior monitoring was consistent with eighth year findings. The comparatively coarser grain size composition (higher sand content; lower clay:mud ratio) at station 16 may be related to the release of effluent from spillway #2. This seems likely, given the higher than normal Zn levels at that location.

BEACH EROSION STUDY

Despite stabilization of the recreational beach in August 1988, erosion continued along the lower dike face and foreshore. Net losses, totalling 3081 yd^3 (2356 m^3), were nearly as severe during the study year (May 1989 - May 1990) as they had been just prior to reconstruction of the beach. Erosion - primarily by wave attack - occurred along the entire stretch of beach north of station 24+00.

PART 1: SEDIMENTARY ENVIRONMENT

INTRODUCTION

Since 1981, the Maryland Geological Survey (MGS) has monitored the sedimentary environment in the vicinity of Hart-Miller Island, a man-made enclosure in northern Chesapeake Bay named for the two natural islands incorporated into its perimeter (Fig. 1-1). The oblong dike, constructed of sediment dredged from its interior, was designed specifically as a containment facility for material dredged from Baltimore Harbor and its approach channels. The older, "pristine" sediment used in dike construction differed from modern sediments accumulating around the island. So did the material dredged from the Harbor's shipping channels, much of which was fine-grained and enriched in trace metals and organic constituents. Those textural and geochemical differences led to the detection of changes attributable to construction and operation of the dike.

PREVIOUS WORK

Events in the history of the containment facility can be meaningfully grouped into the following periods:

1. preconstruction (Summer '81 and earlier)
2. construction (Fall '81 - Winter '83)
3. post-construction
    a. pre-discharge (Spring '84 - Fall '86)
    b. post-discharge (Fall '86 - present).

(A time line showing major events in the life of the dike and the dates of Project II cruises can be found in Appendix A.)

The nature of the sedimentary environment prior to diking of the facility, have been well-documented in previous reports (Kerhin *et al.*, 1982a, 1982b; Wells and Kerhin, 1983; Wells *et al.*, 1984; Wells and Kerhin, 1985). This work established a baseline against which possible changes due to operation of the dike could be compared. The most notable effect of dike construction on the surrounding sedimentary environment was the deposition of a thick, light gray to pink layer of "fluid mud" immediately southeast of the facility. Although the upper sections of this layer have been bioturbated (reworked by bottom-dwelling organisms) and eroded in places, it is still evident in a few cores.

For a number of years after the dike began operating, no major effects were observed on the surrounding sedimentary environment. Then, in April 1989, more than two years after the first release of effluent from the dike, anomalously high Zn values were detected in samples collected near spillway #1 (Hennessee *et al.*, 1990b). Zn levels rose from the regional average enrichment factor of 3.2 to levels approaching 5.5. Effluent discharged during normal operation of the dike was deemed the probable source of the Zn accumulating in the sediments. A flow net developed from preliminary results of a 3-D hydrodynamic model (Johnson *et al.*,

1989) showed that the enriched area should only be affected by low flows from spillway #1 (<5 million gallons/day). Daily discharge records kept by the Maryland Environmental Service (MES) indicated that prior to Fall 1989, comparatively high flow conditions prevailed at spillway #1. After that, much lower volumes of effluent were released. This period of low flow immediately preceded the detection of higher Zn levels in samples collected south of the spillway.

OBJECTIVES

As in the past, the main objectives of the ninth year study were (1) to measure specific physical and geochemical properties of near-surface sediments around Hart-Miller Island and, based on that information, (2) to assess environmental change.

Specifically, ninth year sedimentary monitoring focused on determining the extent and persistence of the area of Zn enrichment and the implications of elevated Zn levels. In addition to the regularly scheduled cruises in November 1989 and April 1990, 67 samples were collected during a third cruise in January 1990 to determine the extent of the enriched area.

Zn is, in itself, an element of environmental concern, but it is also an indicator element. Other metals behave the same way as Zn in the environment. Consequently, when anomalously high levels of Zn are found, levels of other elements may also be elevated. In August 1990, 191 archival sediment samples, collected in April of six consecutive years (1985-1990), were sent to Martel Laboratory Services, Inc. to be analyzed for six other trace metals on EPA's list of priority pollutants: arsenic (As), beryllium (Be), cadmium (Cd), lead (Pb), selenium (Se), and silver (Ag).

Findings from the three sampling periods, as well as the results of Martel's analyses, are presented in this report. The raw data are tabulated in the companion *Ninth Year Data Report*.

Grain size data are presented somewhat differently this year than they have been in the past - as % sand and clay:mud ratios rather than as Shepard's classes. Data from all post-construction cruises were re-examined to discover if differences in the physical environment could be detected before and after the release of effluent from the dike.

METHODOLOGY

FIELD METHODS

Surficial sediment (grab) samples were collected on three occasions during the ninth monitoring year - in November 1989 (Cruise 21), January 1990 (Cruise 22), and April 1990 (Cruise 23). Sample locations are shown in Figure 1-2. Thirty long-established

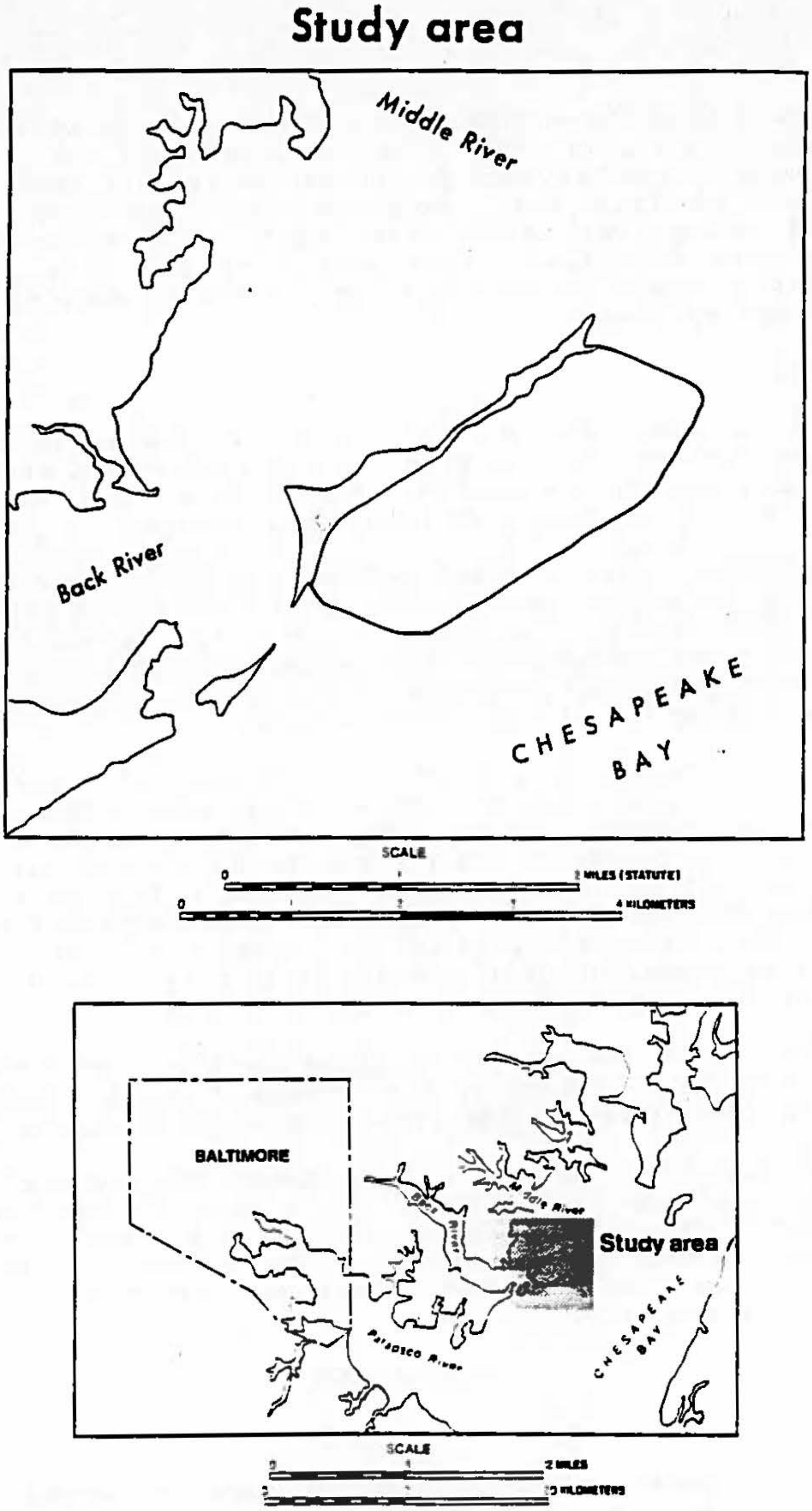


Figure 1-1: Location of the study area.

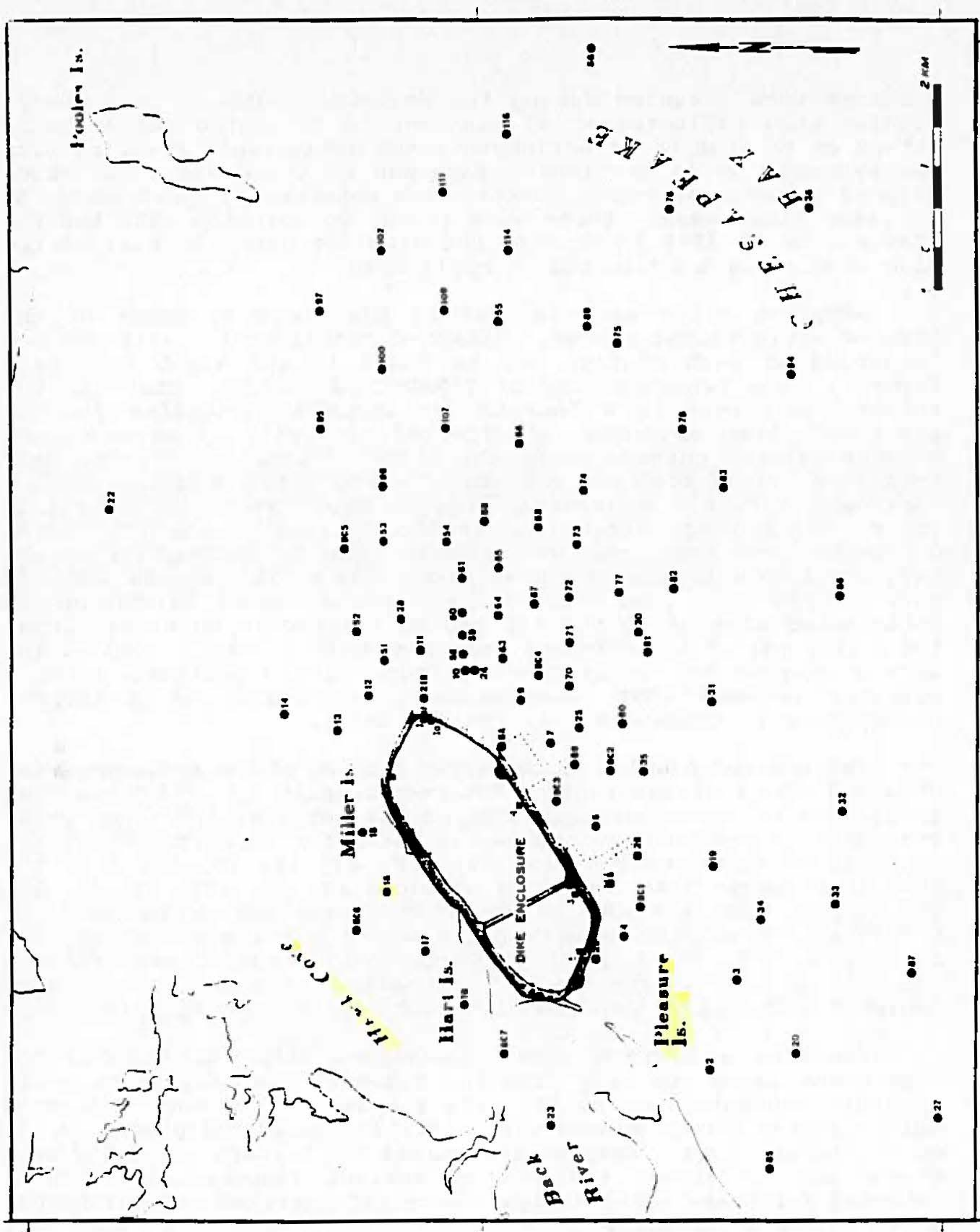


Figure 1-2: Locations of the surficial sediment and core stations sampled during the ninth year of exterior monitoring.

stations were occupied during the November cruise. In January, samples were collected at 67 stations to determine the eastward extent of an area of Zn enrichment; the established sampling plan was expanded by 46 stations. Eighteen of those stations, which defined the area of Zn enrichment, were retained in April 1990. At the same time, seven others were added, to coincide with benthic stations or to fill in gaps in the sampling net. In all, fifty-five samples were collected in April 1990.

Sampling sites 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 *Ninth 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). Therefore, 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). LORAN-C TDs were converted to "corrected" latitudes and longitudes using a computer program that incorporates the results of a LORAN-C calibration in Chesapeake Bay (Halka, 1987).

Undisturbed samples of the upper 8-10 cm of the sediments were obtained with a dip-galvanized Petersen sampler. At least one grab sample was collected at each station for textural and trace metal analyses. A second grab sample was taken for organic contaminant analysis at nine stations (3, 19, 21B, 23, 24, 25, 28, BC3, and BC6) in November 1989 and at 11 stations (3, 19, 21B, 23, 24, 28, 30, 34, 36, BC3, and BC6) in April 1990. Replicate (duplicate or triplicate) grab samples were collected at eight stations (3, 8A, 11, 12, 16, 22, 24, and 28) in November 1989 and at six stations (11, 12, 16, 24, 25 and 28) in April 1990. Upon collection, each sediment sample was described lithologically and subsampled.

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 organic 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) office at the containment facility, then transferred to Biospherics, Inc. (November 1989) or Martel Laboratory Services, Inc. (April 1990) for analysis.

In addition to the grab samples, a gravity core was collected at station 25 during the November cruise. In April 1990, cores were collected at the seven box core (BC) stations and at stations 5, 12, and 25 (Fig. 1-2). A Benthos gravity corer (Model #2171) fitted with clean cellulose acetate butyrate (CAB) liners, 6.7 cm in diameter, was used. Each core was cut and capped at the sediment-water interface and refrigerated until it could be x-rayed and processed in the lab.

LABORATORY PROCEDURES

Radiographic Technique

Prior to processing, the upper 50 cm of each core were x-rayed at MGS, using a TORR-MED x-ray unit (x-ray settings: 90 kv, 5 mas, 30 sec). A negative x-ray image of the core was obtained by xeroradiographic processing. On a negative xeroradiograph, denser objects or materials, such as shells or sand, produce lighter images. Objects of lesser density permit easier penetration of x-rays and, therefore, appear as darker features. The xeroradiographies are reproduced in Appendix B.

Each core was then extruded, photographed, and described. Visual and radiographic observations of the cores are presented in an appendix to the Ninth Year Data Report. On the basis of these observations, sediment samples for textural and trace metal analyses were taken at selected intervals from each core.

Textural Analysis

In the laboratory, subsamples from both the surficial grabs and gravity cores were analyzed for water content and grain size composition. Water content was calculated as the percentage of the water weight to the total weight of the wet sediment:

$$W_c = \frac{W_w}{W_t} \times 100 \qquad (1)$$

where W_c = water content (%)
W_w = weight of water (g)
W_t = 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 in 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 plus 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, and the percentages of sand, silt, and clay were determined.

In past years, the final step in this process was to categorize the sediments according to Shepard's (1954) classification (Fig. 1-3a). This year, however, a new ternary diagram, developed by Pejrup (1988) specifically for estuarine sediments, is being used (Fig. 1-3b). The principle is the same -a means of graphing a three-component system summing to 100%. However, the interior divisions of the two diagrams differ. In Pejrup's diagram, lines parallelling the side of the triangle opposite the sand apex indicate the percentage of sand. Each of the lines fanning out from the sand apex represents a constant clay:mud ratio (the proportion of clay in the mud, or fine, fraction). Class names consist of letter-Roman numeral combinations. Class D-II, for example, includes all samples with less than 10% sand and a clay:mud ratio between 0.50 and 0.80.

The primary advantage of Pejrup's classification system over Shepard's is that the clay:mud ratio can be used as a simple indicator of hydrodynamic conditions during sedimentation. (Here, hydrodynamic conditions refer to the combined effect of current velocity, wave turbulence, and water depth.) The higher the clay:mud ratio, the quieter the depositional environment. Although sand content cannot be similarly used as an indicator of depositional environment, it is well-suited to a rough textural classification of sediment.

Both classification schemes are useful in reducing a three-component system to a single term. However, the arbitrarily defined boundaries separating classes sometimes create artificial differences between similar samples. As has frequently been the case at Hart-Miller Island, samples collected over time from the same location have been assigned to different Shepard's categories, but not because of marked differences in sand-silt-clay composition. Rather, the samples have fallen close to, but on opposite sides of, a class boundary. In order to avoid that problem with Pejrup's diagram, the results of grain size analysis are discussed in terms of % sand and clay:mud ratios, not Pejrup's classes themselves. (Occasionally, references are made to "sand",

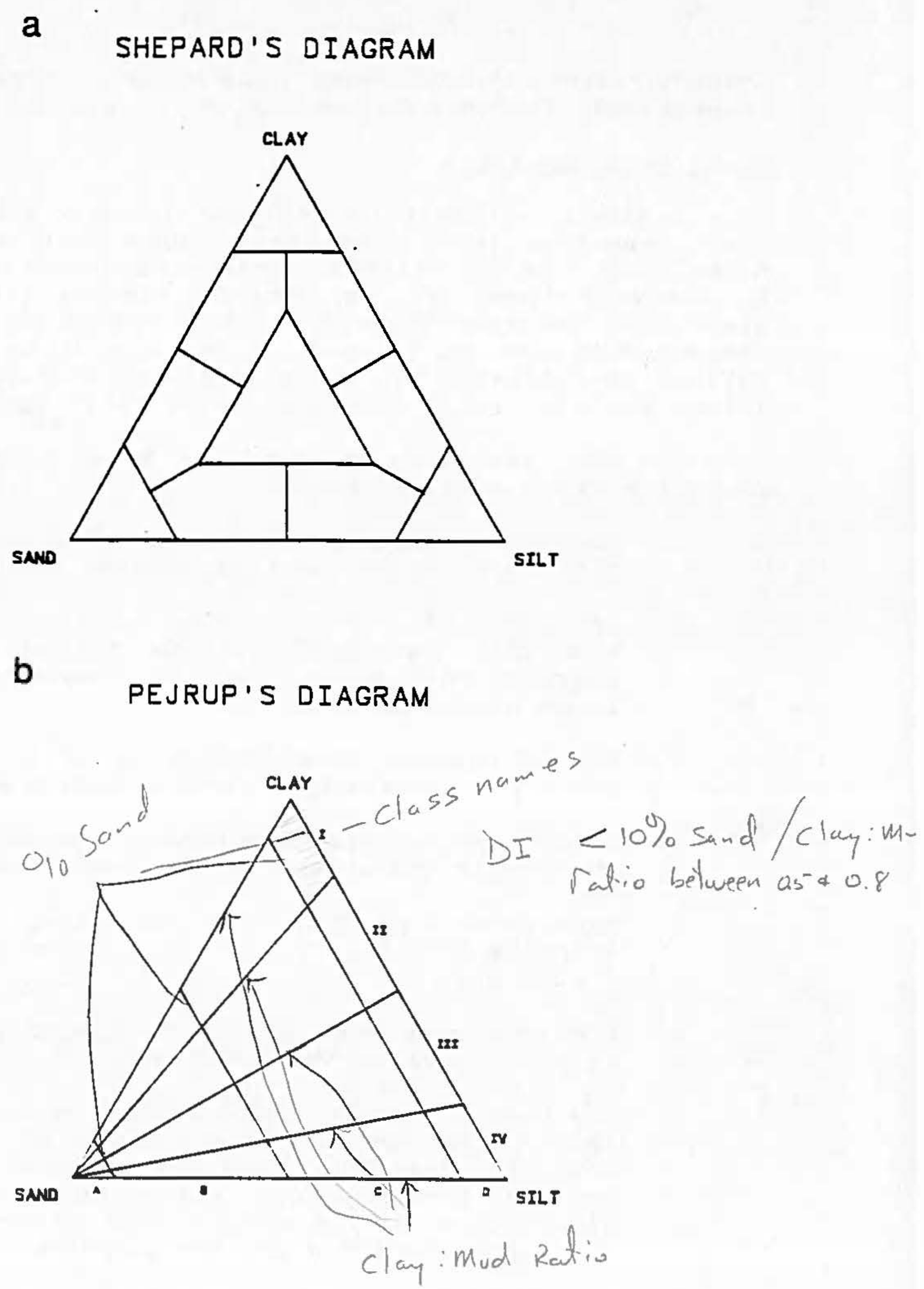


Figure 1-3: Shepard's (a) and Pejrup's (b) classifications of sediment type.

"muddy sand", "sandy mud", and "mud". These do correspond respectively to Pejrup's bands A, B, C, and D.)

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 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 overnight at 110°C 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 (0.25 ± 0.0002 g) into a drill-point graphite crucible (7.8 cc vol.) and mixed with $LiBO_2$ (0.75 ± 0.01 g).

6. The crucibles were placed in a highly regulated muffle furnace at 930 ± 5°C for 20 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.

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

All surfaces that came into 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 to eliminate interference due to aluminum (Al) and silicon (Si) (Butler, 1975). Blanks were run every 12 samples, and the National Institute of Standards and Technology (NIST) Standard Reference Material #1646 (Estuarine Sediment) was run five times every 24 samples.

Two minor modifications in the procedures were made beginning with the November 1989 samples: (1) the fusion temperature was lowered from 1050°C to 930°C and (2) the ratio of sample to flux was increased from 0.2:1.0 to 0.25:0.75. These changes were instituted to increase the detection level of the metals and to reduce the loss of Zn due to volatilization during the fusion process.

Results of the analysis of NIST-SRM #1646 are compared to NIST certified values in Table 1-1. There is excellent agreement between the NIST certified concentrations and MGS's analytical results for all of the elements.

Table 1-1: Results of MGS's analysis of NIST-SRM #1646 compared to the NIST certified values.

Date	Element*					
	Cr	Cu	Fe (%)	Mn	Ni	Zn
11/89	84±1	17±0.4	3.26±0.01	355±3	32±1	130±2
1/90	NA	NA	3.26±0.01	NA	NA	130±2
4/90	81±5	18±0.4	3.29±0.05	380±7	29±0.3	129±2
NIST-1646	76±3	18±3	3.35±0.1	375±20	32±3	138±6

* concentrations in μg/g dry weight unless otherwise noted

This year, in response to the detection of elevated Zn levels, Martel Laboratory Services, Inc. was contracted to analyze 191 archival sediment samples for six additional metals on EPA's list priority pollutants - arsenic (As), beryllium (Be), cadmium (Cd), lead (Pb), selenium (Se), and silver (Ag). The samples, collected in April of six consecutive years (1985-1990), were selected to provide baseline information, as well as information on suspect sediments. "Blind" quality control standards were included in the set.

Martel's performance was unsatisfactory. Turn-around time was poor. Samples were delivered to the lab in August 1990; final results were returned to MGS nearly one year later. The quality of the analytical results was disappointing. For the most part, the analyses were unreliable, due to poor precision and accuracy. This assessment was based on the quality assurance standards included in the sample set and on replicate analyses performed by Martel. An assessment of the quality of the analytical results for each metal follows:

- o <u>Arsenic (As)</u>
  Unacceptable - poor precision and accuracy.

- o <u>Beryllium (Be)</u>
  Unacceptable - poor precision (no SRM).

- o <u>Cadmium (Cd)</u>
  Acceptable.

- o <u>Lead (Pb)</u>
  Unacceptable - poor precision and accuracy.

- o <u>Selenium (Se)</u>
  Acceptable, but highly suspect. All data are below detection limits.

- o <u>Silver (Ag)</u>
  Without certified SRM values, the benefit of the doubt is given to Martel; the data are assumed to be acceptable. All data are below detection limits.

Of the six metals analyzed, only the results for Cd, Se, and Ag were acceptable. Both Se and Ag were below detection. Although Cd results were considered acceptable, they are nonetheless suspect because of Martel's poor track record in analyzing the other metals. Cd data can only be used at the semi-quantitative level; that is, the data may be used to indicate gross trends, but cannot be relied on for an accurate assessment of metal loading. Transforming the data, either by the use of enrichment factors or % excess Cd, is inappropriate.

RESULTS AND DISCUSSION

SEDIMENT DISTRIBUTION

<u>Surficial Sediments</u>

Since November 1983, sand-silt-clay percentages have been measured twice a year at 24 stations around Hart-Miller Island. The grain size composition of these sediments is depicted in ternary diagrams for five different sampling periods (Fig. 1-4). The first diagram (Fig. 1-4a) typifies the post-construction, **pre-discharge** sediment distribution around the facility. The next four diagrams - all **post-discharge** - summarize eighth year (Fig. 1-4 b&c) and ninth year (Fig. 1-4 d&e) findings. Related statistics are presented in Table 1-2.

The eighth and ninth year sediment distributions are very similar to one another. In each diagram, sediment type ranges from very sandy (>95% sand) to very muddy (<1% sand), averaging between 32-35% sand. Sample points are scattered about a line representing a constant clay:mud ratio of 0.51-0.53. Compared to the pre-discharge cruise, samples collected during the four most recent cruises tend to be slightly coarser. Sand content is higher (32-35% versus 26%), and the overall proportion of clay in the fine fraction is slightly lower (0.51-0.53 versus 0.54).

Table 1-2: Summary statistics for five cruises, based on 24 continuously monitored stations around Hart-Miller Island.

Cruise	Date	Clay:mud ratio		% Sand	
		Range	Average	Range	Average
9	11/83	0.39-0.63	0.54	0.33-97.34	26.40
19	11/88	0.36-0.61	0.51	0.25-99.32	33.29
20	4/89	0.31-0.64	0.53	0.37-95.29	32.12
21	11/89	0.33-0.65	0.52	0.56-98.06	35.41
23	4/90	0.35-0.61	0.53	0.69-97.15	31.95

To show the spatial distribution of sediment type, two sets of contour maps were drawn, depicting % sand (Appendix C) and clay:mud ratios (Appendix D). To maintain continuity with previous reports, all but one of the post-construction cruises are represented. The exception is January 1990. The intent of that cruise was to determine the eastward extent of the area of Zn enrichment. Samples were collected according to a dense grid east of the dike. Consequently, results cannot be easily compared with those from other cruises.

The November 1983 sampling period coincided approximately with the end of dike construction and the start of operations. Between November 1983 and April 1986, only a few of the activities at the facility directly affected Bay bottom sediments. These included the dredging of approach channels to the unloading facility; the arrival and departure of barges, with the attendant prop wash from tugs; and, possibly, spillage during barge unloading. The facility itself contributed only minor amounts of sediment to the surrounding Bay bottom - the dike walls, including the recreational

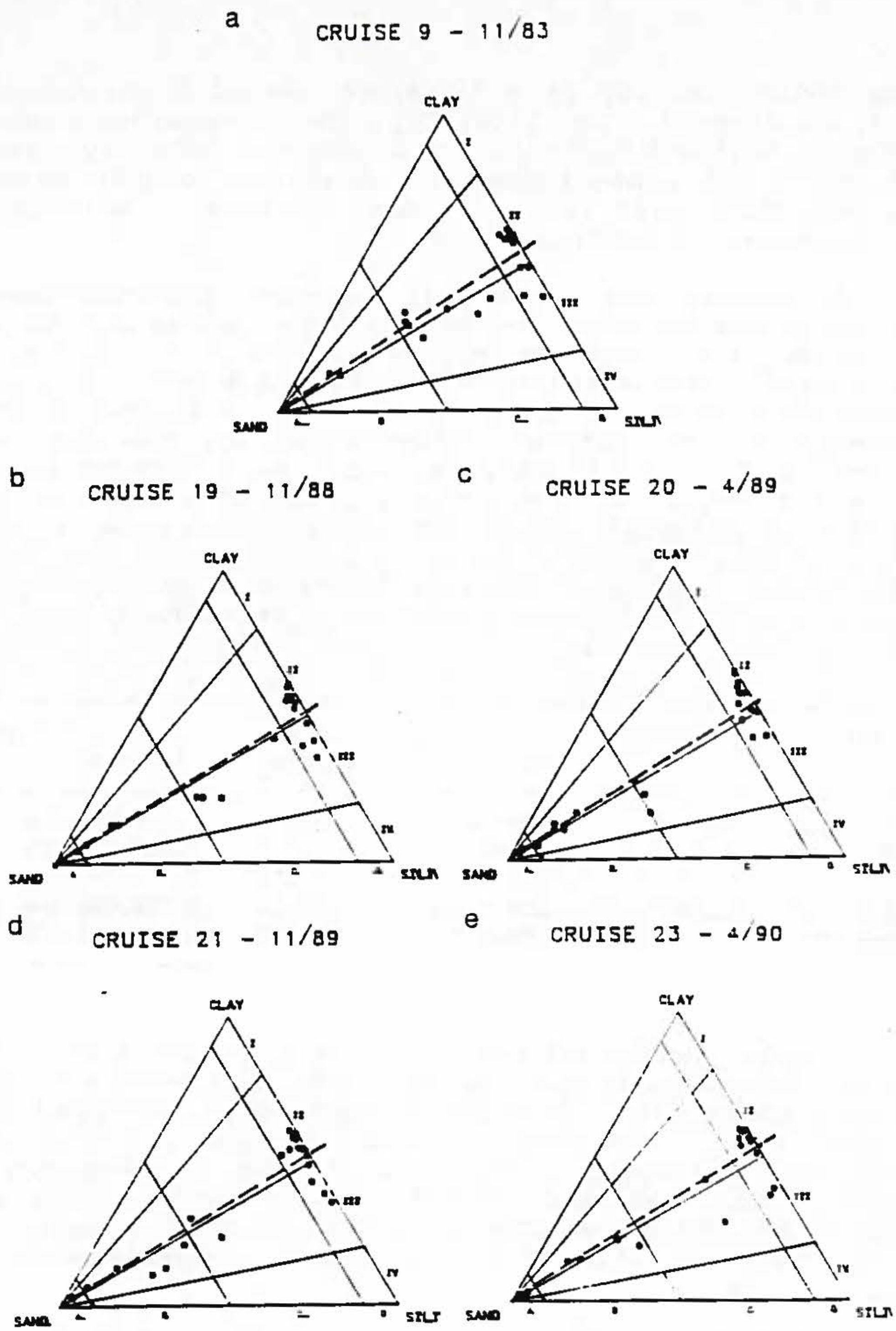


Figure 1-4: Sediment type of samples collected in (a) November 1983 (post-construction, pre-discharge), (b) November 1988, (c) April 1989, (d) November 1989, and (e) April 1990. The dashed line extending from the sand apex diagonally across each diagram represents the average clay:mud ratio for that sampling period.

beach, were subject to erosion by wind and wave activity. The period was one of relative quiescence, during which some degree of equilibrium was established between natural hydrodynamic conditions and the sedimentary environment around Hart-Miller Island.

Beginning in October 1986 and continuing to the present, large quantities of effluent have been released from the dike. The effects of this discharge on the distribution of sediment type can be inferred by comparing maps from this period with pre-discharge maps.

On the basis of the % sand maps, four distinct sediment regimes can be identified around the facility. Each corresponds to a geographic area, for which it is named: (1) Hawk Cove, (2) northeast (of the dike), (3) southeast, and (4) Pleasure Island - Black Marsh. Generally, throughout the entire post-construction period, sand content has varied within a very narrow range in all of these areas except northeast of the dike.

Sediments in Hawk Cove are characterized by a lobe of muddy sand or sandy mud, centered on station 16, protruding into muddy sediments offshore. Before November 1988, sand content at station 16 varied widely (2-52%); since then, it has stabilized, ranging from 47-58%. Other Hawk Cove stations have been consistently muddy throughout the post-construction period.

A similar pattern is apparent east of Pleasure Island and the Black Marsh section of Patapsco River Neck. Broad, gentle contours form a lobe of relatively sandy sediment extending eastward from station 2. For all post-construction sampling periods, sediments are sandiest (>90% sand) near shore. With distance from shore, sand content diminishes gradually to, at most, a few percentage points.

Bayward from the southeastern perimeter of the dike, post-construction sediments have invariably been muddy (<10% sand). The presence of muddy sediments immediately adjacent to the dike is, in part, a consequence of the deposition of a thick layer of "fluid mud" during dike construction. However, even before construction began, sediments in the area were predominantly muddy.

The most variable, and interesting, area around the facility is northeast of the dike. During the pre-discharge period, sand content increased offshore. Beginning with Cruise 9 (November 1983), an irregular lens of sediment, 0.5-1 km away from the dike, evolved from muddy sand to sand. Once established, the shape, location, and sand content of the lens remained largely unchanged until April 1987. Then, the pattern of offshore coarsening began to reverse. By November 1988, the sandiest sediments (>90% sand) were found immediately adjacent to the dike, with gradual fining offshore. That configuration persisted through the ninth year.

Assuming that the reversal in the direction of fining was due to the release of effluent from the dike, the following scenarios are suggested:

(1) The high velocities at which effluent was released from the dike resulted in the winnowing of fine sediments from the vicinity of the spillway. The fine particles were resuspended and transported away from the dike before being redeposited. A lag deposit of coarser sediment remained.

(2) Scouring of sediments near the spillway exposed older, sandier deposits.

Clay:mud ratios are indicative of general hydrodynamic conditions at the site of sediment deposition. The smaller the ratio (i.e., the larger the proportion of silt in the mud fraction), the more turbulent (or shallow) the depositional environment.

The clay:mud ratio maps in Appendix D include, in addition to the contours, an ear-shaped boundary outlining the area around the dike that has been most densely sampled over time. Within this boundary, the zones lying between contours have been shaded - the more clay-rich the fine fraction, the darker the shading. For all of the post-construction cruises, the proportion of clay in the fine fraction almost always increases with distance from the dike. The coarsest (siltiest) sediments are usually found to the northeast, in a band that sometimes extends southward along the eastern flank of the dike.

Pre- and post-discharge maps were compared. Pre-discharge clay:mud ratios tended to vary over a greater range than their post-discharge counterparts. Specifically, the minimum clay:mud ratio was more likely to fall below 0.30 before releases began than afterward.

Since discharge began, a seasonal pattern is evident in the distribution of the fine sediment fraction. Clay:mud ratios vary over a smaller range in the fall than in the spring. These seasonal differences may be related to the interplay between flow from the dike and Susquehanna River discharge. In the fall, sediment distribution is probably more greatly influenced by discharge from the dike - Susquehanna flow is at a minimum during the summer months which precede the November cruise. High flows from the Susquehanna during the spring freshet are probably the chief determinant of April sediment distribution patterns, particularly when spillways have been closed during the winter.

The clay:mud maps for the November 1989 and April 1990 cruises fit these seasonal patterns. The map for April 1990, however, differs somewhat from previous spring distribution patterns in that a pocket of very fine sediment (clay:mud>0.70) occurs in an area due east of spillway #1. Note, though, that the sudden appearance of this clay-rich area is due in part to the denser sampling grid. Before January 1990, samples were not collected in this area.

To pinpoint possible localized effects of dike operation, sediment composition at each station was examined over time by constructing two sets of box-and-whisker plots (Figs. 1-5 and 1-6). The first set depicts sand percentages and the second set, clay:mud ratios. The diagrams cover the entire post-construction period, from November 1983 to April 1990.

A box-and-whisker diagram consists of a narrow box divided in two by a horizontal line. 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 quartiles, the difference between which is termed the "interquartile range". "Whiskers" extend from the ends of the box to the highest and lowest values still lying within 1.5 x the interquartile range. Extreme values, beyond 1.5 x interquartile range, are plotted as separate points (Tukey, 1977). In the figures, those outliers associated with ninth year cruises are identified by the date of collection.

Consider, for example, the diagram in Figure 1-6 representing the distribution of clay:mud ratios at station 2. The ratios are listed in Table 1-3, first in order by date of collection, then rank-ordered from highest value to lowest. The last column in the table shows the values of the 75th, 50th (median), and 25th percentiles.

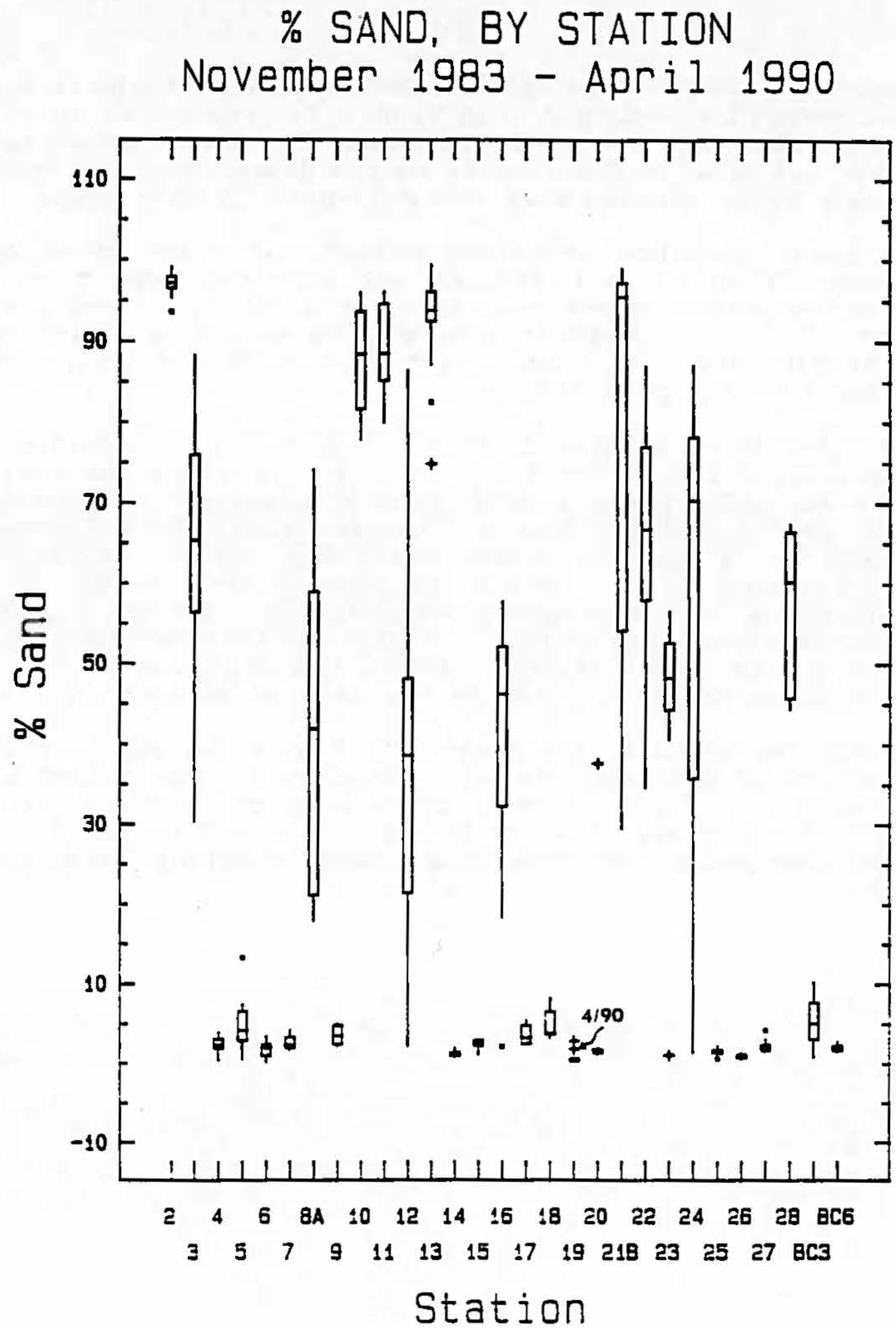


Figure 1-5: Box-and-whisker plots of % sand for all long-term stations, based on data collected between November 1983 and April 1990. Ninth year outliers are identified by date of collection.

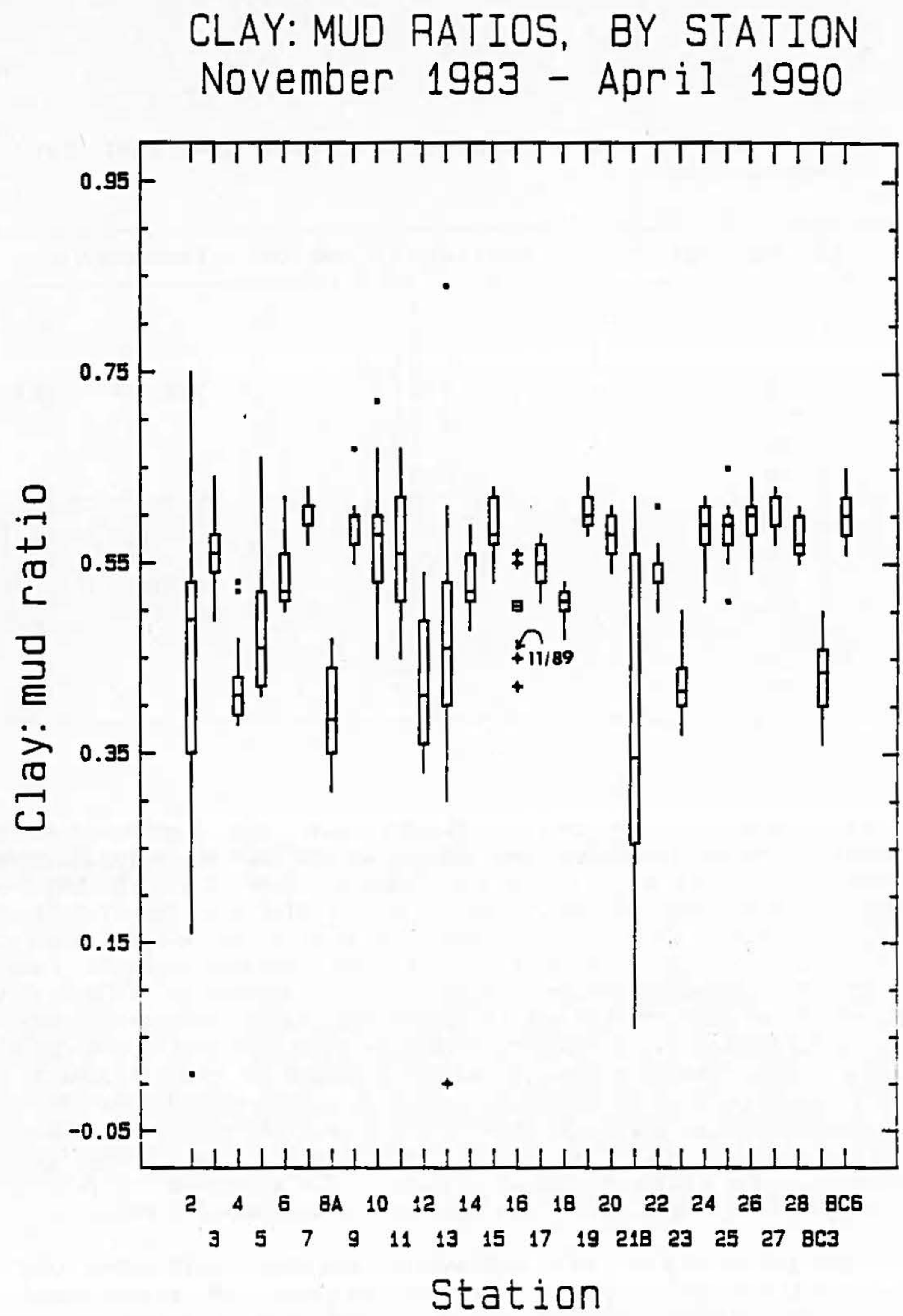


Figure 1-6: Box-and-whisker plots of clay:mud ratios for all long-term stations, based on data collected between November 1983 and April 1990. Ninth year outliers are identified by date of collection.

Table 1-3: Clay:mud ratios at station 2, from November 1983 to April 1990.

Date	Clay:mud ratio	Ranking of ratios	Percentile
11/83	0.48	0.75	
6/84	0.16	0.67	
11/84	0.45	0.61	
4/85	0.50	0.53	75th = 0.5275
11/85	0.50	0.51	
4/86	0.51	0.50	
11/86	0.35	0.50	
4/87	0.75	0.49	50th = 0.49
11/87	0.01	0.48	
4/88	0.21	0.45	
11/88	0.67	0.43	25th = 0.3525
4/89	0.53	0.35	
11/89	0.61	0.21	
1/90	0.43	0.16	
4/90	0.49	0.01	

In the diagram, the bar dividing the box represents the median, 0.49, the value above and below which lie an equal number of observations - seven, in this case. The top of the box corresponds to the 75th percentile, 0.5275, the bottom of the box to the 25th percentile, 0.3525. The difference between these two values, 0.5275 - 0.3525 = 0.175, is the interquartile range. Multiplying the interquartile range by 1.5 gives 0.2625. This number is then added to the 75th percentile (0.5275 + 0.2625 = 0.79) and subtracted from the 25th percentile (0.3525 - 0.2625 = 0.09) to determine the maximum possible extent of the whiskers and to identify outliers. The upper whisker extends to 0.75, the highest measured value still within the range 0.09-0.79; the bottom whisker extends to 0.16, the lowest measured value still within range. The single extreme value - 0.01 - is plotted as a point, which corresponds to a sample collected in November 1987.

Only two of the outliers represent samples collected during ninth year monitoring. These extreme values are summarized in Table 1-4. The distributions of clay:mud and % sand at these stations are graphed in Figure 1-7.

Table 1-4: Extreme clay:mud ratios or % sand values - ninth year monitoring.

Station	Cruise	Date	Variable	High/low
16	21	11/89	clay:mud	low
19	23	4/90	% sand	high

The spike in sand content at station 19 is minor; % sand rose from an average of about 0.5% to less than 2%. A similar, isolated rise in sand content occurred before, in April 1985.

The station 16 outlier is more problematic. Before November 1988 (Cruise 19), sand content at this site fluctuated a great deal, as noted earlier. Since then, the pattern has changed - sand content has remained comparatively high and has been steadily, if slowly, increasing. The trend shown by clay:mud ratios at this station also changed at the same time. Before November 1988, the ratio fluctuated erratically, but always remained above 0.50. Since then, the variability has become more extreme, and the ratio has fallen below 0.50 on two occasions. The first time was in November 1988 and the second, in November 1989. Spillway #2 was first opened in April 1988. It is possible that flow from the spillway is affecting sedimentation at station 16 by altering circulation patterns in Hawk Cove. That possibility is strengthened by the fact that higher than normal Zn levels were detected at station 16 in November 1989. Scenario runs of the 3-D model should clarify how natural flow patterns around the dike are altered by releases from spillway #2.

<u>Gravity Cores</u>

Gravity cores collected at stations BC-1 through BC7 in April 1990 were very similar to those collected the previous spring, indicating that no major changes occurred at those locations during the past year. Evidence of the fluid mud layer - soft, creamy, cohesive texture; grayish orange pink and medium gray color bands; laminations - was again found at stations BC-1 and BC-3. The layer extended from the top of the core to about 10 cm at BC-1 and to about 30 cm at BC-3. At BC-3, the upper 10 cm of the core have been largely recolonized and heavily bioturbated; most of the fluid mud characteristics have been erased. In contrast, the top of BC-1 is only slightly bioturbated. Between April 1988 and April 1989, sediment appears to have been scoured from BC-1; the thickness of the fluid mud layer decreased from about 20 cm to about 12 cm. Organisms have had less time to rework the uppermost section of the core. Within a few more years, though, the fluid mud layer will probably no longer be recognizable at BC-1.

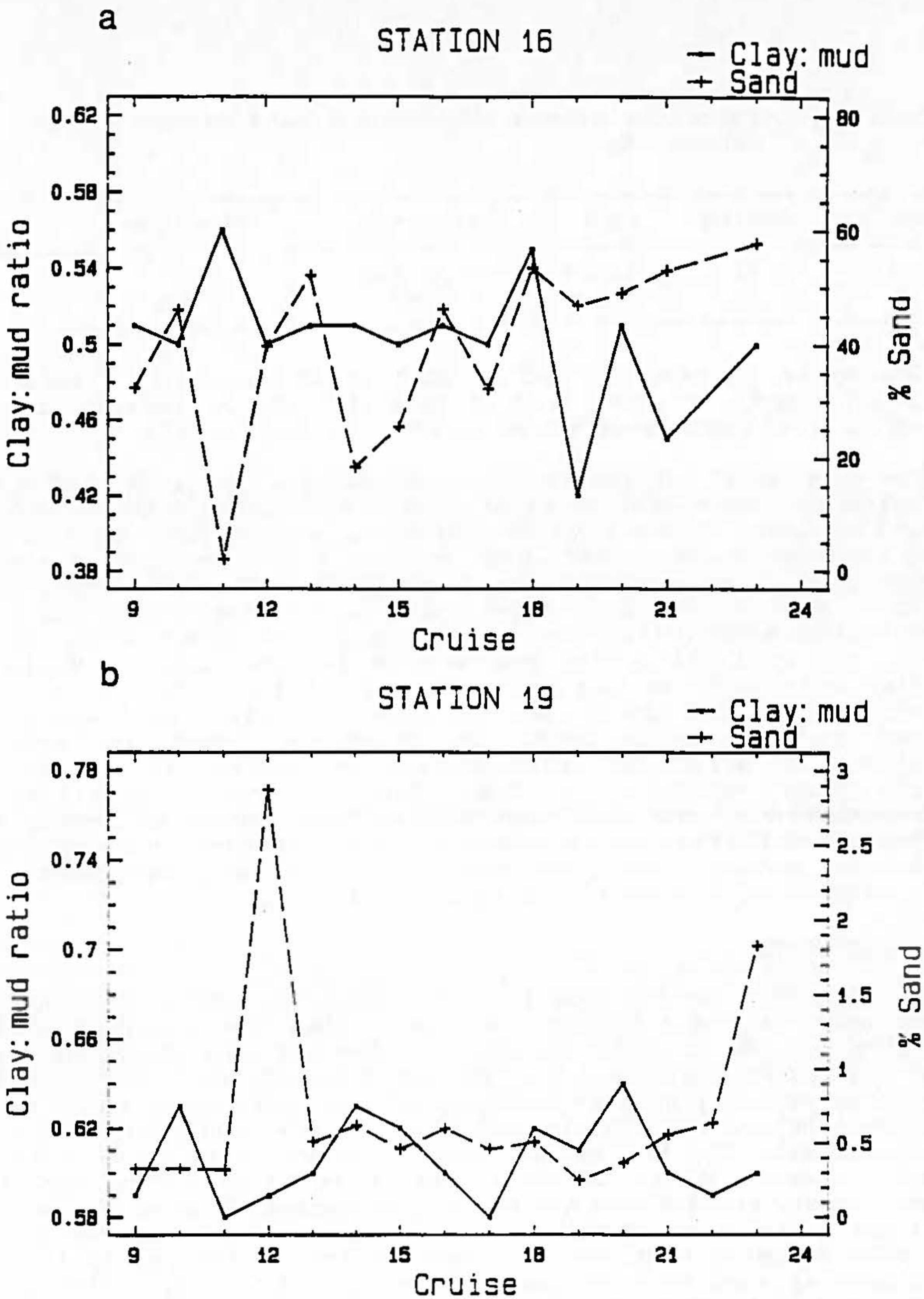


Figure 1-7: % sand and clay:mud ratios, over time, for (a) station 16 and (b) station 19, the two stations with extreme ninth year values.

TRACE METALS

Six trace metals were analyzed as part of the ongoing effort to assess the effects of operation of the containment facility on the surrounding sedimentary environment. The method used to interpret changes in the observed metal concentrations takes into account grain size induced variability and references the data to a regional norm. The method involves correlating trace metal levels with grain size composition on a data set which can be used as a reference for comparison. For the Hart-Miller Island study area, data collected between 1983 and 1988 are used as the reference. Samples collected during this time showed no aberrant behavior in trace metal levels. Normalization of grain size induced variability of trace element concentrations was accomplished by fitting the data to the following equation:

$$X = a(\text{Sand}) + b(\text{Silt}) + c(\text{Clay}) \qquad (2)$$

where X = the element of interest
a,b, and c = the determined coefficients, and
Sand, Silt, and Clay = the grain size fractions of the sample.

A least squares fit of the data was obtained by using a Marquardt (1963) type algorithm. The results of this analysis are presented in Table 1-5. The correlations are excellent for Cr, Fe, Ni, and Zn, indicating that these metals are either components of the mineral grains or proportionally related by adsorption processes. The correlations for Mn and Cu are weaker, though still strong. In addition to being part of the lattice and adsorbed structure of the mineral grains, Mn occurs as oxy-hydroxide chemical precipitate coatings. These coatings cover exposed surfaces; that is, they cover individual particles as well as particle aggregates. Consequently, the correlation between Mn and the disaggregated sediment size fraction is weaker than for elements, like Fe, that occur primarily as components of the mineral structure. The behavior of Cu is more strongly influenced by sorption into the oxy-hydroxide than are the other elements.

Table 1-5: Least squares coefficients and correlation coefficients for the analyzed trace metals.

Metal	Least squares coefficient a	b	c	R^2
Cr	25.27	71.92	160.8	0.733
Mn	668.0	217.7	4157.	0.356
Fe	0.5533	1.169	7.573	0.915
Ni	15.03	0.00	136.0	0.819
Cu	12.37	18.74	70.80	0.613
Zn	44.43	0.00	472.5	0.767

The strong correlation between the metals and the physical size fractions makes it possible to predict metal levels at a given site if the grain size composition is known. This can be done by substituting the least squares coefficients from Table 1-5 for the determined coefficients in equation 2. These predicted values can then be used to determine variations from the regional norm due to deposition; to exposure of older, more metal-depleted sediments; or to loadings from anthropogenic or other enriched sources.

The following equation was used to examine the variation from the norm around the containment facility:

$$\%\text{ excess Zn} = \frac{(\text{measured Zn} - \text{predicted Zn})}{\text{predicted Zn}} * 100 \quad (3)$$

Here, the differences between the measured and predicted Zn levels (positive values => enrichment; negative values => depletion) are normalized to predicted Zn levels.

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 several 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.

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

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

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

Appendix E shows % excess Zn for seven sampling periods. The April 1987 sampling period is typical of the area before November 1988; that is, there may be a sporadic high or low station, but the area is not large and there are no systematic changes through time. Starting in April 1988, an area of enrichment, incorporating station 25, appears east of the facility in the vicinity of spillway #1.

To determine the eastward extent of the affected area, MGS intensively sampled the area in January 1990, collecting 67 surficial samples. Fe and Zn were the only elements analyzed on the January samples. Restricting the number of elements analyzed allowed for a denser sampling of the area and a more rapid turn-around time for assessing the perceived problem.

The sampling plan for the January 1990 cruise (Fig. 1-2) made use of preliminary results of the 3-D hydrodynamic model (Johnson *et al.*, 1989) and MES discharge records for spillway #1. Flow lines were interpolated from a net tidal average velocity vector field. The trajectories of the effluent discharged at various flow rates (from 0.1 to 100 million gallons/day) from spillway #1 were calculated and mapped (solid grid lines in Fig. 1-8). The dashed lines in Figure 1-8 represent the distance the effluent travels along a calculated trajectory within a specified period (from 0.5 to 3 hours). (Time is an important factor in the sedimentation of material from the effluent.) Sampling stations were located at the grid nodes and at intermediate points along the grid lines. The trajectory map indicates that sediments immediately adjacent to the dike should only be affected by low discharge rates from the dike. Releases greater than 5 million gallons/day (mgd) are targeted for areas beyond the established sampling grid, and their effects on the sedimentary environment would not have been measured.

Figure E-6 shows the results for the January 1990 cruise. The contours clearly show a plume structure for % excess Zn. The plume starts east of spillway #1 and tapers southward following the net non-tidal flow in the Bay along the 1 mgd flow line. This agrees with discharge records from spillway #1 (Fig. 1-9). The association between increased levels of Zn in the sediments and consistently low discharge rates since November 1988 confirms the relation between the flow rate and site of deposition of discharged material. This also explains why no effects of discharge were noted until November 1988; prior to that time, material was discharged into the main Bay beyond the monitored area.

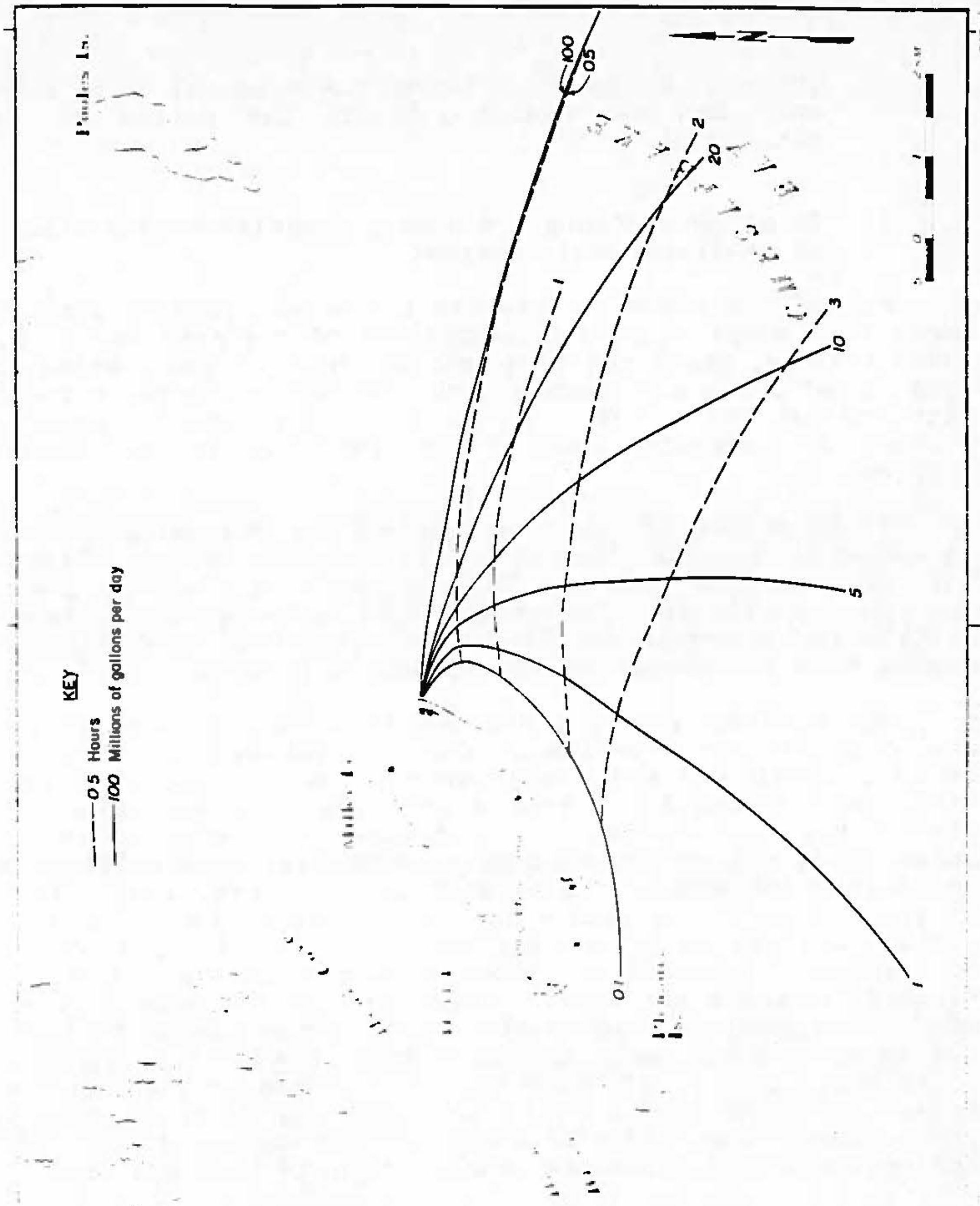


Figure 1-8: Flow net showing trajectories followed by effluent released at different rates from spillway #1 (solid lines) and time elapsed from moment of discharge (dashed lines).

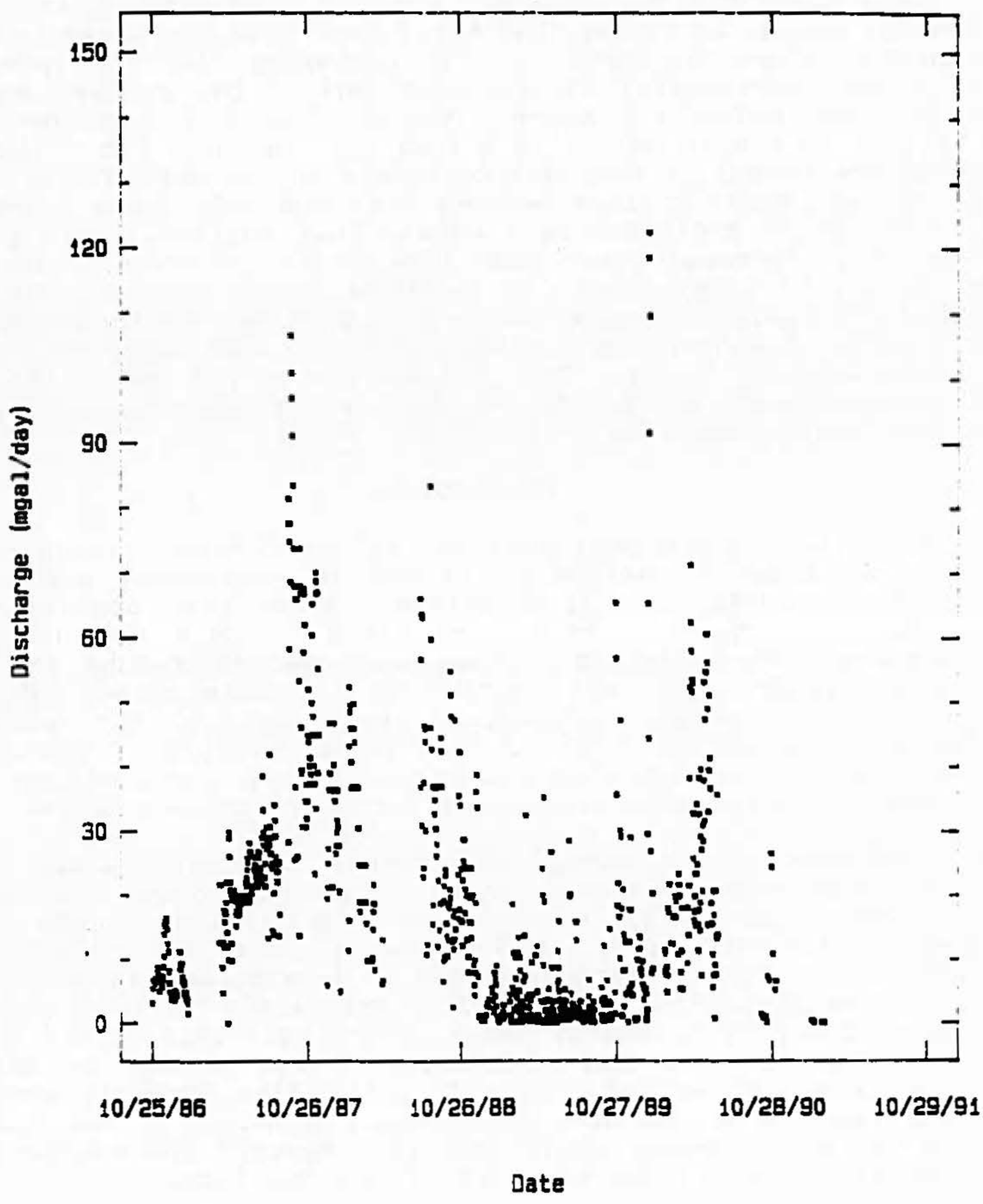


Figure 1-9: Daily discharge (million gallons/day) from spillway #1, from MES records.

The overall level of Zn enrichment diminished from April 1989 through January 1990. However, in April 1990 (Fig. E-7), Zn levels rebounded to the April 1989 high, indicating that the problem persists.

Semi-quantitative results for Cd indicate that, since discharge began, levels of that metal have also increased in bottom sediments around the facility. In reviewing historic (pre-1984) data around Hart-Miller Island, over 80% of the samples analyzed for Cd were below 1.0 mg/kg (ppm). Over 95% were below 1.5 mg/kg,with no sample exceeding 2.0 mg/kg. Appendix F contains maps showing the trends in sediment Cd levels in the Hart-Miller Island area for six April cruises between 1985 and 1990. The trends for Cd follow those indicated by % excess Zn. Initially, the primary source of Cd appears to have been Back River. However, starting in April 1987, Cd levels began to increase around spillway #1. This increase, in both areal extent and intensity, continued through April 1990. The stations highest in Cd (>2.0 mg/kg) were the same as those highest in Zn. This substantiates the use of Zn as an indicator element and points to the need for further analysis to quantify toxics loadings to the area.

CONCLUSIONS

This year, grain size data for all post-construction cruises were re-examined to determine if the pre-discharge sedimentary environment could be distinguished from the post-discharge environment on the basis of texture alone. Such a distinction was not apparent when Shepard's class was used to reduce the three component (sand-silt-clay) system to a single term. Pejrup's classification scheme, developed specifically for estuarine sediments, was adopted instead. In keeping with that system, two components - % sand and clay:mud ratios - were examined over time. Pre- and post-discharge cruises differed on both variables.

Northeast of the dike, the pre-release distribution of the sand fraction - coarsening offshore - reversed following the onset of discharging. Since November 1988, sand content has systematically decreased with distance from the dike (fining offshore). Clay:mud ratios show the development of a seasonal trend in the distribution of the fine fraction. The clay component of mud varies over a smaller range in the fall than in the spring. Both of these effects may be related to the release of effluent from spillways #1 and #2. Flow from the dike probably scours or winnows fines from the area immediately adjacent to the dike and alters the hydrodynamic conditions that control the sedimentation of fine particles in the vicinity of the facility.

With the exception of one station, sediment composition during the ninth year of exterior monitoring was consistent with other post-discharge cruises. The comparatively coarser grain size composition (higher sand content; lower clay:mud ratio) at station

16 may be related to the release of effluent from spillway #2. This seems likely, given the higher than normal Zn levels at the station.

During the ninth monitoring year, Zn levels remained significantly higher in bottom sediments near spillway #1. The source of Zn was traced to the release of effluent during normal operation of the dike. Although effluent has been discharged from the spillway since October 1986, Zn levels in bottom sediments remained consistent with the regional average until November 1988. The stations showing excessively high levels of Zn are affected by low flows (<5 mgd) from the dike; at higher discharge rates, the effluent bypasses previously established stations. Discharge rates consistently fell below 5 mgd starting in November 1988. With the onset of low flow releases, Zn levels increased and were initially observed following the April 1989 cruise. High Zn levels have persisted through April 1990. The extensive sampling done in January 1990 provided a detailed picture of the plume of Zn enrichment emanating from the containment facility and confirmed the relationship between discharge rate and Zn enrichment in the sediments adjacent to Hart-Miller Island. Furthermore, semi-quantitative results for Cd indicate that Cd in bottom sediments is following the distribution of Zn; elevated levels of Cd might be expected in areas high in Zn.

RECOMMENDATIONS

Since the detection of Zn enrichment, a number of steps have been taken to assess the environmental impact of the contaminated area:

1. Additional benthic stations have been established to assess the effect of the elevated metal levels on benthic fauna. Several of these sites were selected to correspond with sediment sampling locations.

2. Funding for the 3-D hydrodynamic model has been obtained so that a more responsive sampling program can be initiated. In the interim, the sediment sampling grid is being modified based on existing model runs and discharge information from MES (discharge rates from active spillways).

3. Effluent samples are now being routinely analyzed for Fe and Zn on a weekly basis. This is being done so that the total loading from the facility can be estimated.

4. Samples were sent to an outside laboratory to measure six other trace metals on EPA's list of priority pollutants: arsenic (As), beryllium (Be), cadmium (Cd), lead (Pb), selenium (Se), and silver (Ag).

Besides retaining the additional benthic and sediment stations and analyzing effluent samples for Fe and Zn on a weekly basis, we recommend that the Hart-Miller Island Technical Review Committee:

1. <u>Consider including bioassay work in the scope of exterior monitoring.</u>
   To date it has been impossible to relate sediment loadings to the effects on the biota at sub-lethal levels. Geochemical data provide an adequate picture of the extent of the physical influence of the dike on the sediment, but this is unrelated to toxicological effects on the biota.

2. <u>Consider quantifying toxics loadings to the area around the dike.</u>
   Although archived sediment samples were analyzed for additional trace metals, the laboratory results were either unacceptable or acceptable only at the semi-quantitative level. Further analyses of other metals and toxic materials should be carried out in the area of Zn enrichment to determine loadings to the sediment.

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; Dave Bibler, Bob Cuthbertson, Jeff Halka, Katy Koczot, Jim Lowry, Laura Malinoski, and Bill Panageotou, for braving the elements during sample collection; Bill Panageotou, for helping to x-ray the cores; Bob Conkwright and June Park, for coaxing the lab equipment to produce results; Katy Koczot and Laura Malinoski, for their careful analysis of sediment samples; and Randy Kerhin, for his open door and his guidance in political matters. In addition to MGS staff members, we extend our thanks to Cece Donovan at MES, who adroitly administered the contract with Martel and provided us with much of the information related to site operation.

PART 2: BEACH EROSION STUDY

INTRODUCTION

One of the first sections of the dike to be constructed was the segment between Hart and Miller Islands. Construction of the recreational beach, bordering on Hawk Cove, required approximately 500,000 yd^3 of sediment, pumped from the interior area of what was to become the diked containment facility and deposited between Hart and Miller Islands (Fig. 2-1). A recreational beach was established on the western side of that segment for the general public. The new beach shoreline reflected the curvilinear path of the dike, convex at the northern end (Miller Island) and concave at the southern end (Hart Island). The original engineering plans indicated that the new beach would be gently sloping with a grade of 15:1 or 3.8° and, therefore, be approximately 270 ft wide.

Natural erosional and depositional processes acting upon the newly established beach began modifying the shoreline immediately. Storm waves, combined with higher than normal tides, produced a vertical escarpment of varying height shortly after construction of the beach. Rain on the upper dike face caused sheetwash erosion and gully formation. Significant volumes of sediment were eroded from the recreational beach over the years, and the shoreline was, therefore, altered. The northern section of the beach eroded quickly, narrowing the beach and removing part of the lower dike face. The southern section of the beach accreted due to the littoral drift of sediments eroded from the northern section. Through the years, the beach has been resurfaced by bulldozing in the spring to improve its appearance. There were detrimental effects associated with the anthropogenic alteration of the beach: erosion increased, and the beach eroded faster after each subsequent resculpting by bulldozers.

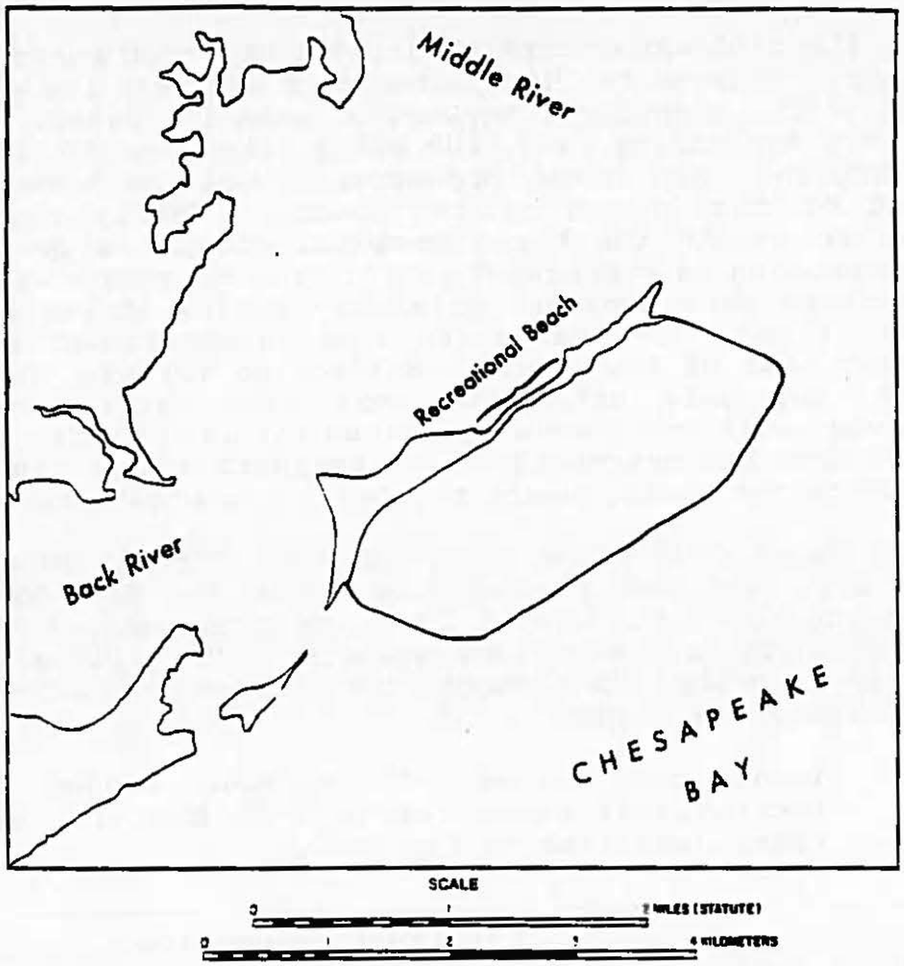
In August 1988, to stabilize the recreational beach, two berms and two drainage ditches were constructed on the upper dike face. Grass was planted on the upper dike face, and the lower dike face and foreshore were smoothed. Erosion continued on the lower dike face and foreshore areas. The beach was not regraded in the years following due to the lack of sediment and financial problems.

PREVIOUS WORK

The Maryland Geological Survey (MGS) has investigated the transfiguration of the recreational beach since 1984. Results of those investigations may be found in previous reports (Wells *et. al.*, 1985, 1986, 1987 and Hennessee *et. al.*, 1989, 1990a, 1990b). Those reports give a detailed account of the forces of nature and man acting upon the recreational beach.

Based on analysis of the profile surveys, the beach was divided into three geomorphic areas (Fig. 2-2): (1) <u>the outer dike face</u>, extending from the chain link fence at the edge of the dike

Study area



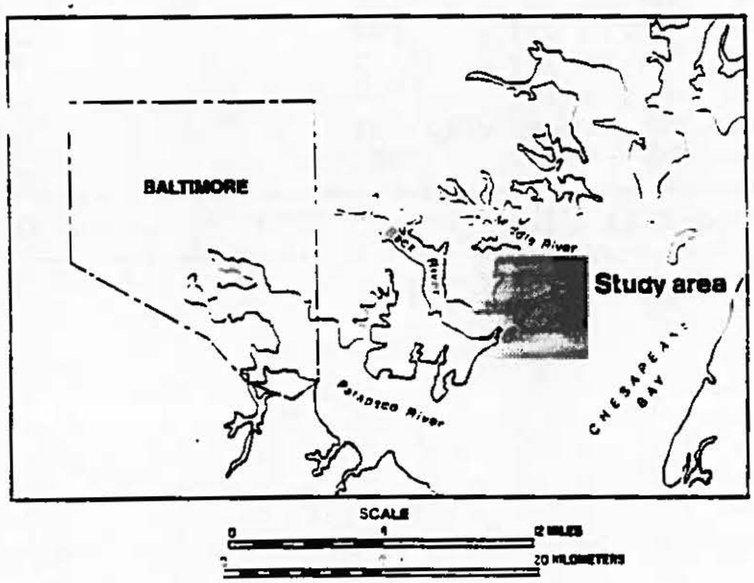


Figure 2-1: Location of the study area.

roadway to the high water mark, usually a wave-cut escarpment; (2) the foreshore, between the high water mark and mean low water (0 ft MLW); and (3) the nearshore, bayward of mean low water. For years prior to this monitoring year, the outer dike face was affected by pluvial, aeolian, and human processes. Gullies were prevalent along most of the length of the beach. Yearly regrading by bulldozers to smooth the beach promoted steeper slopes, thereby increasing erosion in subsequent years. The foreshore was modified by wind-induced wave erosion, primarily during storms and higher than normal tides. The waves produced an escarpment of varying height along most of the beach. Bulldozing removed the wave-cut escarpment, but only until the next high water event. The nearshore was modified by wave-generated littoral drift. Sediments were eroded from the nearshore of the northern end of the beach and transported to the south, where the beach accreted into Hawk Cove.

Net sediment loss along the recreational beach is summarized in Table 2-1 for the period June 1984 to May 1990. The approximations for net sediment loss are conservative due to the omission of gully and nearshore erosion. If gully erosion and nearshore erosion were considered, the figures in Table 2-1 would be approximately 10% higher.

Table 2-1: Total net volume of sediment eroded from the recreational beach (above 0 ft MLW) for each study year, June 1984 to May 1990.

Time period	Sediment volume lost* (yd^3)	(m^3)
June 1984 - March 1985	1190	910
June 1985 - April 1986	2083	1593
June 1986 - March 1987	3472	2656
June 1987 - May 1988	3129	2394
September 1988 - May 1989	594	454
May 1989 - May 1990	3081	2356
Total (June 1984 - May 1990)	13549	10363

* based on ISRP (Birkemeier, 1986)

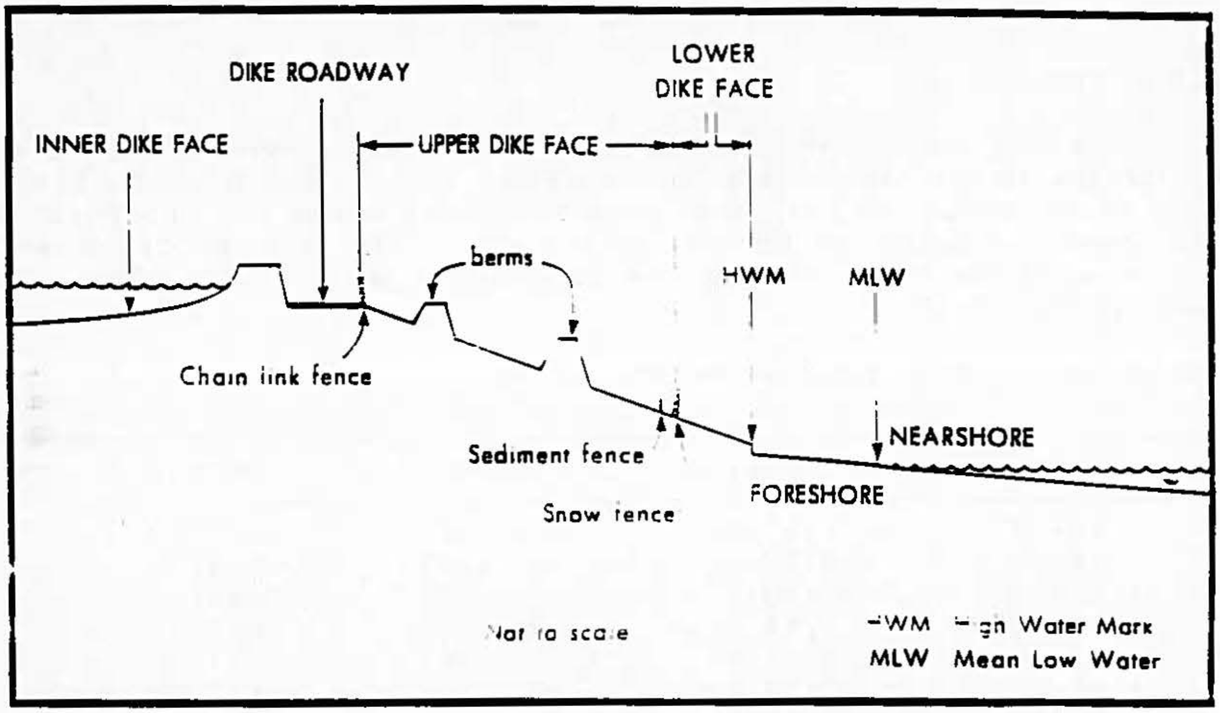


Figure 2-2: Post-reconstruction (August 1988) schematic cross-section of the dike illustrating geomorphic regions of the beach.

OBJECTIVES

This report was designed mainly to be a summary of the monitoring of the recreational beach. The objectives of this report are to:

1. identify areas of erosion/deposition;
2. calculate the amount of sediment eroded/deposited along the recreational beach; and
3. exhibit, through the use of cross-sectional profiles, a proposed beach with a grade of 15:1 or 3.8°.

METHODOLOGY

FIELD METHODS

MGS monitored ten profile lines along the recreational beach below the constructed snow fence (Fig. 2-3). The profile lines, with minor modification, have been monitored since the inception of the beach erosion study in June 1984. The ten profiles were surveyed three times during the monitoring period, May 1989 - May 1990 (Table 2-2).

Table 2-2: Beach profile survey dates.

Profile	Survey 1	Survey 2	Survey 3
21+75	5/17/89	9/14/89	5/2/90
24+00	5/17/89	9/14/89	5/2/90
28+00	5/17/89	9/14/89	5/11/90
30+00	5/17/89	9/14/89	5/7/90
32+00	5/17/89	9/14/89	5/7/90
36+00	5/18/89	9/14/89	5/11/90
40+00	5/18/89	9/15/89	5/11/90
44+00	5/18/89	9/15/89	5/11/90
48+00	5/18/89	9/15/89	5/7/90
49+00	5/18/89	9/15/89	5/11/90

Distance and elevation data collected during the three surveys are listed in the Ninth Year Data Report. Standard techniques of leveling were followed in surveying the ten profiles, using a Sokkisha engineers precision automatic level (Model B1).

Elevations along each profile were transferred directly from Maryland Port Administration bench mark number 281614 (elevation = 14.57 ft MLW), located approximately 22 ft east of the centerline of the dike roadway at station 30+00, and bench marks established by the Great Lakes Dredging Company along the dike roadway, shown in Figure 2-3 and listed in Table 2-3.

Table 2-3: Bench mark location, elevation, and type of structure.

Station	Elevation (ft)	Type of structure
25+36.45	18.37	cemented pipe
28+55.39	18.29	cemented pipe
30+00	14.57	nipple inside pipe
31+50	18.38	stake
34+91.04	18.00	cemented pipe
39+73.7	18.21	stake
44+90	21.75	on fence cross pipe
47+00	19.49	stake
49+50	21.91	on fence cross pipe

The centerline of the dike roadway was located by measuring 13 ft from the chain link fence with a fiberglass tape. The correct angle of the roadway with each profile was maintained by using a portable, hand-held compass. The chain link fence was also marked with orange paint to indicate the direction of the profile as viewed from the level set up along the centerline of the dike roadway. Elevations were transferred from the centerline of the dike roadway to wooden stakes placed several feet bayward of the snow fence. Each profile was then surveyed below the snow fence. The transfer of elevations was necessary in order to reduce errors introduced by wind bending the survey rod.

Photographs were taken during each of the surveys to document the erosional/depositional changes occurring along the beach. A photograph was taken at each profile from approximately 50 ft offshore. Several photographs were taken facing to the north and south in selected areas in order to observe the trend of the beach. Areas exhibiting excessive erosion, not on profiles, were also photographed. Aerial photographs were taken in May 1989 and May 1990 to record the overall changes in the shoreline configuration and escarpment/gully formation.

DATA REDUCTION

To calculate the sediment gains and losses above and below datum (0 ft MLW) for each profile, a computer program (Interactive Survey Reduction Program (ISRP)) was employed (Birkemeier, 1986). The net sediment gains/losses for two adjacent profiles were averaged in order to approximate the actual results of processes on the interlying areas. The averaged gains/losses for adjacent profiles were multiplied by the distance between them. The

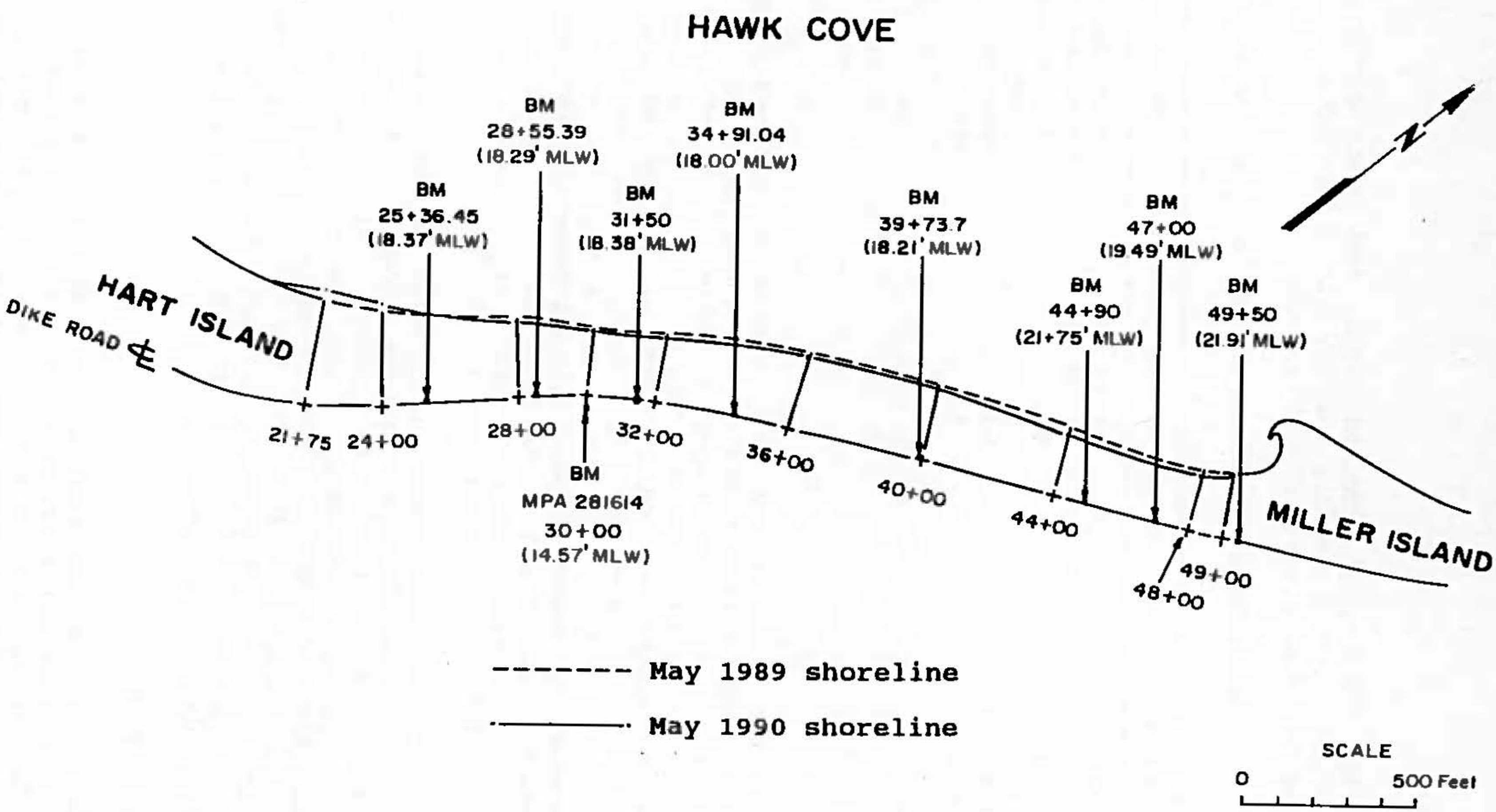


Figure 2-3: Dike location of the surveyed profile lines, bench marks, and comparison of the May 1989 and May 1990 shorelines.

products were summed, providing a net volume change along the entire beach.

RESULTS AND DISCUSSION

To illustrate the changes in beach configuration during the study period, the shorelines for May 1989 and May 1990 were compared (Fig. 2-3; Table 2-4). Ten cross-sectional profiles were constructed to assess the changing slope of the beach (Appendix G).

The recreational beach experienced both erosion and deposition during the time period May 1989 to May 1990. Erosion occurred along the entire reach of beach north of dike station 24+00; deposition was limited to the section of beach south of 24+00. Erosion of the beach north of 24+00 was produced by wind-driven waves assaulting the beach during periods of higher than normal tides, probably during storms. The evidence for the erosion of the beach north of 24+00 was the presence of an escarpment of varying height. The amount of land remaining from the high water mark to the snow fence was considerably reduced by the end of the study year. In the region of the beach located between 41+50 and 42+50, the lower dike face receded past the snow fence.

Table 2-4: Distance (ft) from the centerline of the dike roadway to the 0 ft contour.

Dike station	Distance (ft)	
	5/89	5/90
21+75	310	342
24+00	276	303
28+00	227	223
30+00	200	197
32+00	195	192
36+00	233	217
40+00	233	219
44+00	207	190
48+00	172	162
49+00	198	188

The amount of sediment removed from the foreshore and lower dike face north of 24+00 was approximately 3500 yd^3 (2676 m^3). The severe erosion of the beach between 41+50 and 43+50 was not included in the total amount of sediment removed due to the lack of measurements. An estimated 110 yd^3 (84 m^3) of material were removed between those two stations, in addition to the calculated amount of sediment lost between 40+00 and 44+00. The nearshore area (below 0 ft MLW) north of 24+00 sustained a loss of approximately 600 yd^3 (459 m^3). A wave-cut escarpment and large pebbles/small boulders (stones) were the features that remained as a result of the erosion.

The strewn stones, located primarily along the foreshore north of 44+00, were the result of the winnowing action by waves. Winnowing is the process whereby one substance is separated from another by an outside source, in this case the waves separated the fine sand from the stones, leaving the stones along the foreshore. The existence of the stones was attributed to the poor sorting of the sediments used for the construction of the beach and dike.

The foreshore and nearshore areas south of dike station 24+00 exhibited deposition of sediments as determined from the comparisons of the shorelines (Fig. 2-3) and the cross-sectional profiles (Figs. G-1 and G-2). South of 24+00 the beach gained approximately 400 yd^3 (306 m^3) of well-sorted, medium sand above datum and approximately 250 yd^3 (191 m^3) of sand in the nearshore. Therefore, of the calculated 3500 yd^3 (2676 m^3) of sand eroded from the beach, approximately 650 yd^3 (497 m^3), or 19 %, was accounted for. The remainder of the eroded sand was removed from the surveyed area.

Wind-generated waves, at times of higher than normal tides, eroded sediments from the beach north of 24+00 and created longshore currents that effectively moved the sand from north to south. Erosion north of 24+00 was documented by comparison of shorelines (Fig. 2-3) and cross-sectional profiles (Figs. G-3 through G-10). Miller Pt., on Miller Island bordering the northern end of the recreational beach, acted as a barrier or a deflection point at which the beach to the south suffered sand starvation. The shoreline north of Miller Pt., comprised of marsh vegetation with a clay substrate, contained little sand. Without the nourishment of sand, eroded from the shores north of Miller Pt., the section of beach from 32+00 north to 49+00 became the sand supply for the remainder of the recreational beach.

In addition to sand starvation of the northern shoreline, the slope of the beach was steep, as previously reported (Hennessee, et. *al*., 1989, 1990a). If average beach slopes exceeded 4.1°, erosion occurred. Table 2-5 indicates the potential for erosion along the recreational beach with respect to the slope of the beach.

The average slopes of all profiles north of station 24+00 were greater than 4.1° in May 1990. Furthermore, average slopes increased during the study year. These data indicated that erosional severity was increasing between dike stations 24+00 and 49+00. At the end of the monitoring year, May 1990, there was only a small strip of land remaining between the high water mark (base of the wave-cut escarpment) and the snow fence along most of the beach. Between 41+50 and 43+50, the beach had eroded past the snow fence, and part of the lower dike face was removed.

Table 2-5: Average slopes (°) of beach profiles comparing May 1989 and May 1990 from the snow fence bayward to the water line.

Dike station	Slope (°) 5/89	5/90
21+75	3.5	2.5
24+00	4.2	3.3
28+00	5.4	6.1
30+00	6.8	7.3
32+00	8.7	9.5
36+00	7.8	8.7
40+00	8.3	9.0
44+00	8.8	8.8
48+00	10.0	11.2
49+00	9.2	8.5

The section of beach located between 41+50 and 43+50 was the hardest hit by erosion during the monitoring year. The accelerated erosion in that area was primarily due to the remnants of a constructed drainage ditch consisting of small boulders. The piled boulders channeled storm waves toward the shoreline adjacent (both north and south) to the drainage ditch located at 42+50.

Sand replenishment along the recreational beach has been proposed for the past five years. Addition of a suitable sand would serve to reduce the average slope of the beach and provide an adequate recreational area for the public. An appropriate grade for the beach would be 15:1 or 3.8°, as per the original engineering plans. Appendix H contains cross-sectional profiles showing the proposed replenishment grade, designated October 1990, and the May 1990 shoreline. The section of beach south of dike station 28+00 does not require replenishment and, therefore, was omitted from the figures in Appendix H.

Approximately 30,500 yd^3 (23,320 m^3) of clean, medium-sized sand (0.25-0.50 mm) would be needed to provide the 15:1 grade as of May 1990. Although the addition of sand would appreciably lower the degree of erosion, it would not eliminate erosion. The site, if replenished, would have to be maintained every few years by the addition of more sand.

CONCLUSIONS

The area of the recreational beach prone to erosion lies north of dike station 24+00. A wave-cut escarpment and gullies were the reminders of the amount and intensity of erosion along the beach. Erosion will continue at an accelerated rate as the shoreline recedes toward the dike roadway. At the end of the study year, the shoreline between stations 41+50 and 43+50 had receded beyond the snow fence, encroaching on the lower berm. Erosion will continue to be more severe along this section as long as the boulders used in the construction of the drainage ditch remain in place. The expanse of beach between the dike roadway and the snow fence was reconstructed to alleviate erosion of the upper dike by sheetwash erosion. If allowed to go unchecked, the eroding lower dike will destroy the reconstructed area.

Deposition on the beach was limited to the south of dike station 24+00. The sediments eroded north of 24+00 were transported southward via longshore currents. Deposition will continue as long as there are sediments that can be eroded from the beach north of 24+00.

Approximately 4100 yd^3 (3135 m^3) of sediments were eroded from the recreational beach (above and below datum) north of 24+00. Approximately 600 yd^3 (459 m^3) of sand were deposited along the beach from 24+00 south to 21+75. These calculated amounts will surely increase as the shoreline recedes.

Analyses of the cross-sectional profiles showed that the grade of the beach was increasing as the beach receded. A proposed grade of 15:1 or 3.8° was also presented as a cross-sectional profile in order to exemplify a shoreline that would probably experience less erosion than that experienced along the recreational beach during the study year.

RECOMMENDATIONS

The recreational beach should continue to be monitored due to the vulnerability of the area to wave attack. The foreshore and nearshore areas of the beach north of dike station 24+00 should have approximately 30,500 yd^3 (23,320 m^3) of clean, well-sorted, medium-grained sand deposited. The addition of sand will reduce the grade of the beach to 15:1 or 3.8°, reduce the severity of erosion, and provide the public with ample space for beach activities.

The shoreline would continue to erode after replenishment. Therefore, a plan to conserve the beach as much as possible should be formulated. The least expensive and most tolerable to the public would be periodic renourishment of sand.

ACKNOWLEDGMENTS

The data collection for the compilation for this report could not have been accomplished without the efforts of the survey crews: Lamere Hennessee, Randall Kerhin, Kathryn Koczot, Laura Malinoski, Brian MacCubbin, William Panageotou, June Park, and Darlene Wells. Word processing help in assembling this report was accomplished by Sally Jones.

REFERENCES

Birkemeier, W.A., 1986, The Interactive Survey Reduction Program: Users's Manual to ISRP-PC 1.21, Waterways Experiment Station Coastal Engineering Research Center, Vicksburg, MS, 38 p.

Blatt, H., Middleton, G., and Murray, R., 1980, Origin of Sedimentary Rocks: Englewood Cliffs, NJ, Prentice-Hall, Inc., 782 p.

Butler, L.R.P., 1975, Application of atomic absorption spectrometry in geochemistry, in Dean, J.A., and Rains, T.C., eds., Flame Emission and Atomic Absorption Spectrometry: Volume 3 - Elements and Matrices: New York, Marcel Dekker, Inc., p. 510-547.

Cantillo, A.Y., 1982, Trace elements deposition histories in the Chesapeake Bay, Unpubl. Ph.D. dissertation, Chemistry Dept., Univ. of Maryland, College Park, MD, 298 p.

Halka, J.P., 1987, LORAN-C Calibration in Chesapeake Bay: Baltimore, MD, Maryland Geol. Survey Report of Investigations No. 47, 34 p.

Hennessee, L., Cuthbertson, R., and Hill, J.M., 1989, Sedimentary environment, in Assessment of the Environmental Impacts of the Hart-Miller Island Containment Facility: 6th Annual Interpretive Report Aug. 86 - Aug. 87: Annapolis, MD, Maryland Dept. of Natural Resources, Tidewater Admin., p. 9-96.

Hennessee, L., Cuthbertson, R., and Hill, J.M., 1990a, Sedimentary environment, in Assessment of the Environmental Impacts of the Hart and Miller Islands Containment Facility: 7th Annual Interpretive Report Aug. 87 - Aug. 88: Annapolis, MD, Maryland Dept. of Natural Resources, Tidewater Admin., p. 29-143.

Hennessee, L., Cuthbertson, R., and Hill, J.M., 1990b, Sedimentary environment, in Assessment of the Environmental Impacts of the Hart and Miller Islands Containment Facility: 8th Annual Interpretive Report Aug. 88 - Aug. 89: Annapolis, MD, Maryland Dept. of Natural Resources, Tidewater Admin., p. 20-144.

Johnson, B.H., Heath, R.E. and Kim, K., 1989, Development of a three-dimensional hydrodynamic model of the upper Chesapeake Bay: Final Report to the Maryland Dept. of Natural Resources, Tidewater Admin.

Kerhin, R.T., Hill, J., Wells, D.V., Reinharz, E., and Otto, S., 1982a, Sedimentary environment of Hart and Miller Islands, in Assessment of the Environmental Impacts of Construction and Operation of the Hart and Miller Islands Containment Facility: First Interpretive Report August 1981 - August 1982: Shady Side, MD, Chesapeake Research Consortium, p. 64-99.

Kerhin, R.T., Reinharz, E., and Hill, J., 1982b, Sedimentary environment, in Historical Summary of Environmental Data for the Area of the Hart and Miller Islands in Maryland: Hart and Miller Islands Special Report No. 1: Shady Side, MD, Chesapeake Research Consortium, p. 10-30.

Kerhin, R.T., Halka, J.P., Wells, D.V., Hennessee, E.L., Blakeslee, P.J., Zoltan, N., and Cuthbertson, R.H., 1988, The Surficial Sediments of Chesapeake Bay, Maryland: Physical Characteristics and Sediment Budget: Baltimore, MD, Maryland Geol. Survey Report of Investigations No. 48, 82 p.

Marquardt, D.W., 1963, An algorithm for least squares estimation of nonlinear parameters: Jour. Soc. Industrial and Applied Mathematics, v. 11, p. 431-441.

Pejrup, M., 1988, The triangular diagram used for classification of estuarine sediments: a new approach, in de Boer, P.L., van Gelder, A., and Nio, S.D., eds., Tide-Influenced Sedimentary Environments and Facies: Dordrecht, Holland, D. Reidel Publishing Co., p. 289-300.

Shepard, F.P., 1954, Nomenclature based on sand-silt-clay ratios: Jour. Sed. Petrology, v. 24, p. 151-158.

Sinex, S.A., Cantillo, A.Y., and Helz, G.R., 1980, Accuracy of acid extraction methods for trace metals in sediments, Anal. Chem., v. 52, p. 2342-2346.

Sinex, S.A., and Helz, G.R., 1981, Regional geochemistry of trace metals in Chesapeake Bay sediments, Environ. Geology, v. 3, p. 315-323.

Suhr, N.H., and Ingamells, C.O., 1966, Solution techniques for analysis of silicates, Anal. Chem., v. 38, p. 730-734.

Tukey, J.W., 1977, Exploratory Data Analysis: Reading, MA, Addison-Wesley Publishing Co., 688 p.

Van Loon, J.C., 1980, Analytical Atomic Absorption Spectroscopy: Selected Methods: New York, Academic Press, 337 p.

Wells, D.V., and Kerhin, R.T., 1983, Areal extent of recently introduced sediments to the Hart-Miller Islands area: Unpubl. special report submitted to Chesapeake Research Consortium: Baltimore, MD, Maryland Geol. Survey, 30 p.

Wells, D.V., and Kerhin, R.T., 1985, Modification of the sedimentary environment during construction of the Hart-Miller Island Diked Disposal Facility, in Magoon, O.T., Converse, H., Miner, D., Clark, D., and Tobin, L.T., eds., Coastal Zone '85: Volume 2: New York, Amer. Soc. of Civil Engineers, p. 1462-1480.

Wells, D.V., Kerhin, R.T., Reinharz, E., Hill, J., and Cuthbertson, R., 1984, Sedimentary environment of Hart and Miller Islands, in Assessment of the Environmental Impacts of Construction and Operation of the Hart and Miller Islands Containment Facility: Second Interpretive Report August 1982 - August 1983: Shady Side, MD, Chesapeake Research Consortium, p. 64-150.

Wells, D.V., Kerhin, R.T., Hill, J., Cuthbertson, R., and Reinharz, E., 1985, Sedimentary environment, in Assessment of the Environmental Impacts of Construction and Operation of the Hart and Miller Islands Containment Facility: 3rd Annual Interpretive Report Aug. '83 - Aug. '84: Annapolis, MD, Maryland Dept. of Natural Resources, Tidewater Admin., p. 93-247.

Wells, D.V., Conkwright, R.D., Hill, J.M., and Cuthbertson, R.H., 1986, Sedimentary environment, in Assessment of the Environmental Impacts of the Hart and Miller Islands Containment Facility: 4th Annual Interpretive Report Aug. '84 - Aug. '85: Annapolis, MD, Maryland Dept. of Natural Resources, Tidewater Admin., p. 19-103.

Wells, D.V., Cuthbertson, R., and Hill, J., 1987, Sedimentary environment, in Assessment of the Environmental Impacts of the Hart and Miller Islands Containment Facility: 5th Annual Interpretive Report Aug. '85 - Aug. '86: Annapolis, MD, Maryland Dept. of Natural Resources, Tidewater Admin., p. 9-87.

APPENDICES

Appendix A:	Hart-Miller Island time line, showing dates of Project II monitoring cruises.
Appendix B:	Xeroradiographies of the gravity cores.
Appendix C:	Contour maps of % sand, for all post-construction cruises (November 1983 - April 1990).
Appendix D:	Contour maps of clay:mud ratios for all post-construction cruises (November 1983 - April 1990).
Appendix E:	Contour maps of % excess Zn for seven monitoring periods.
Appendix F:	Contour maps of Cd concentrations for six consecutive April cruises (1985-1990).
Appendix G:	Cross-sectional profiles of the recreational beach.
Appendix H:	Cross-sectional profiles of the recommended renourished beach.

Appendix A

Hart-Miller Island time line, showing dates of Project II monitoring cruises.

HART-MILLER ISLAND TIME LINE

Monitoring year	Cruise	Date MM/YY	Date MM/DD/YY	Event
1	1	8/81	8/27/81	
	2	12/81	12/ 2/81	
	3	2/82	2/24/82	
	4	7/82	7/ 2/82	
2	5	10/82	10/ 6/82	
	6	12/82	12/17/82	
	7	2/83	2/24/83	
	8	6/83	6/ 2/83	
3	9	11/83	11/28/83	
	10	6/84	6/ 6/84	
4	11	11/84	11/26/84	
	12	4/85	4/15/85	
5	13	11/85	11/ 6/85	
	14	4/86	4/28/86	
				10/25/86 - Began discharging from spillway #1
6	15	11/86	11/20/86	
				3/27-31/87 - Dredged access channel - N unloading facility
	16	4/87	4/22/87	
				5/87 - Start date - Contract #1
7	17	11/87	11/ 3/87	
	18	4/88	4/12/88 4/14/88	
				4/25/88 - Began discharging from spillway #2
				5/88 - Began discharging from spillway #3
8	19	11/88	11/15/88	
	20	4/89	4/ 3/89 4/ 4/89	Zn enrichment detected
				9/15/89 - Projected start date - Contract #2

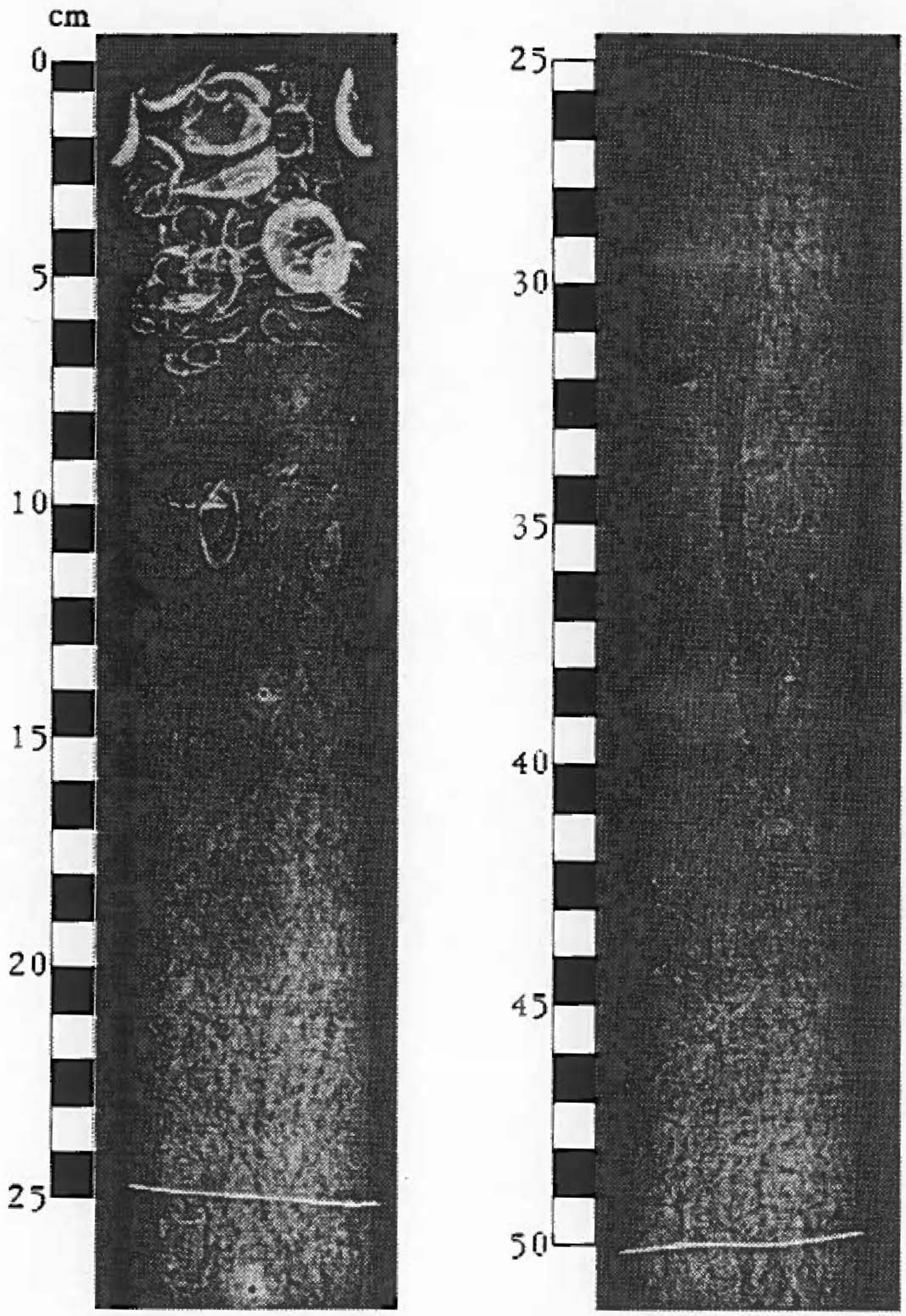
HART-MILLER ISLAND TIME LINE, CON'T

Monitoring year	Cruise	Date MM/YY	MM/DD/YY	Event
9	21	11/89	11/14/89	
	22	1/90	1/16/90	
			1/17/90	
			1/25/90	
	23	4/90	4/18/90	
			4/19/90	

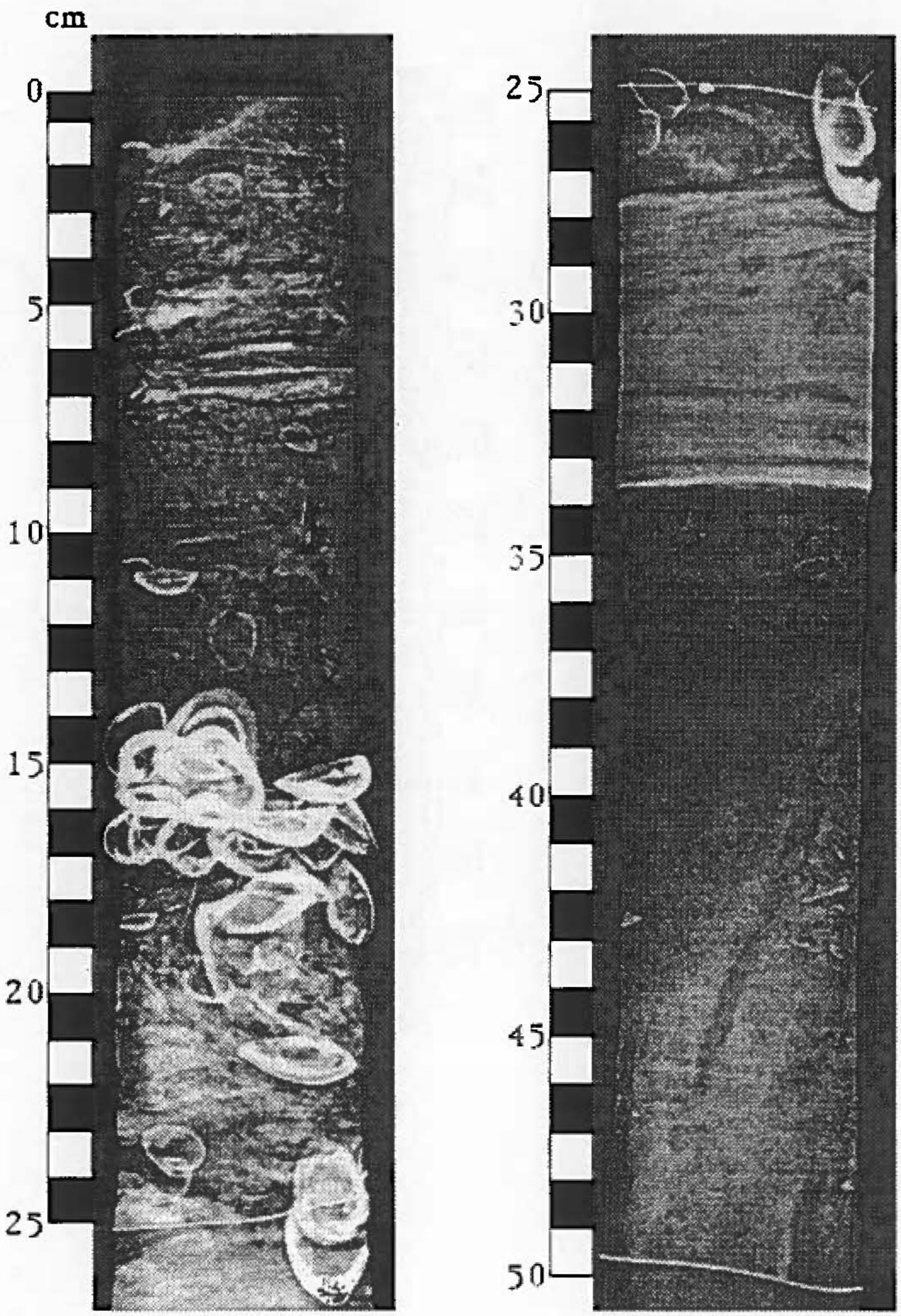
Appendix B

Xeroradiographies of the gravity cores.

HART-MILLER ISLAND - 9th Year
Core 25   November 14, 1989

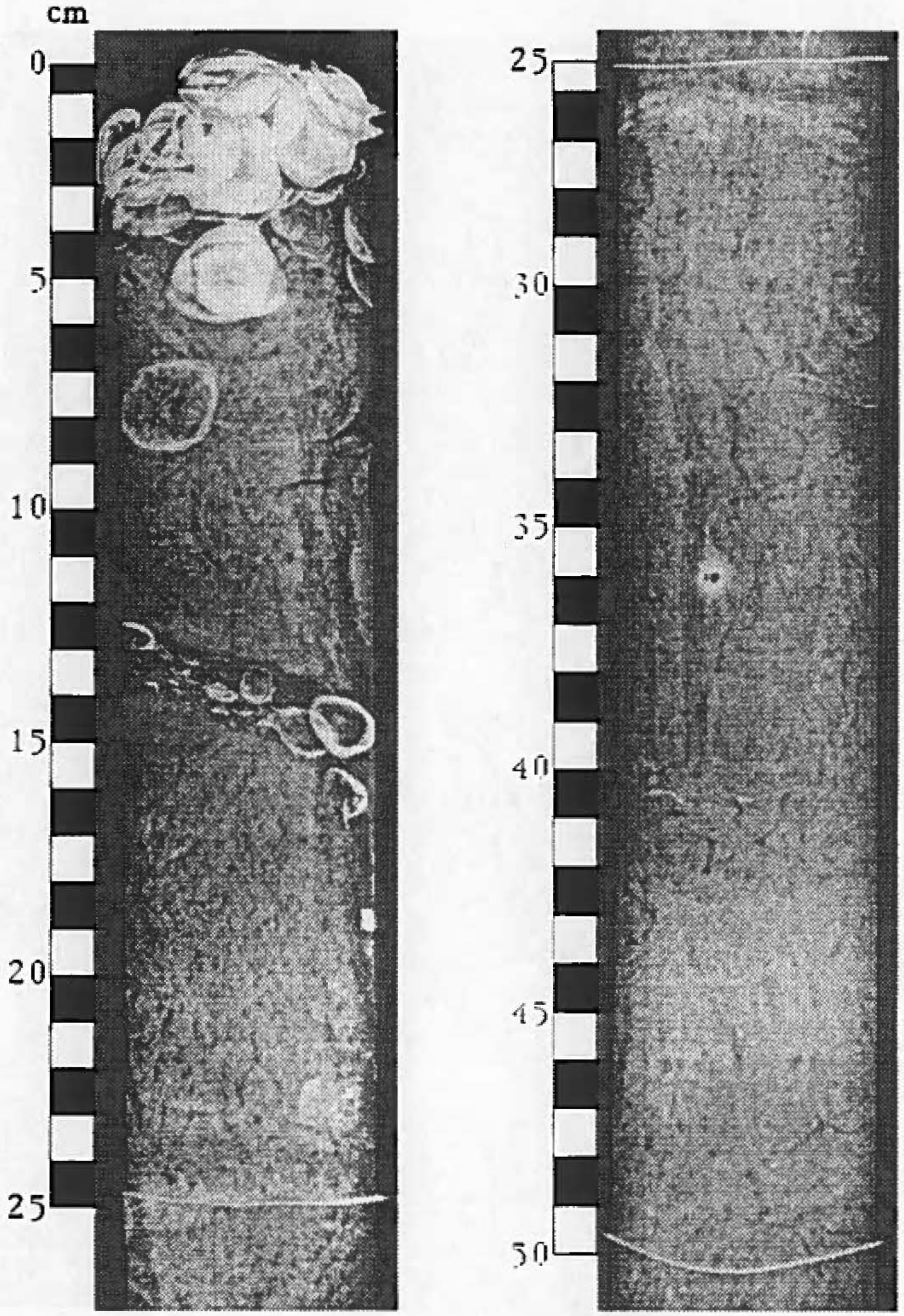


HART-MILLER ISLAND - 9th Year
Core 5   April 19, 1990

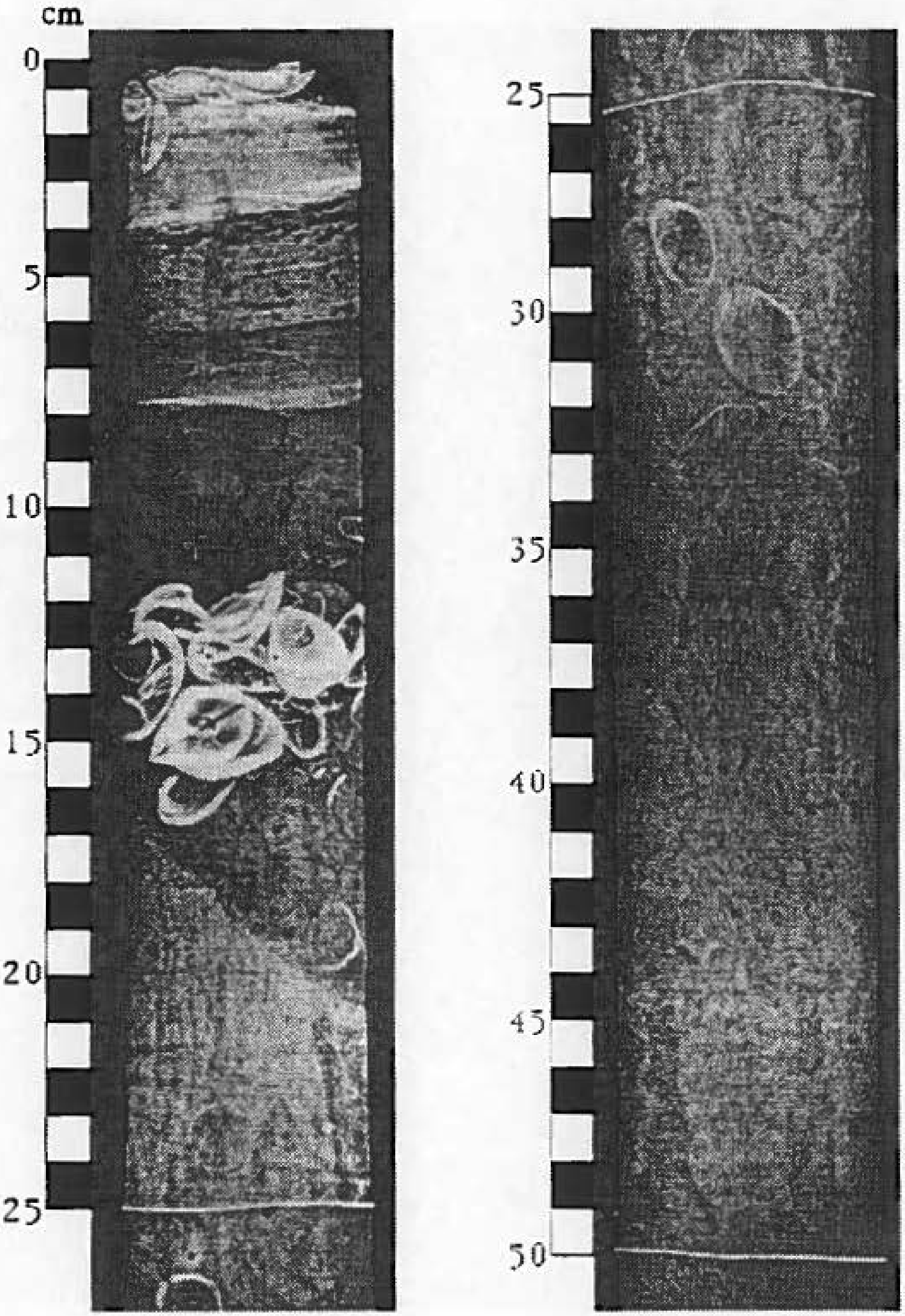


HART-MILLER ISLAND - 9th Year
Core 12 April 19, 1990

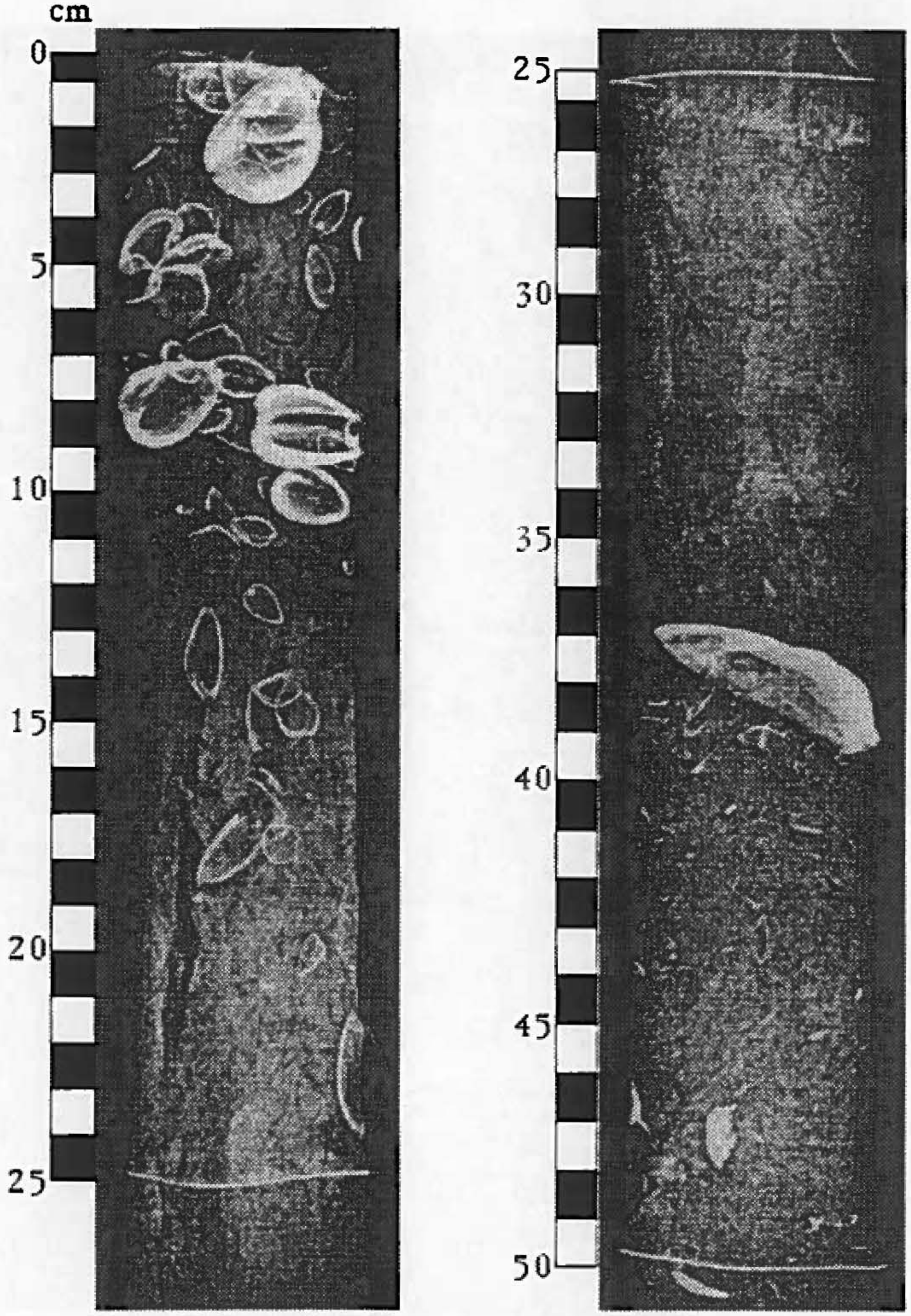
HART-MILLER ISLAND - 9th Year
Core 25 April 19, 1990



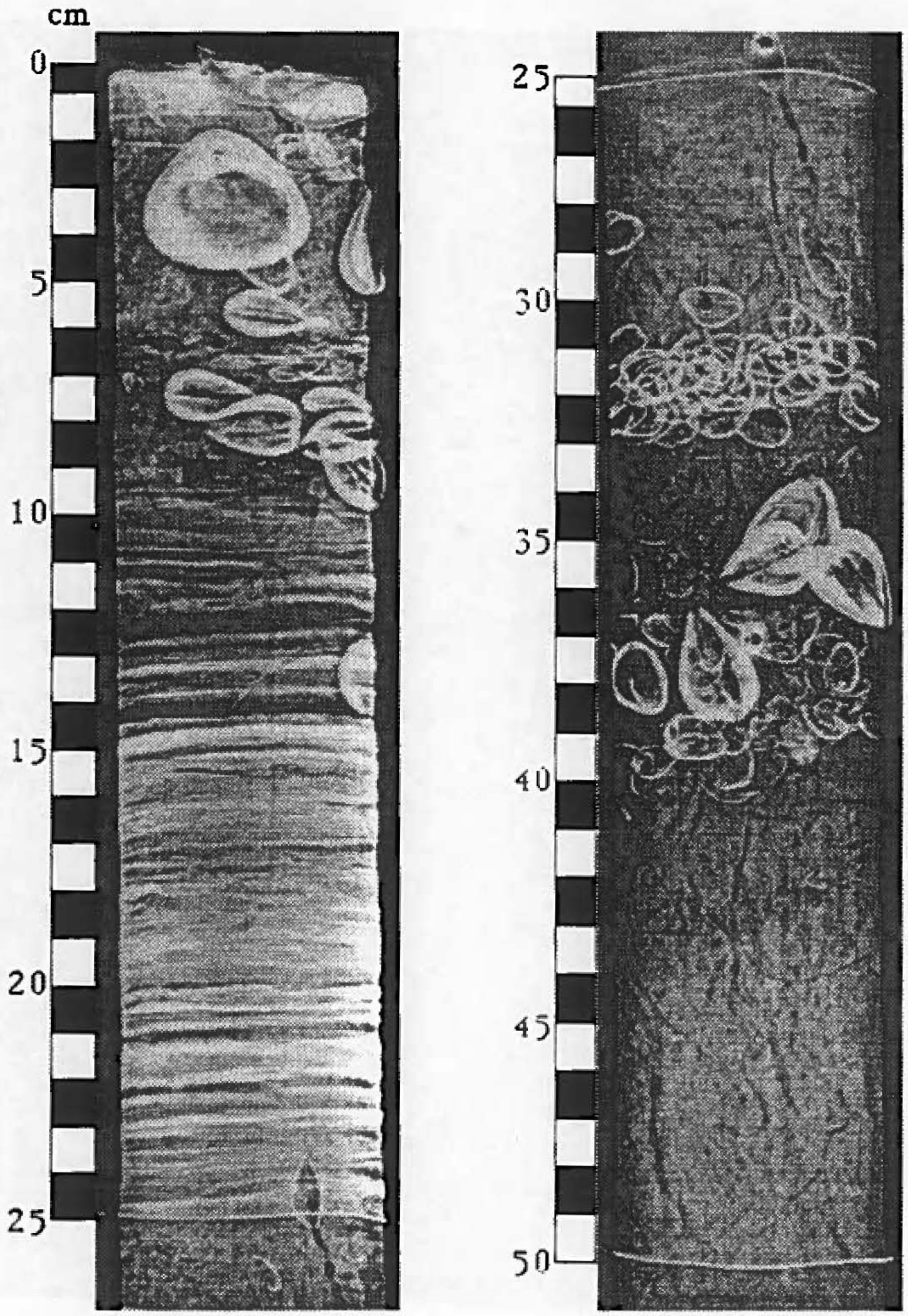
HART-MILLER ISLAND - 9th Year
Core BC-1 April 19, 1990



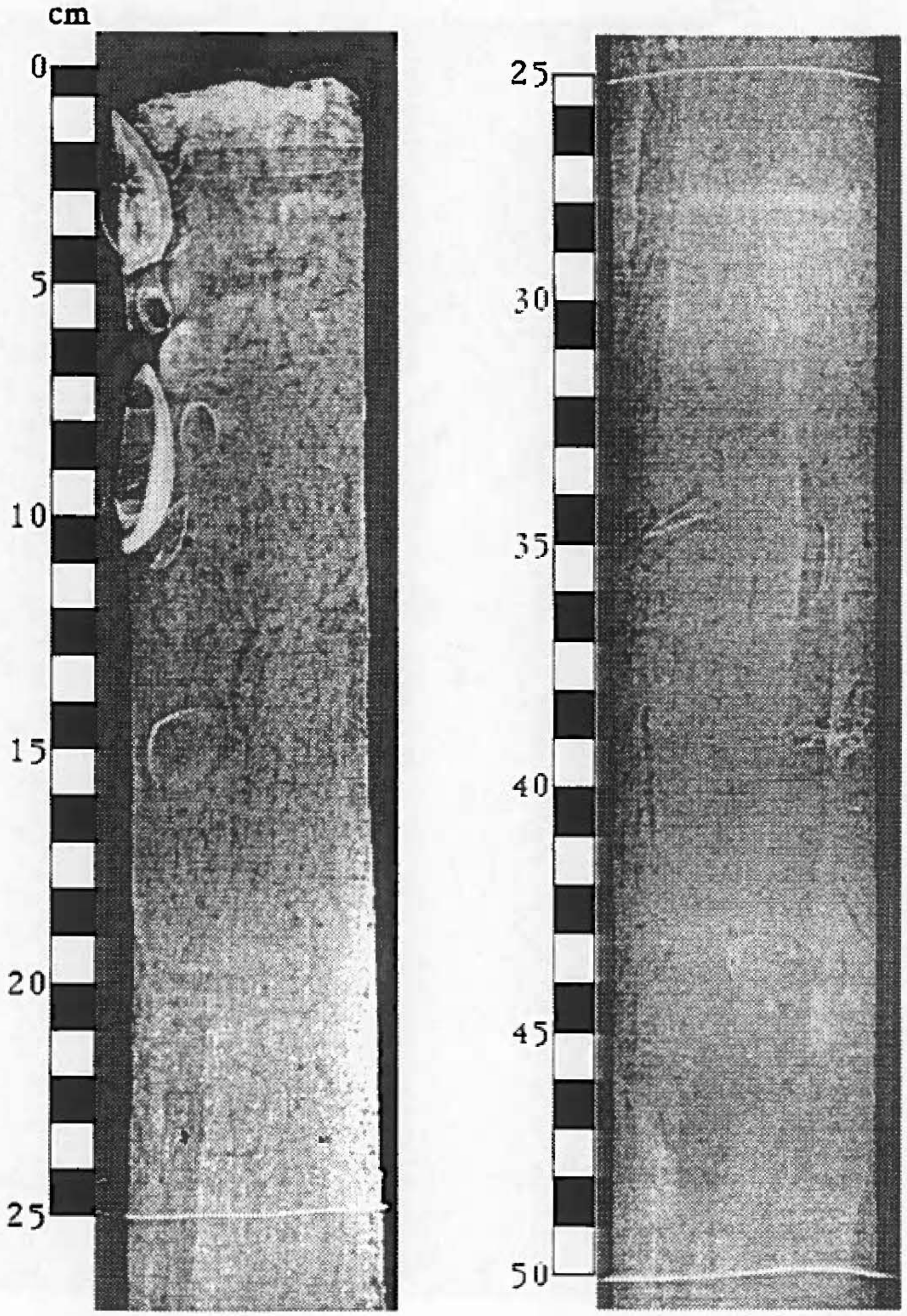
HART-MILLER ISLAND - 9th Year
Core BC-2 April 19, 1990



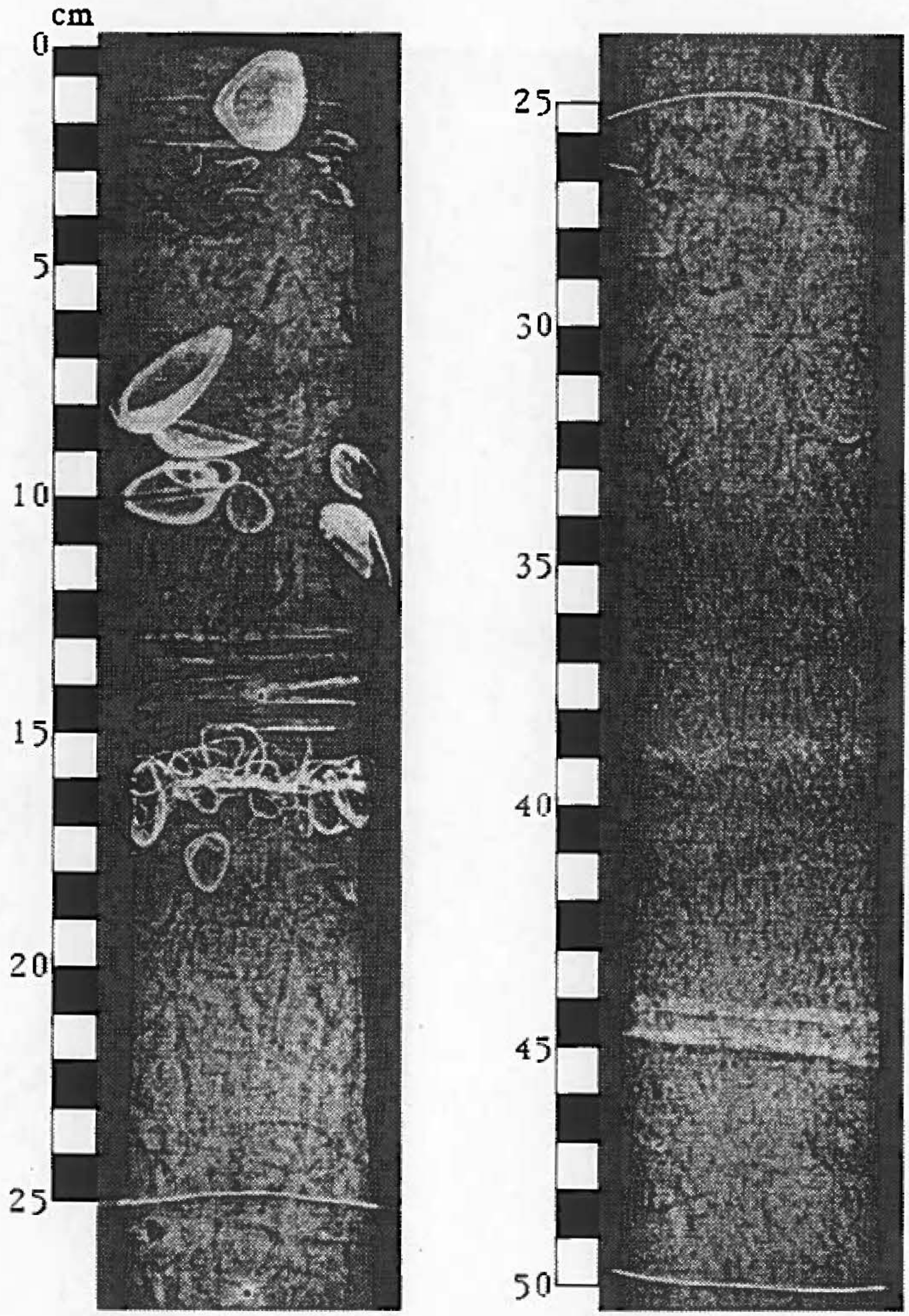
HART-MILLER ISLAND - 9th Year
Core BC-3 April 19, 1990



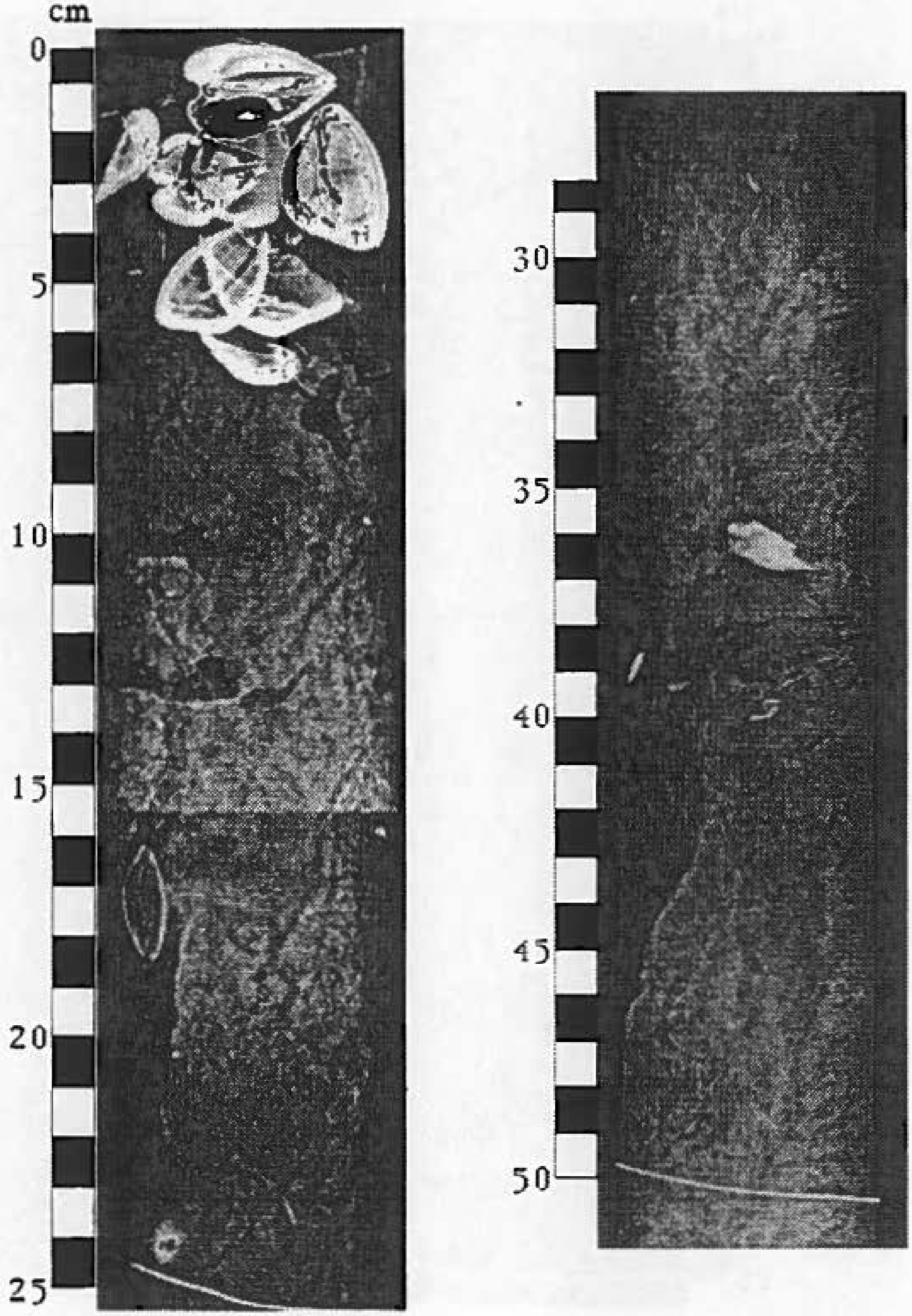
HART-MILLER ISLAND - 9th Year
Core BC-4   April 19, 1990



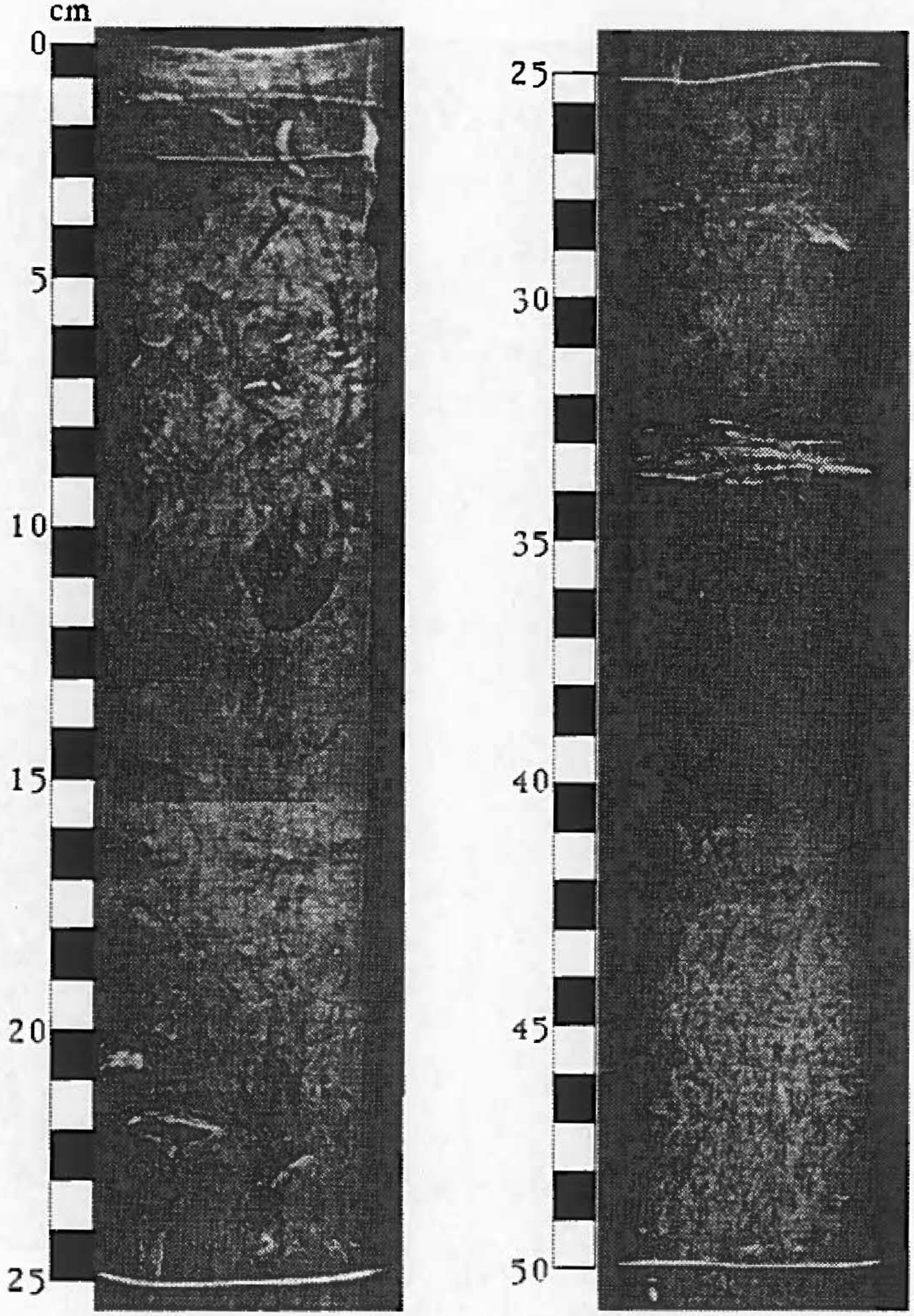
HART-MILLER ISLAND - 9th Year
Core BC-5   April 19, 1990



HART-MILLER ISLAND - 9th Year
Core BC-6 April 19, 1990

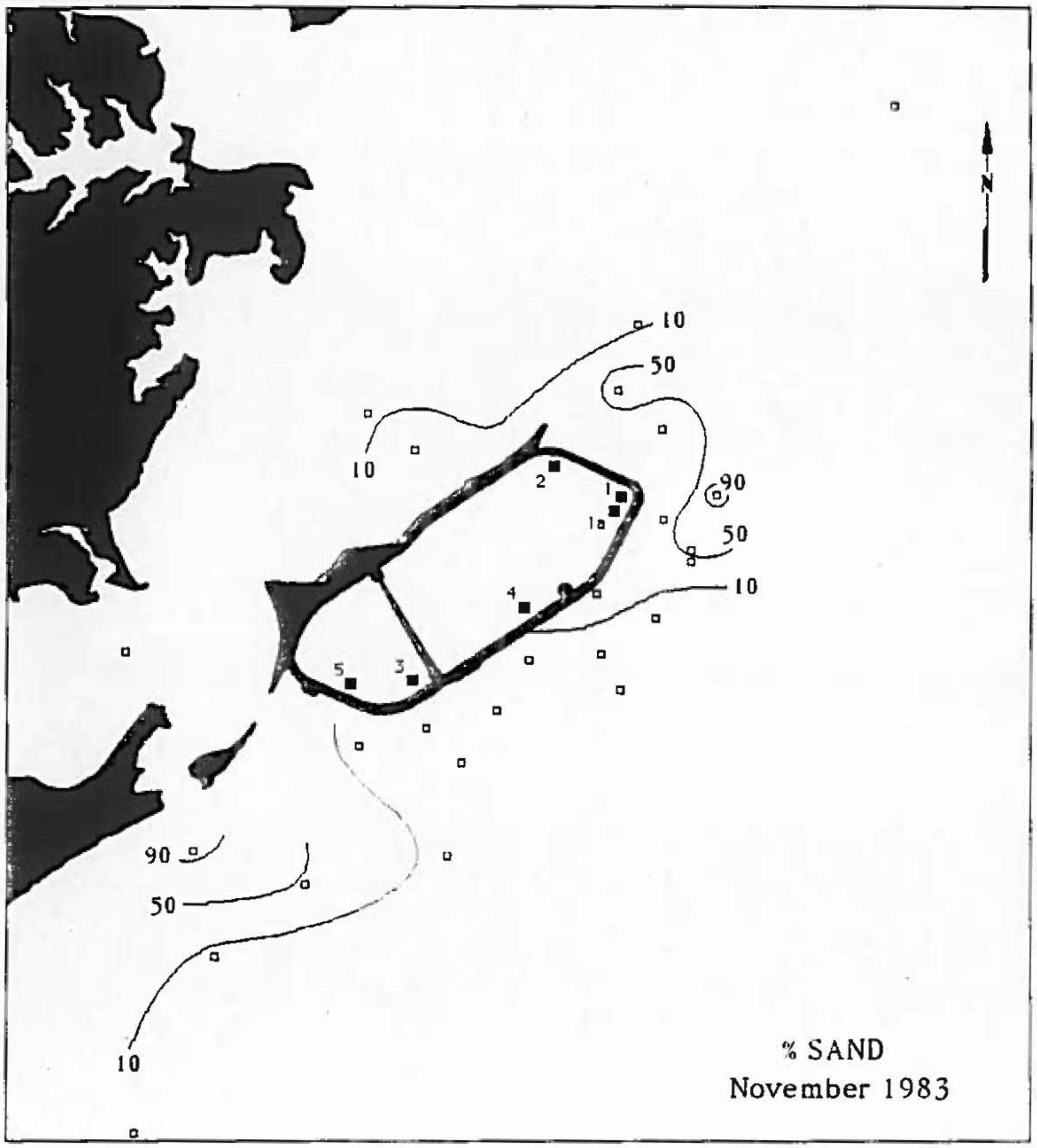


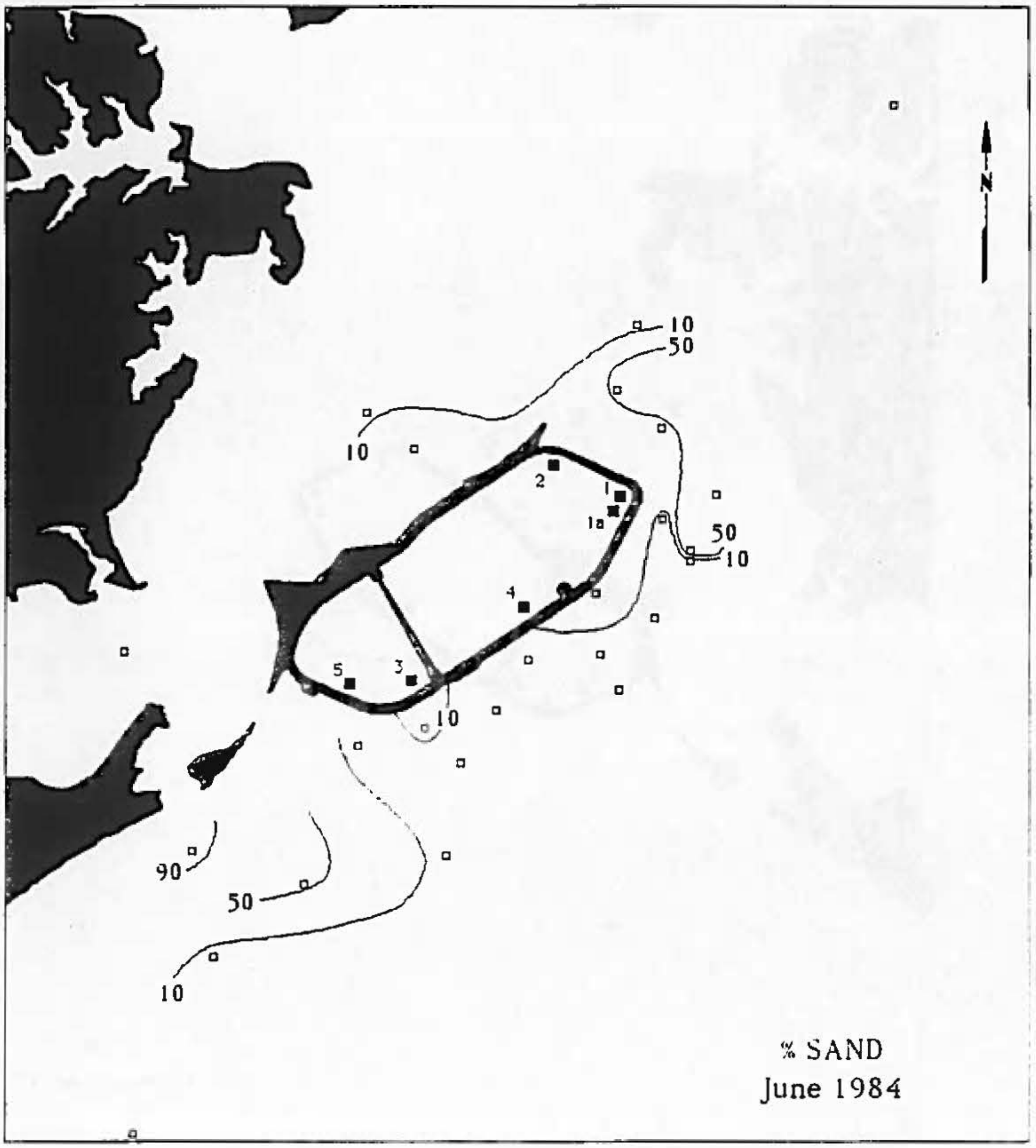
HART-MILLER ISLAND - 9th Year
Core BC-7 April 19, 1990

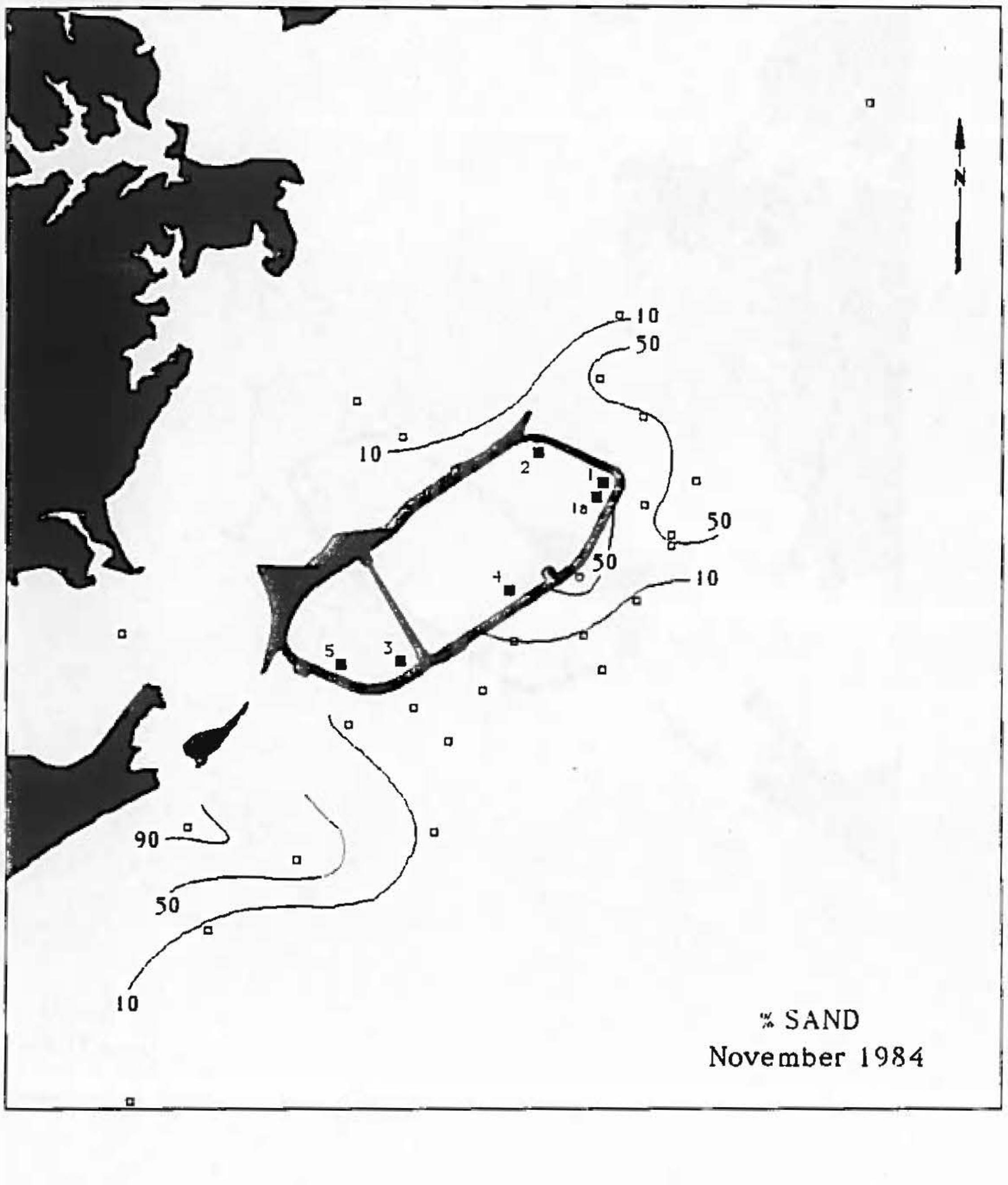


Appendix C

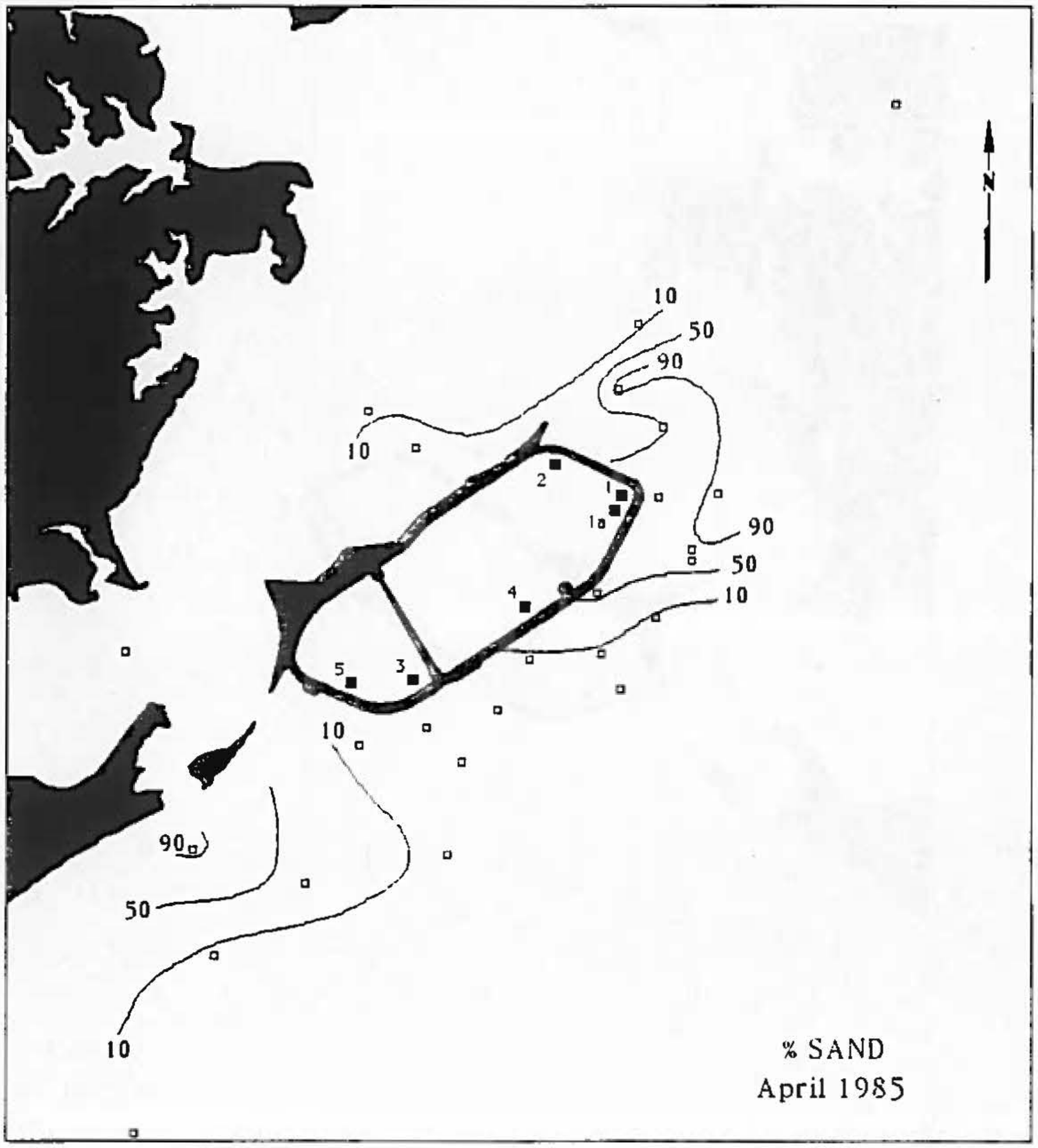
Contour maps of % sand, for all post-construction cruises (November 1983 - April 1990).


N
10
50
10
2
1
1a
90
50
4
10
5
3
90
50
10
% SAND
November 1983

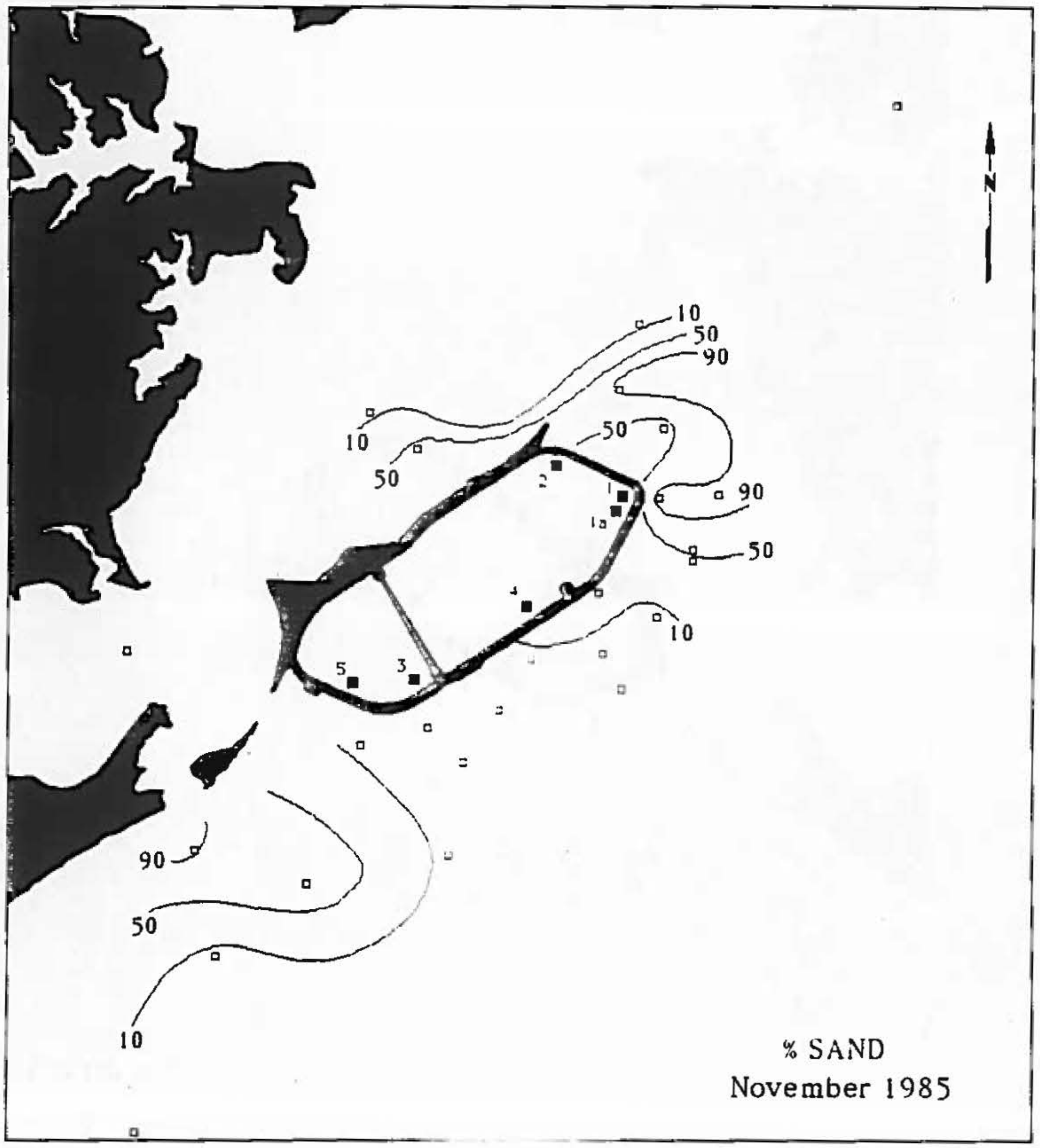

10
50
10
2
1
1a
50
10
4
5
3
10
90
50
10
% SAND
June 1984
N



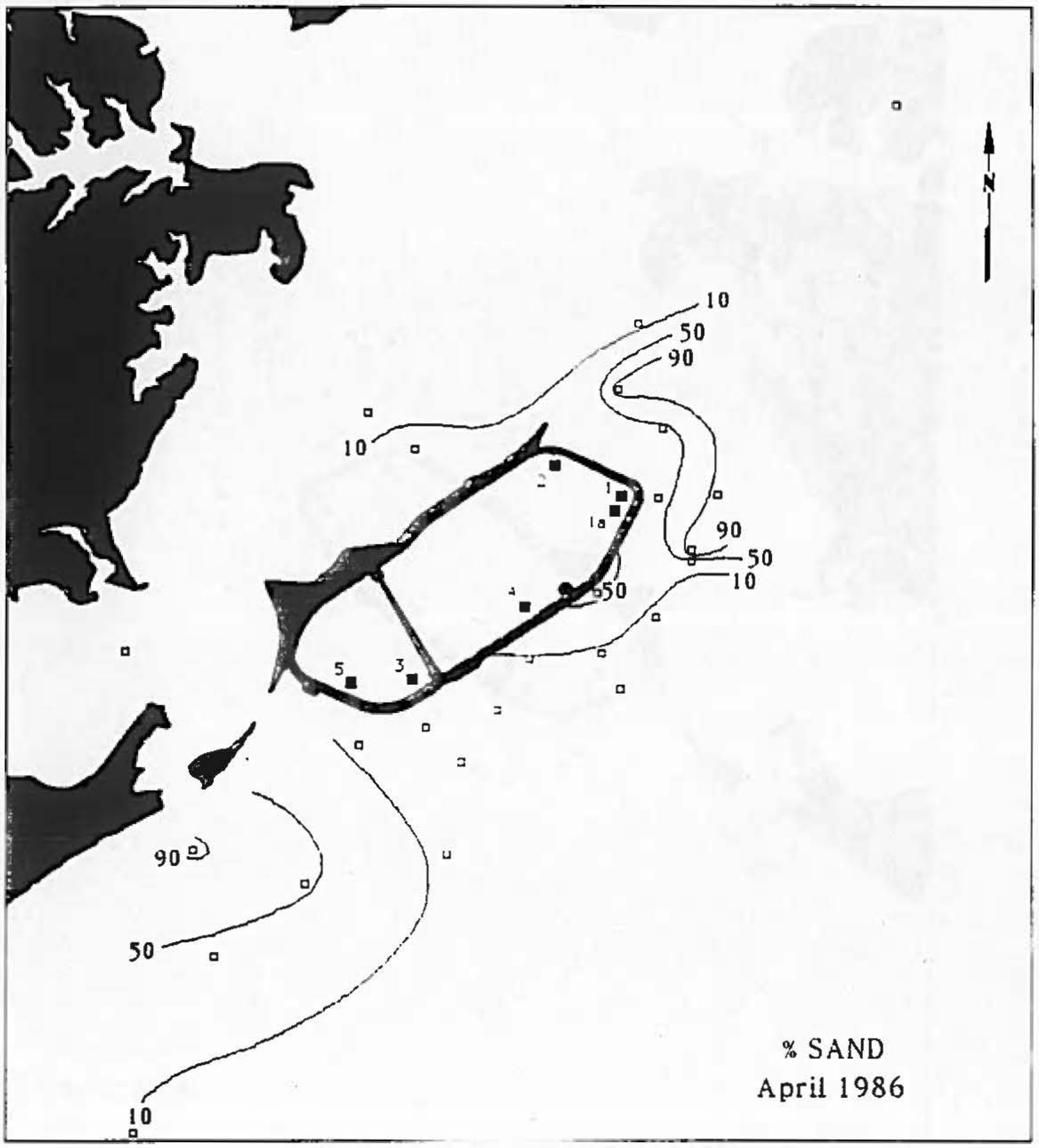
10
50
10
2
1
1a
50
50
4
10
5
3
90
50
10
% SAND
November 1984



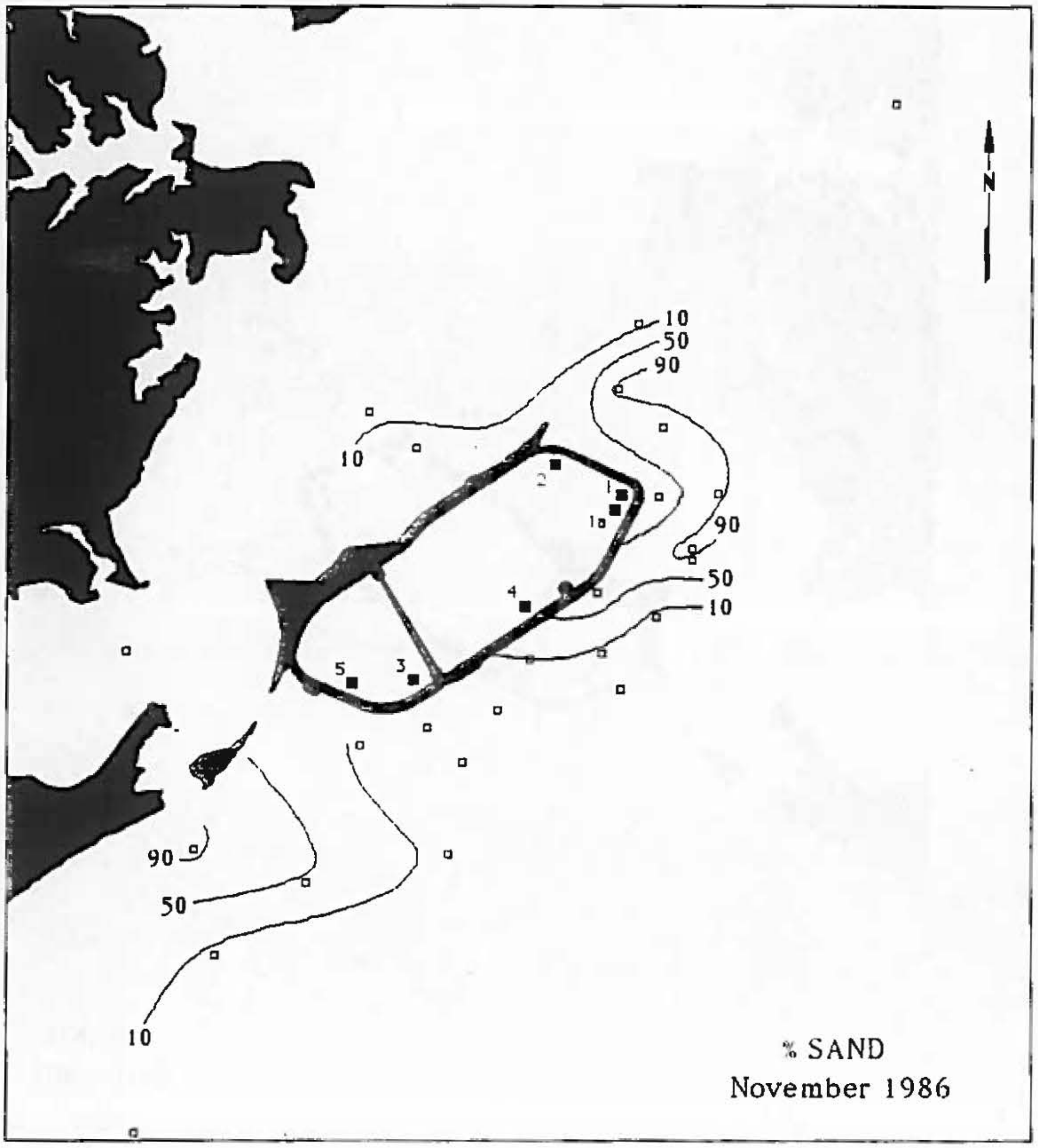
N
10
50
90
10
2
1
1a
90
50
10
4
5
3
10
90
50
10
% SAND
April 1985



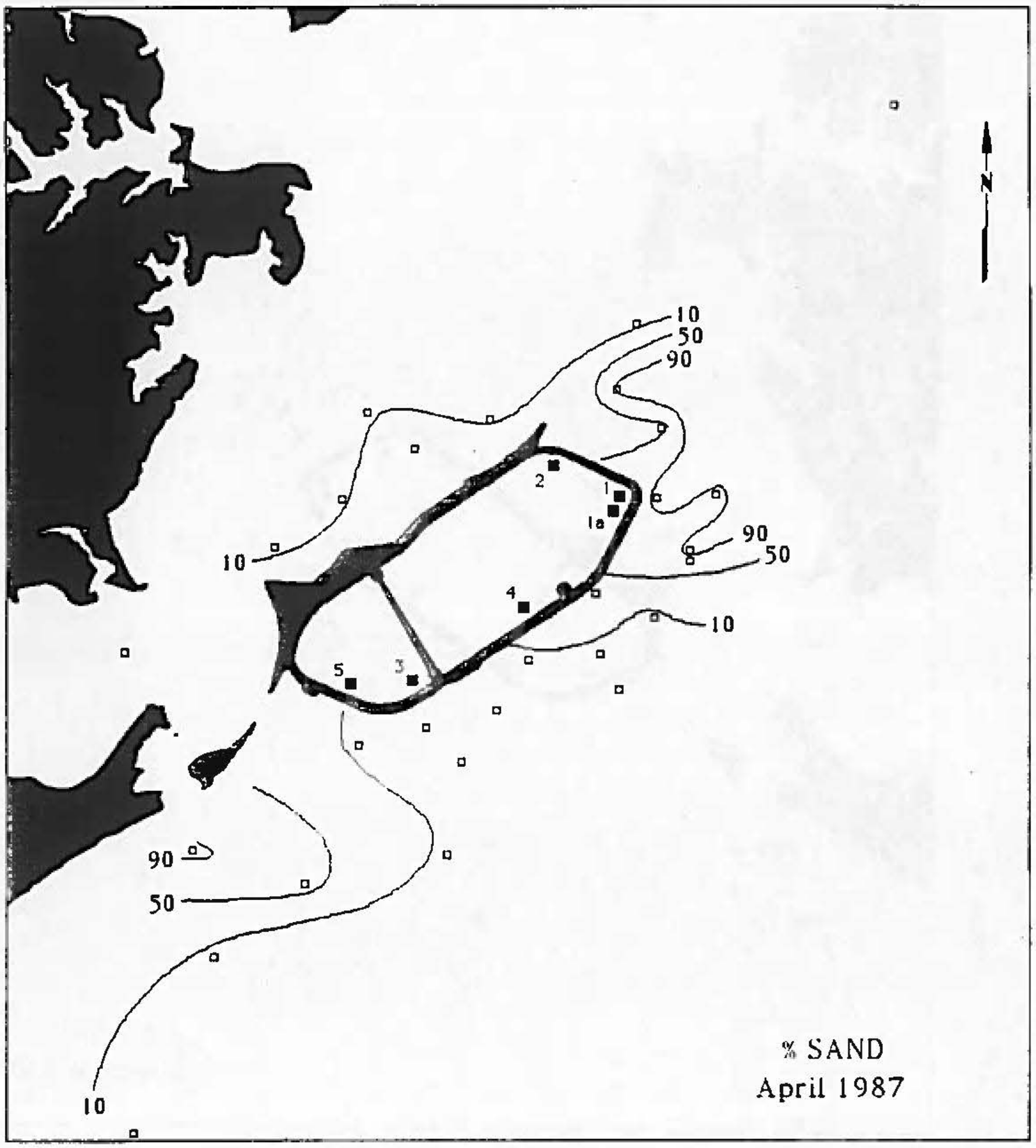
N
10
50
90
10
50
50
90
50
10
90
50
10
% SAND
November 1985



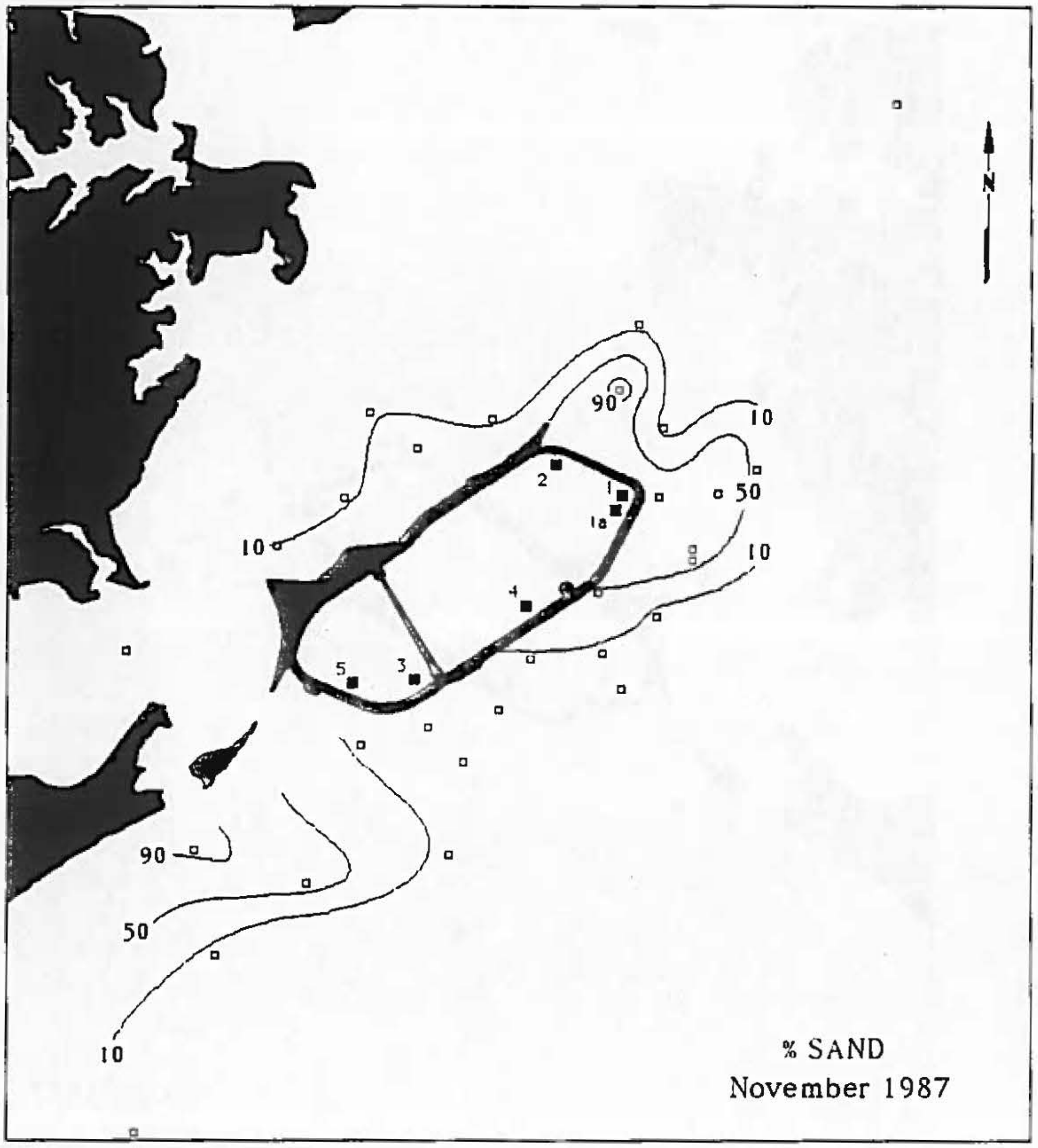
N
10
50
90
10
2
1
1a
90
50
10
50
4
5
3
90
50
10
% SAND
April 1986

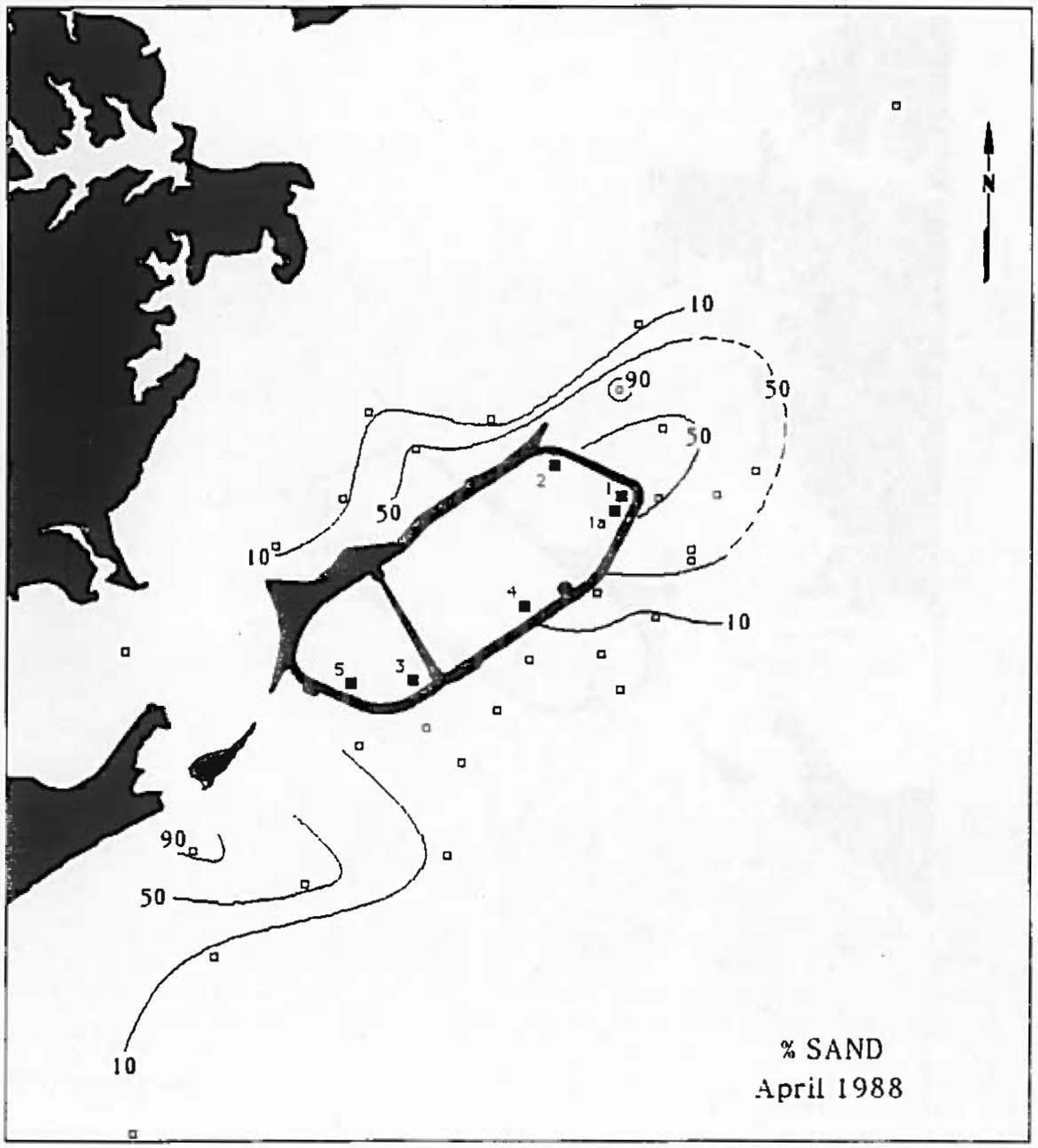


N
10
50
90
10
2
1
1a
90
50
10
4
5
3
90
50
10
% SAND
November 1986

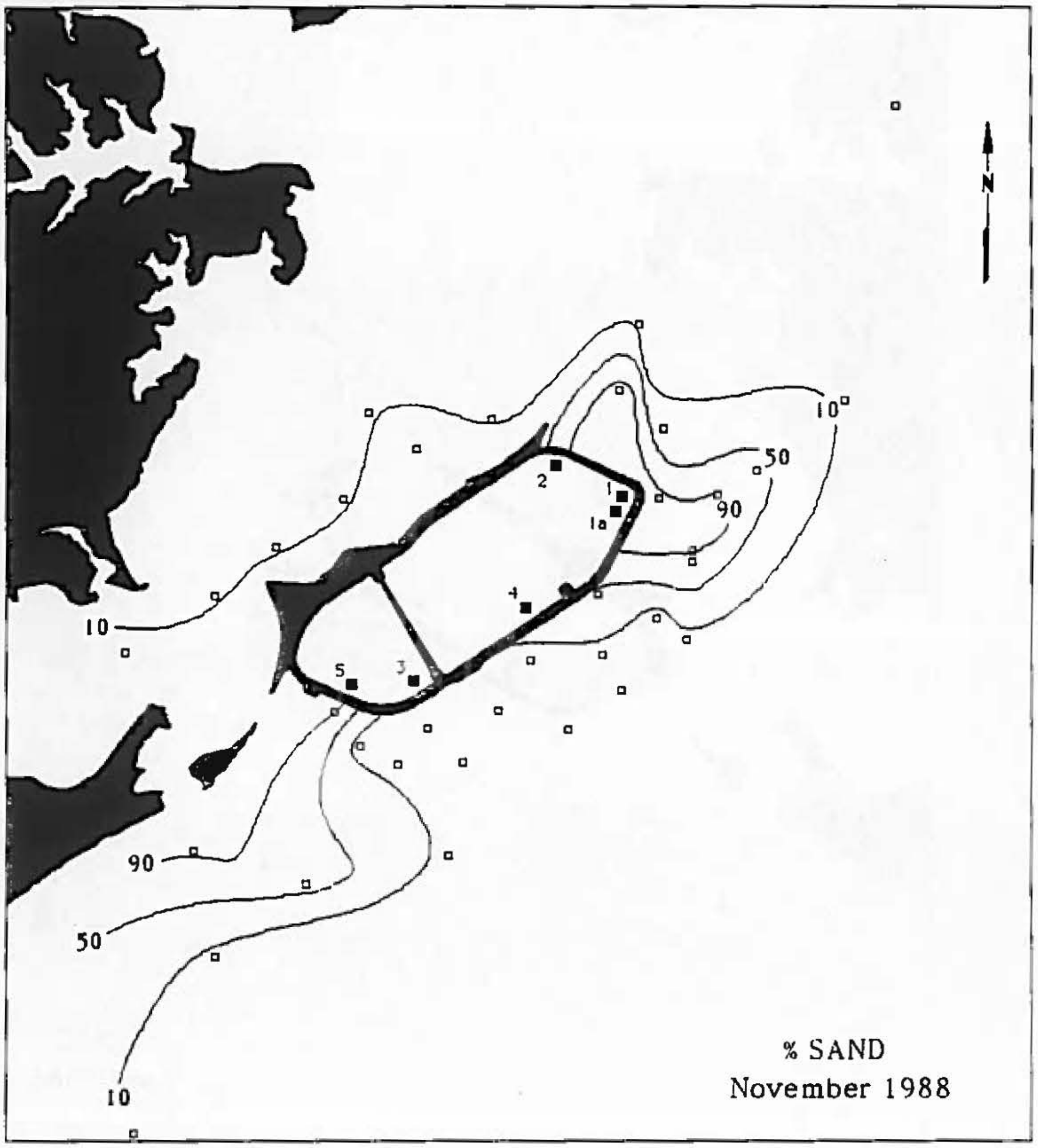


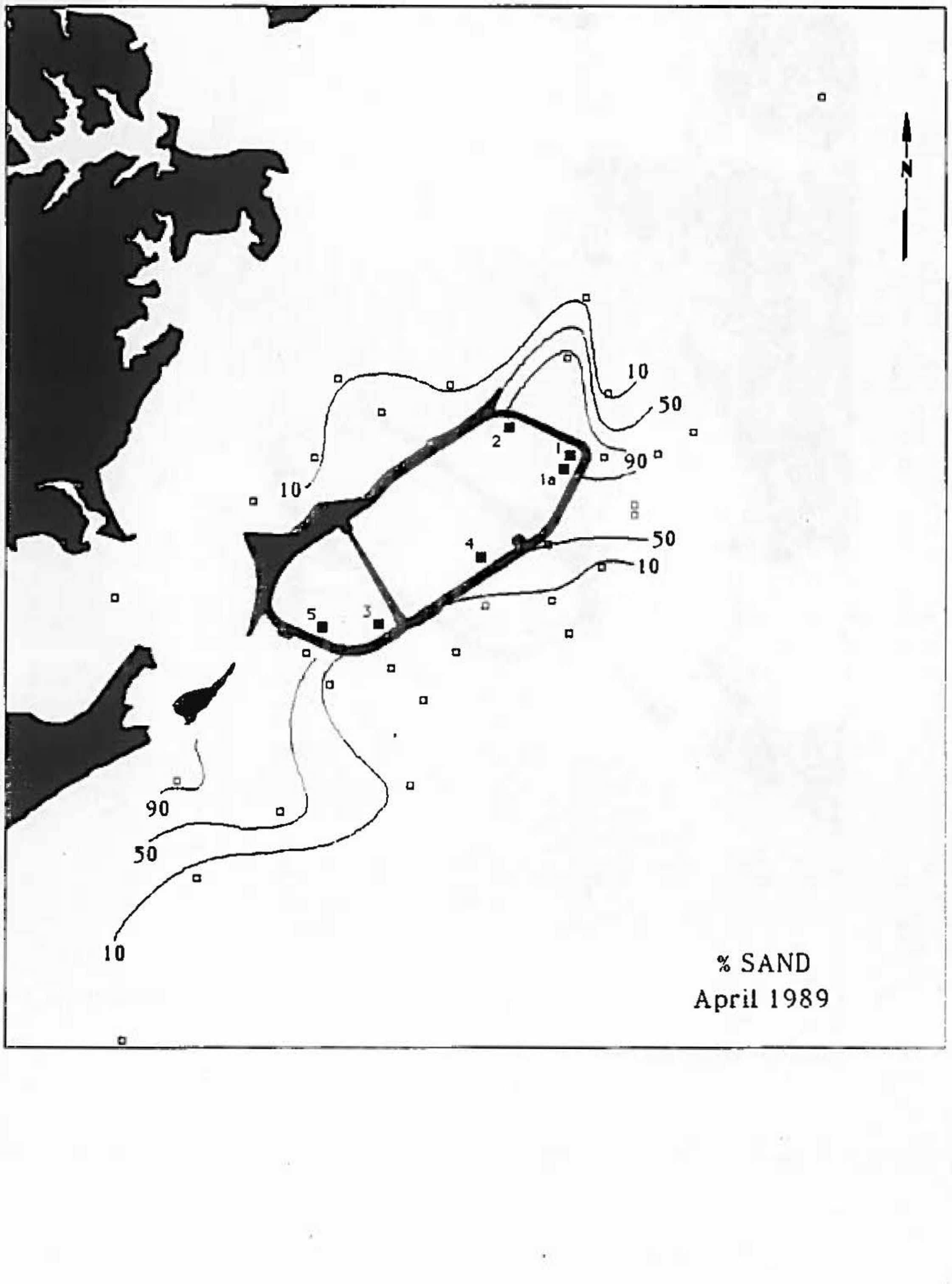
10
50
90
2
1
1a
90
50
10
4
10
5
3
90
50
10
% SAND
April 1987
N

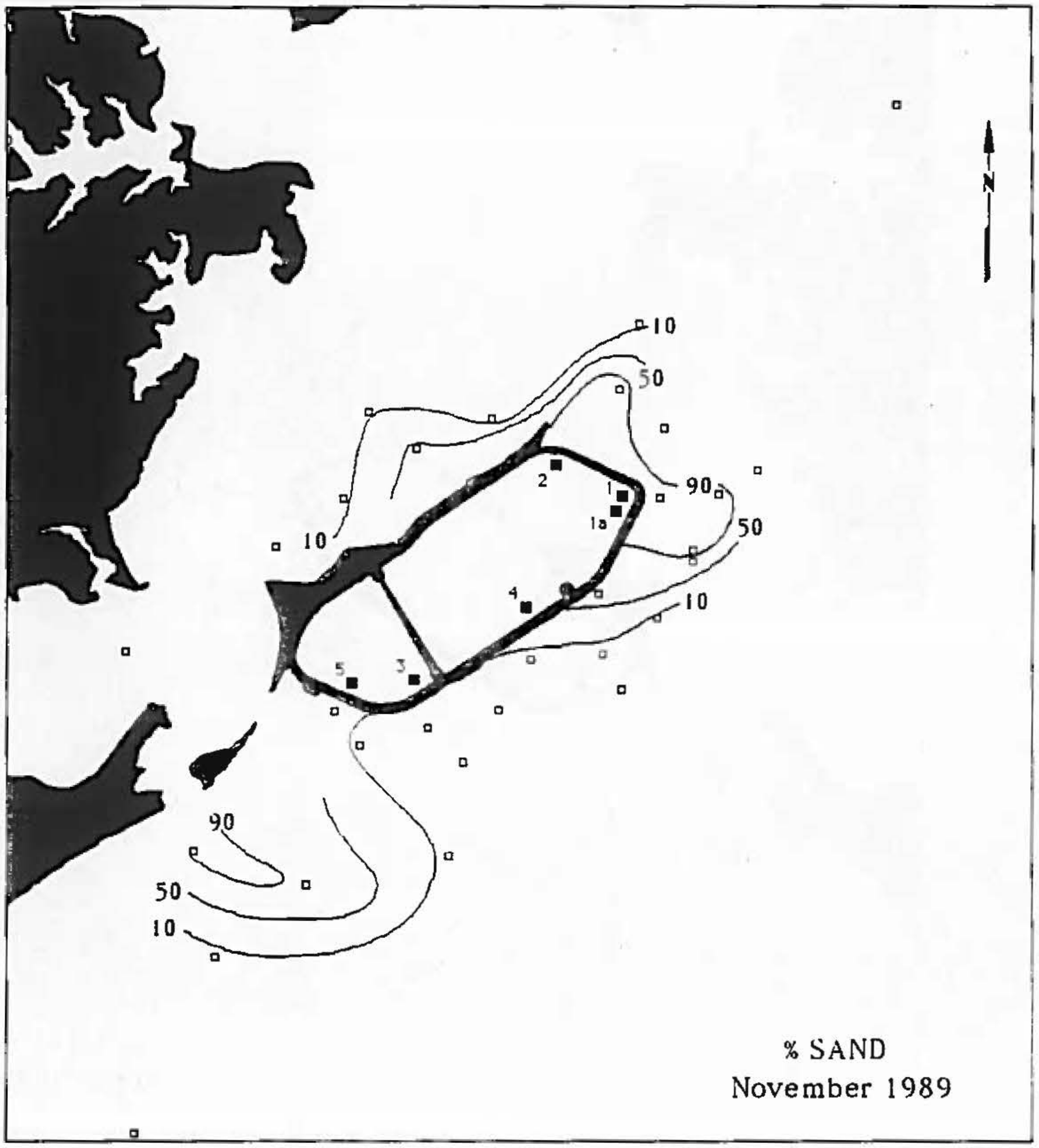

N
90
10
2
1
1a
50
10
10
4
5
3
90
50
10
% SAND
November 1987

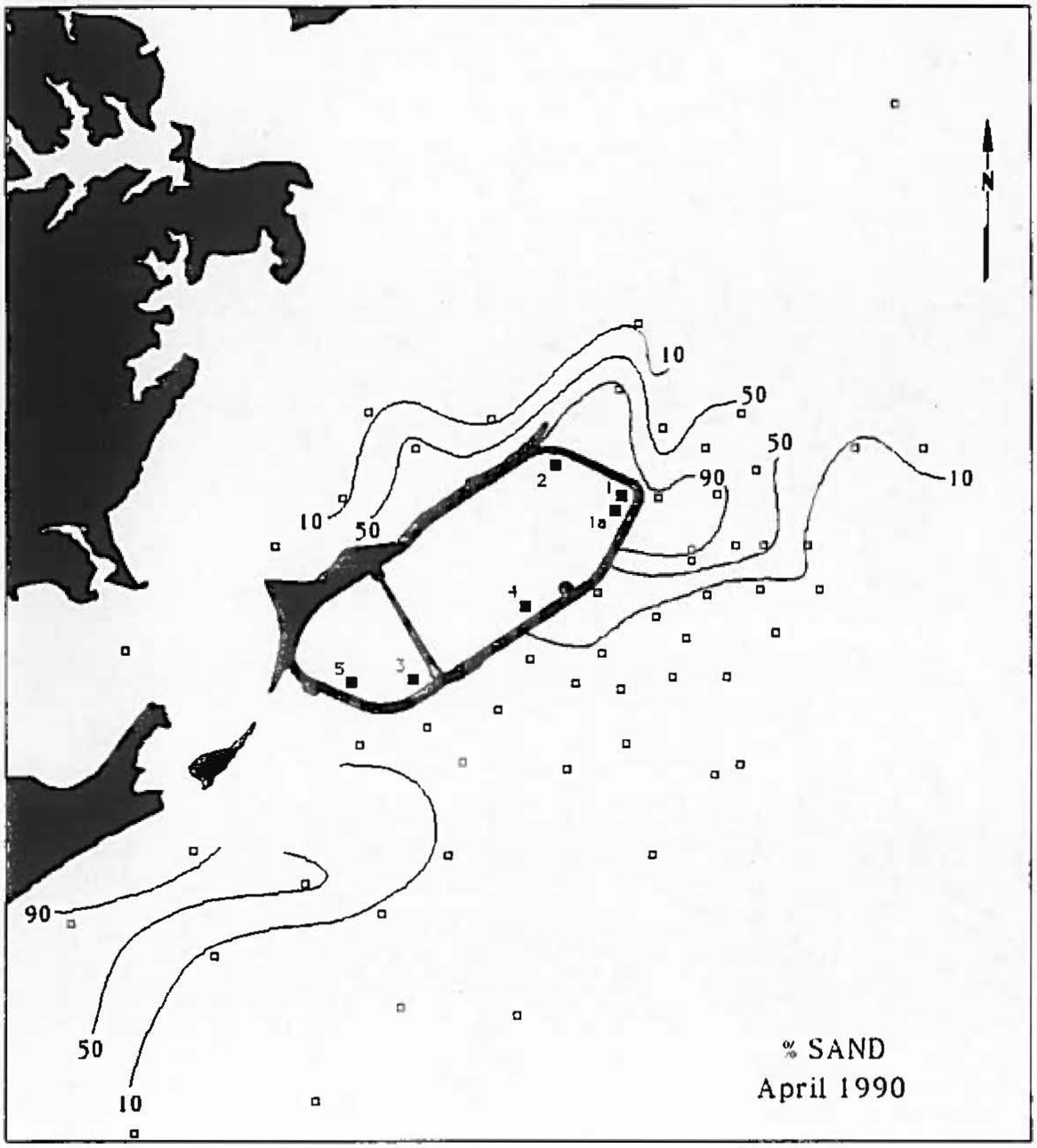


N
10
90
50
50
2
1
1a
50
10
4
10
5
3
90
50
10
% SAND
April 1988


N
10
50
90
2
1
1a
4
5
3
10
90
50
10
% SAND
November 1988

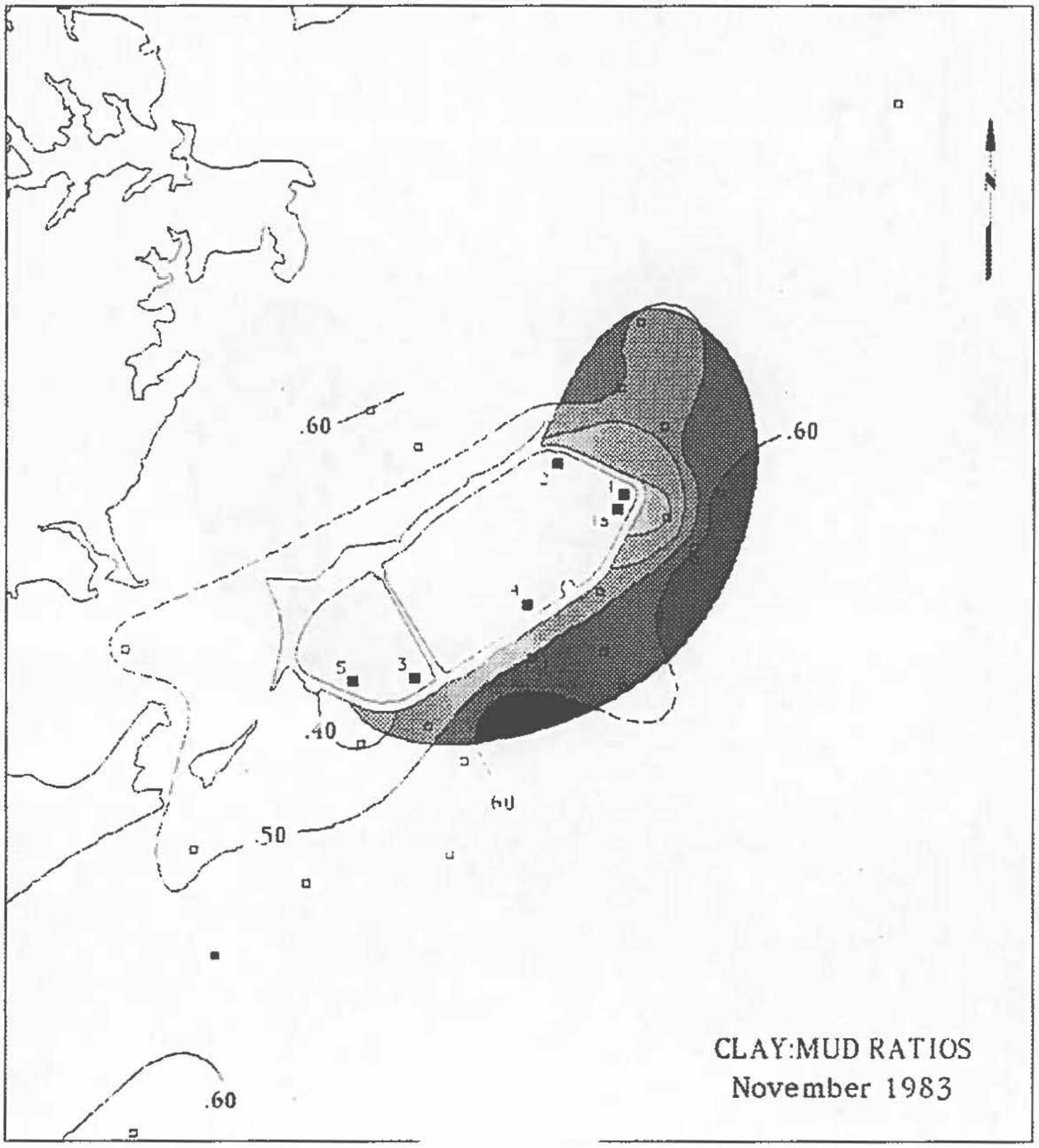

N
10
50
90
2
1
1a
10
50
10
4
5
3
90
50
10
% SAND
April 1989


10
50
2
1
1a
90
50
10
10
4
5
3
90
50
10
% SAND
November 1989

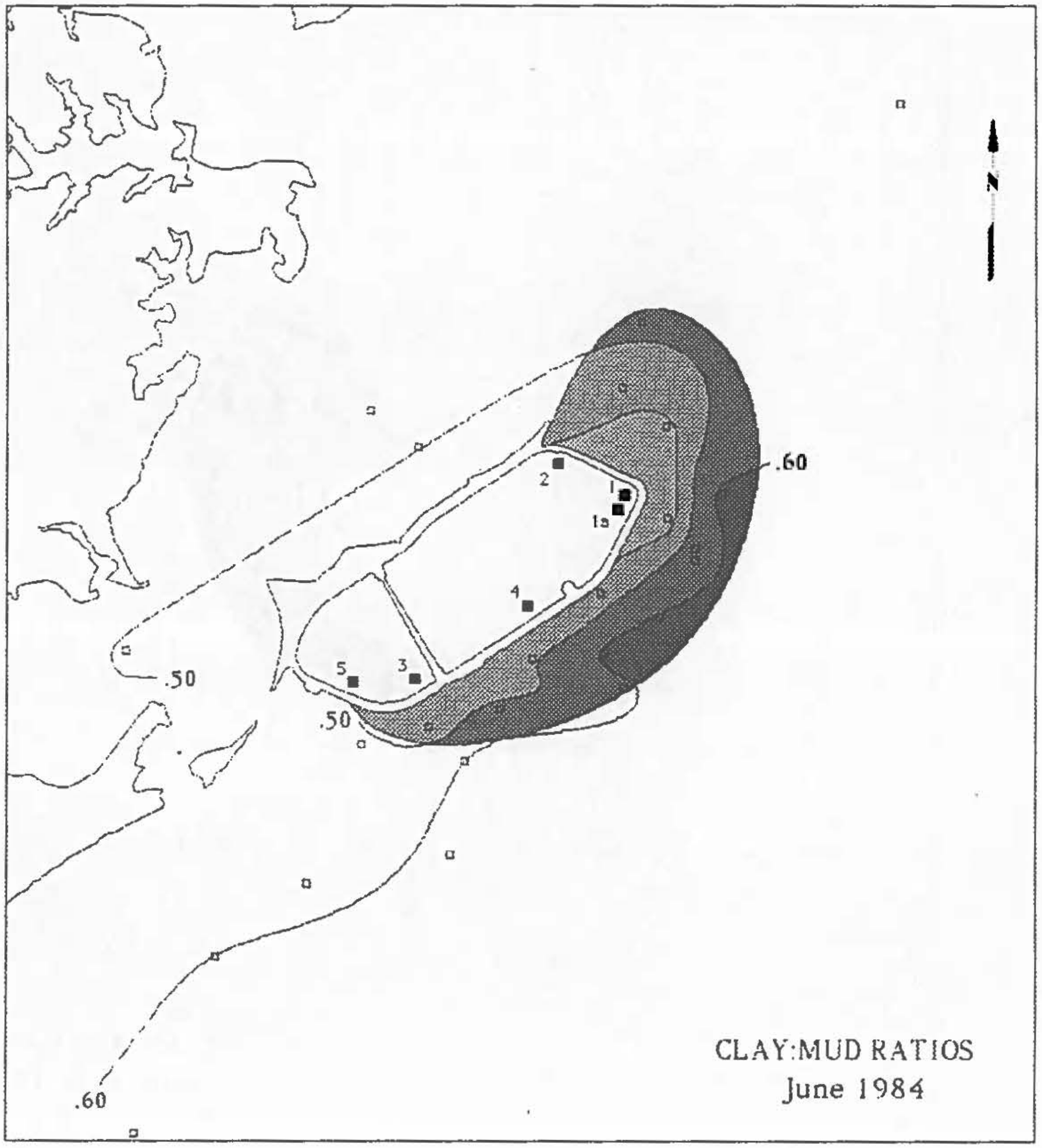

N
10
50
50
90
10
2
1
1a
10
50
4
5
3
90
50
10
% SAND
April 1990

Appendix D

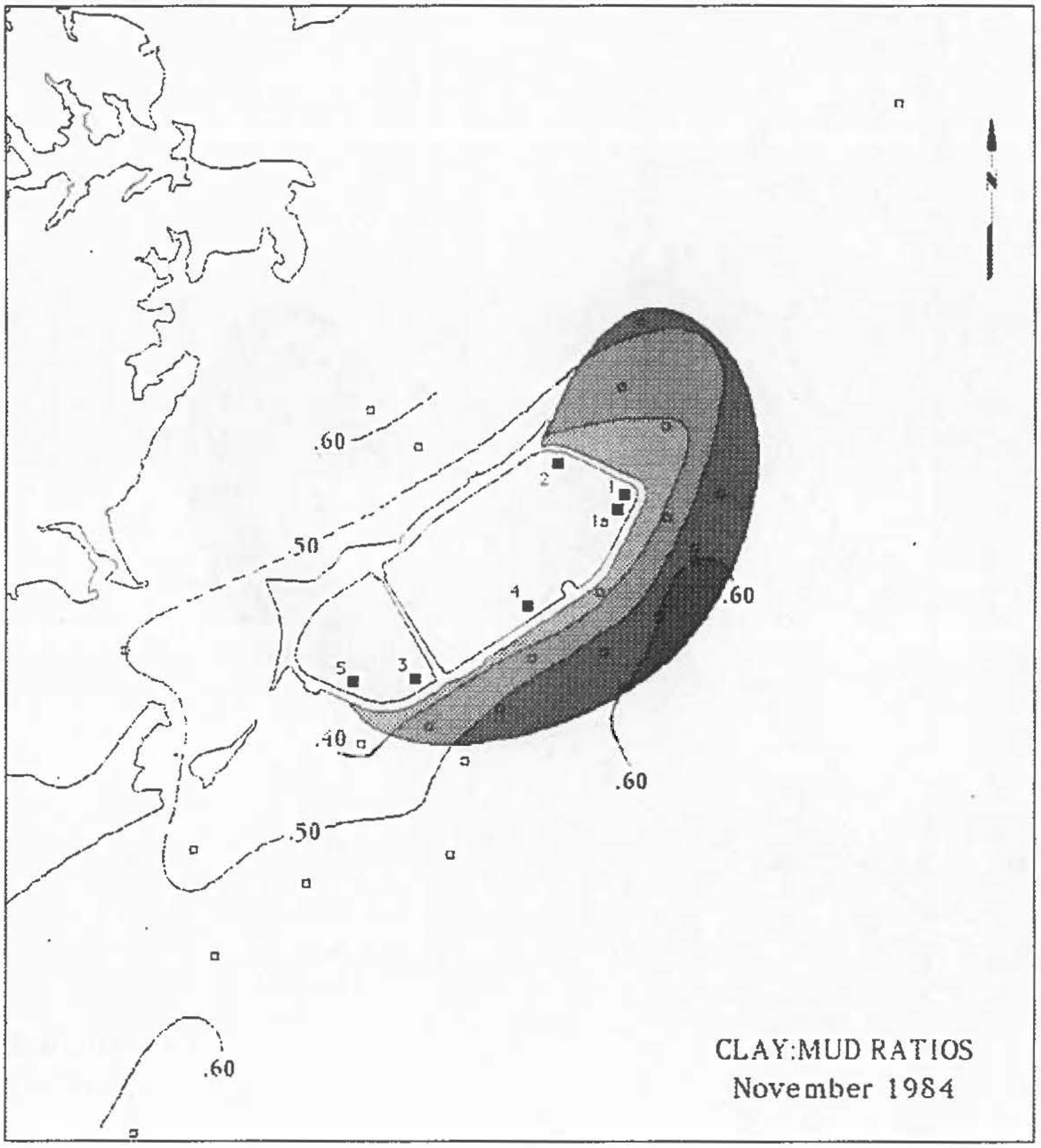
Contour maps of clay:mud ratios for all post-construction cruises (November 1983 - April 1990).



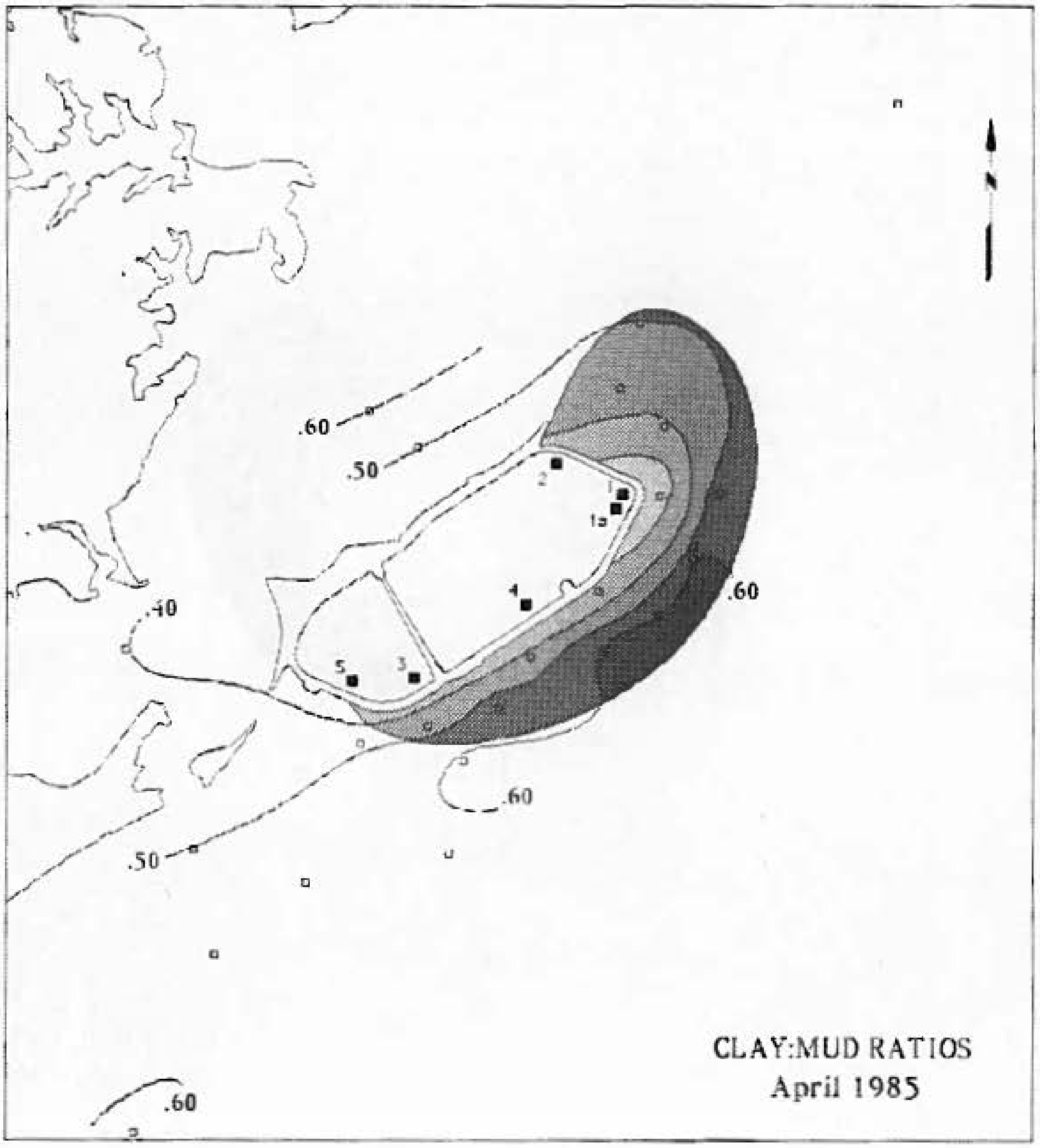
.60
.60
.40
60
.50
.60
5
3
4
1
CLAY:MUD RATIOS
November 1983

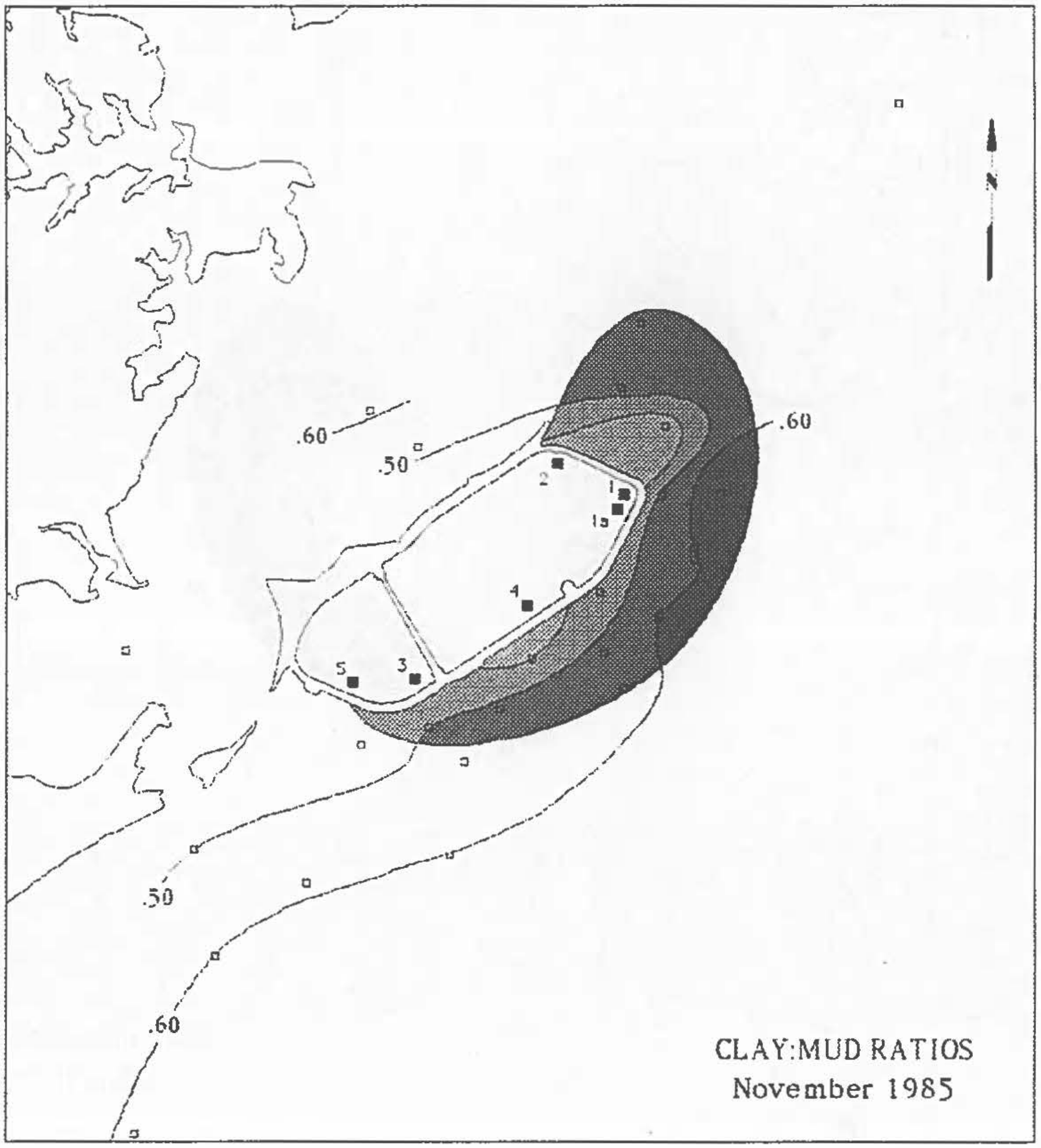


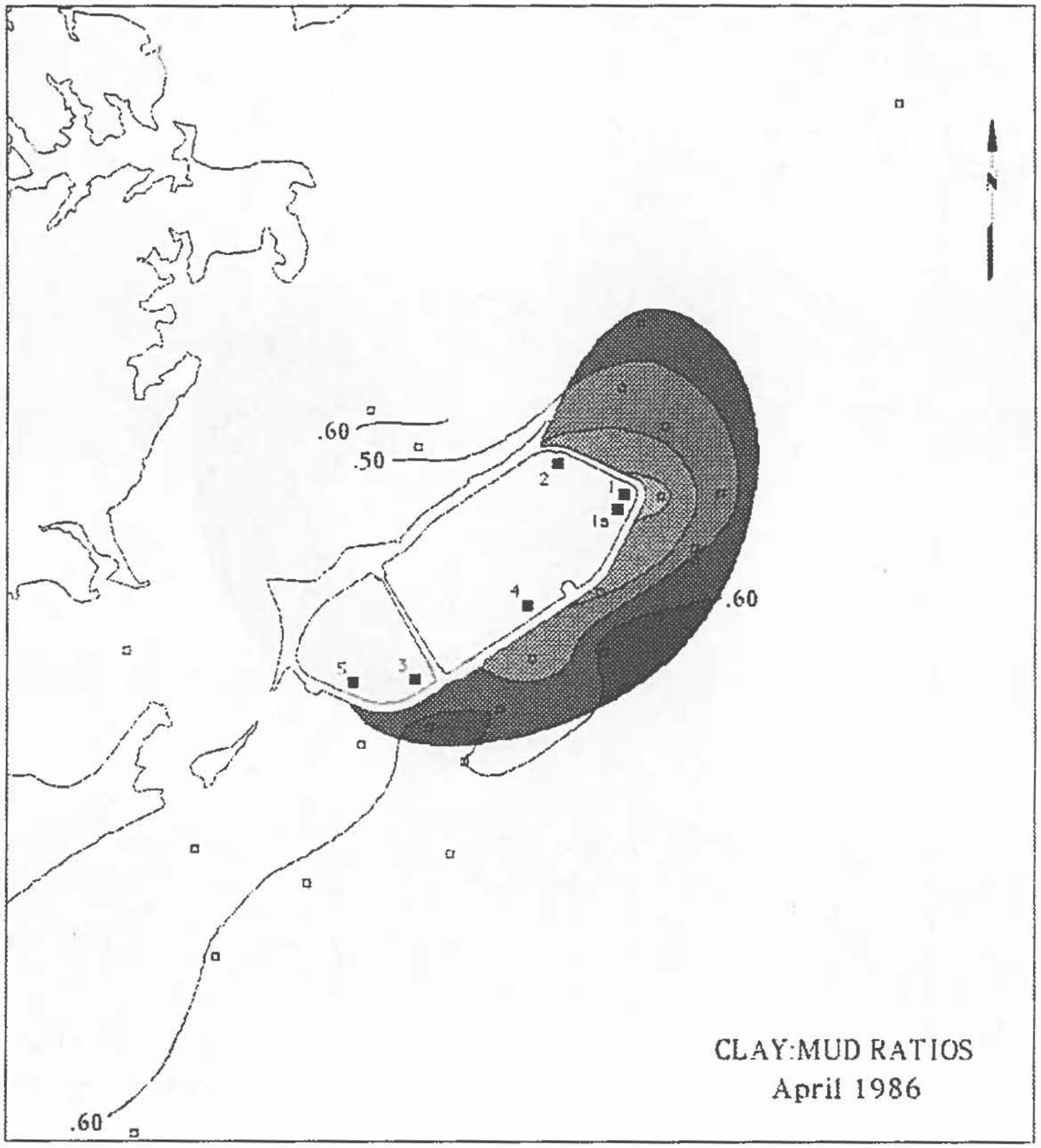
.60
2
1
1a
4
5
3
.50
.50
.60
CLAY:MUD RATIOS
June 1984

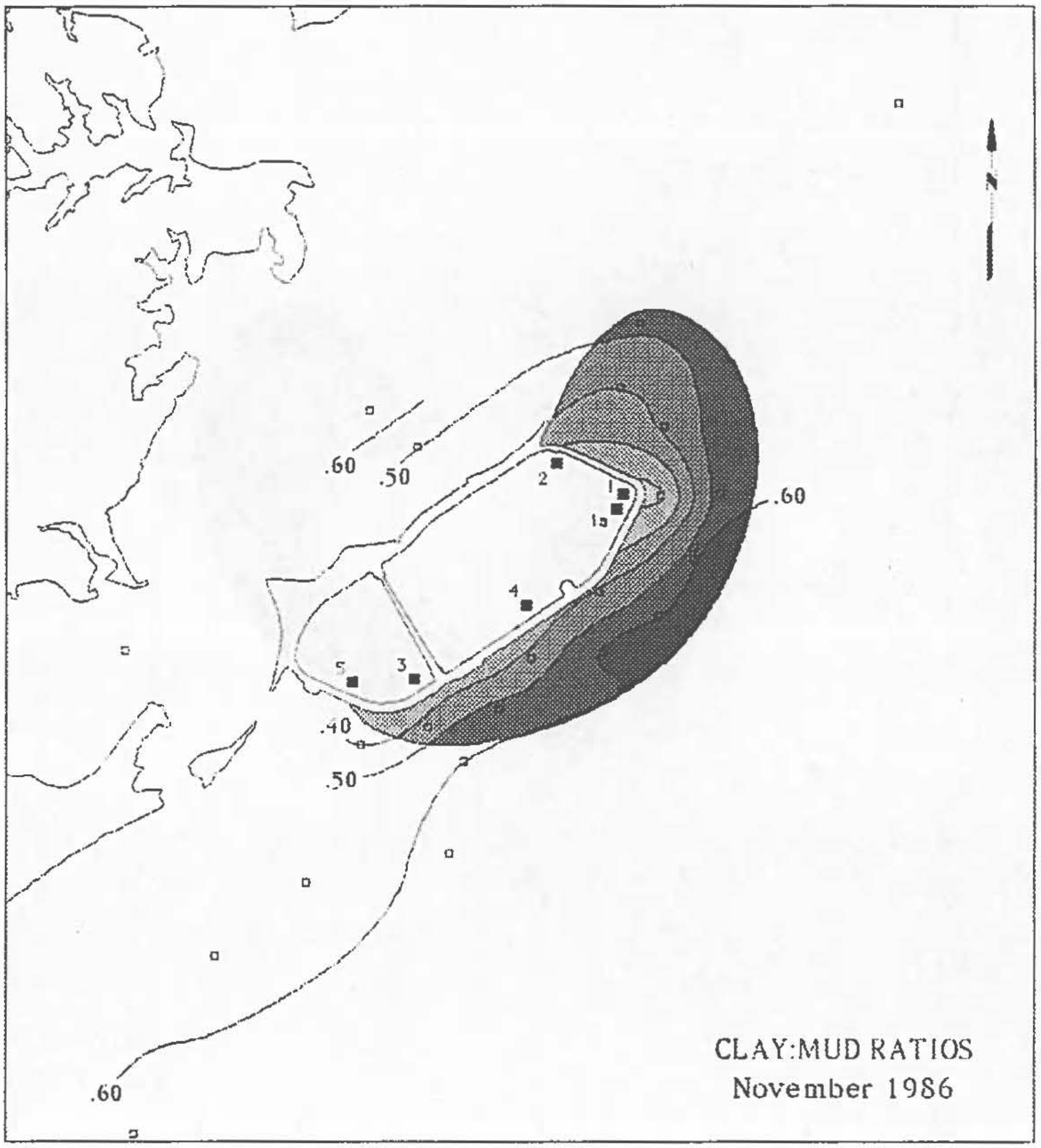


.60
.50
.40
.50
.60
.60
.60
2
1
1a
4
5
3
N
CLAY:MUD RATIOS
November 1984

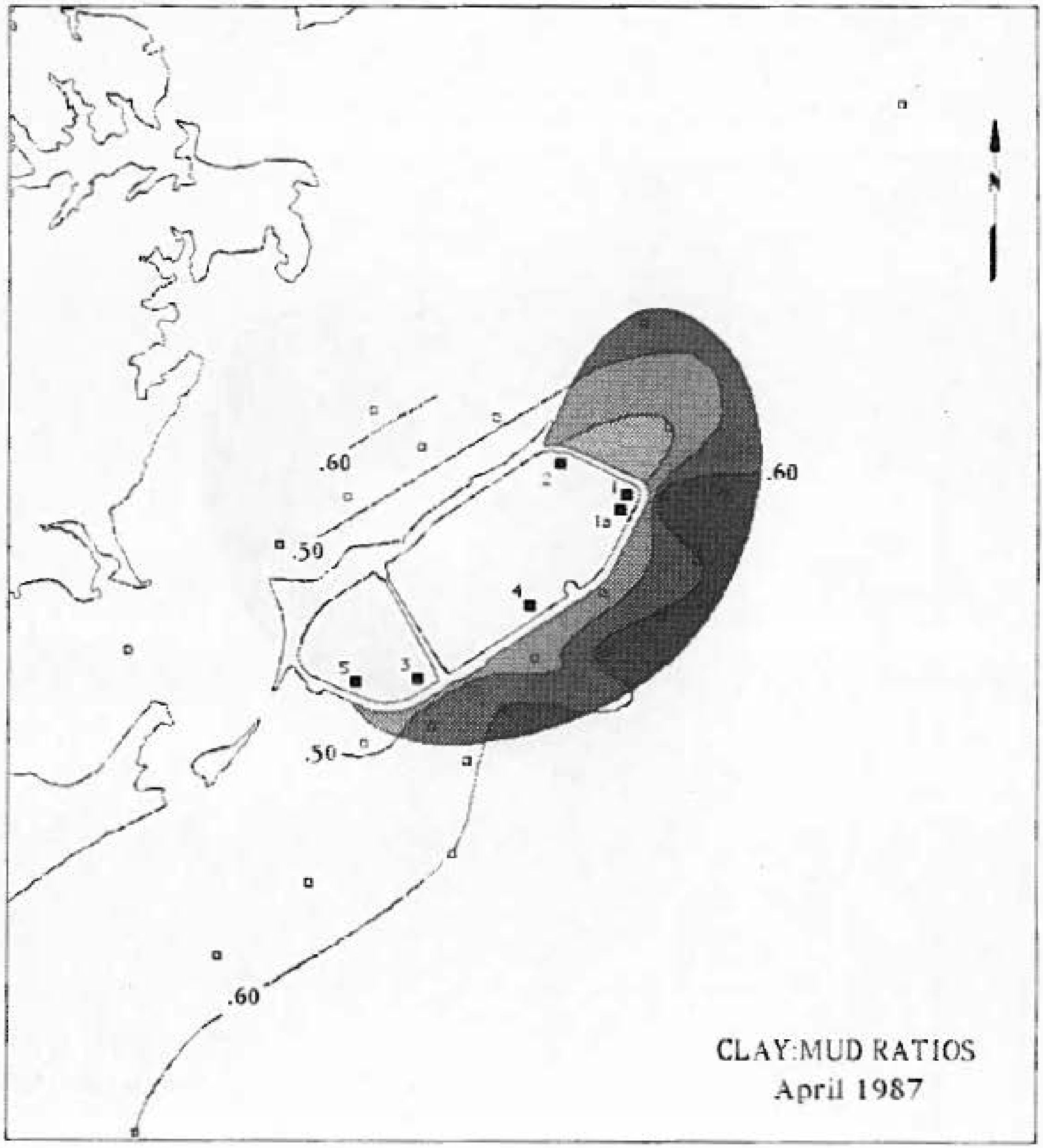

.60
.50
2
1
1a
4
.40
5
3
.60
.60
.50
.60
CLAY:MUD RATIOS
April 1985

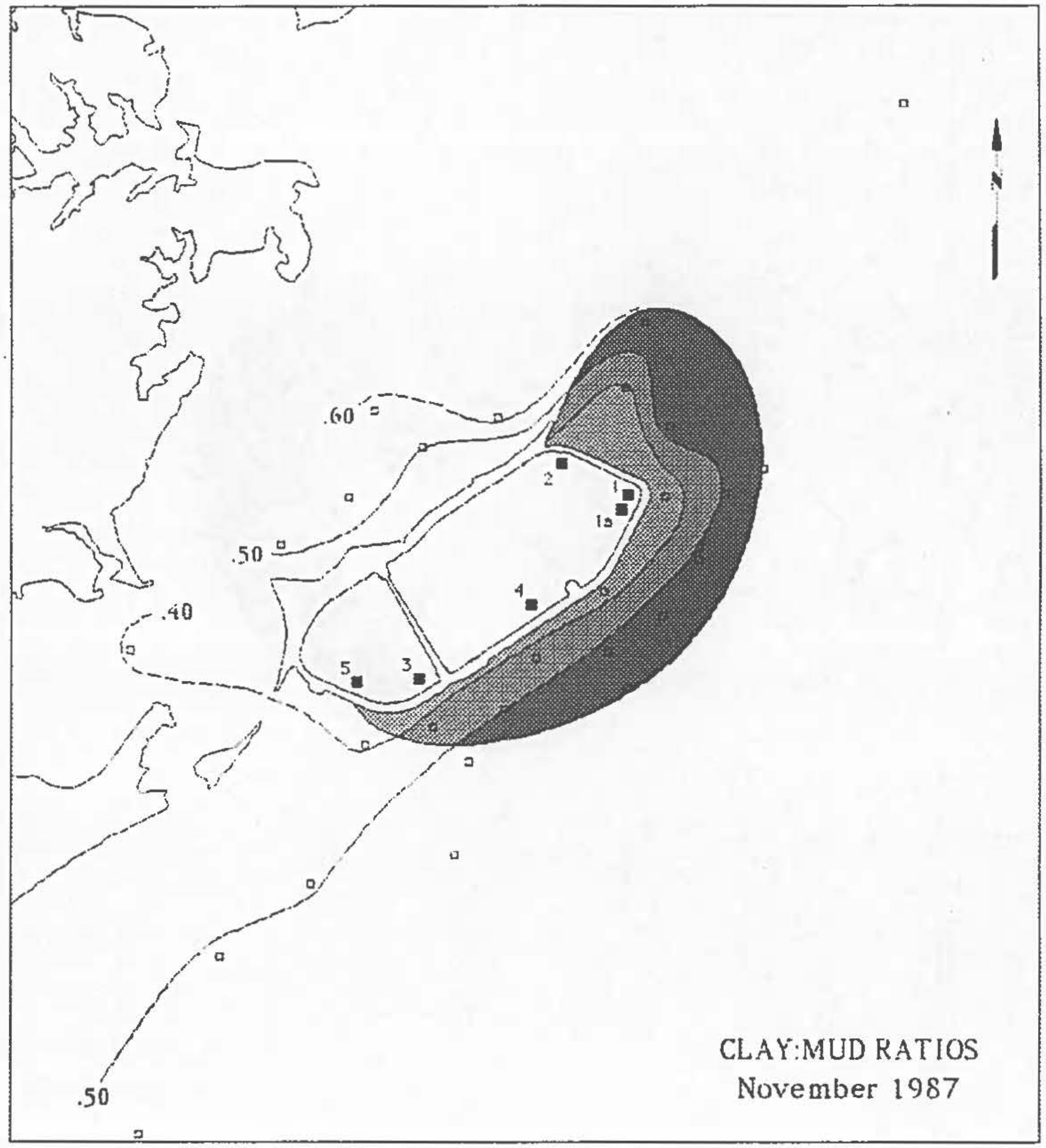

.60
.50
2
1
1a
4
5
3
.60
.50
.60
N
CLAY:MUD RATIOS
November 1985

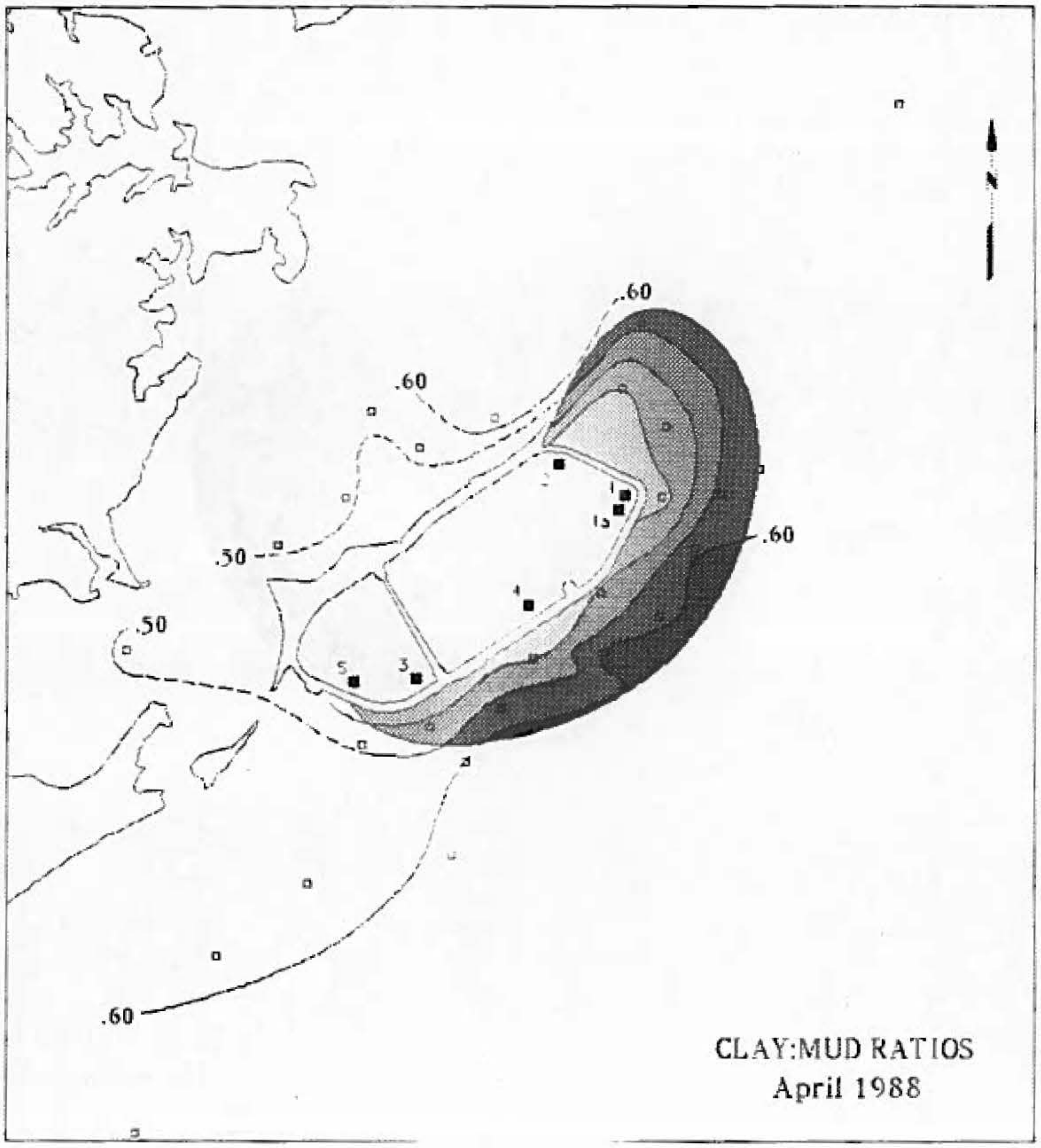

.60
.50
2
1
1a
4
.60
5
3
.60
CLAY:MUD RATIOS
April 1986



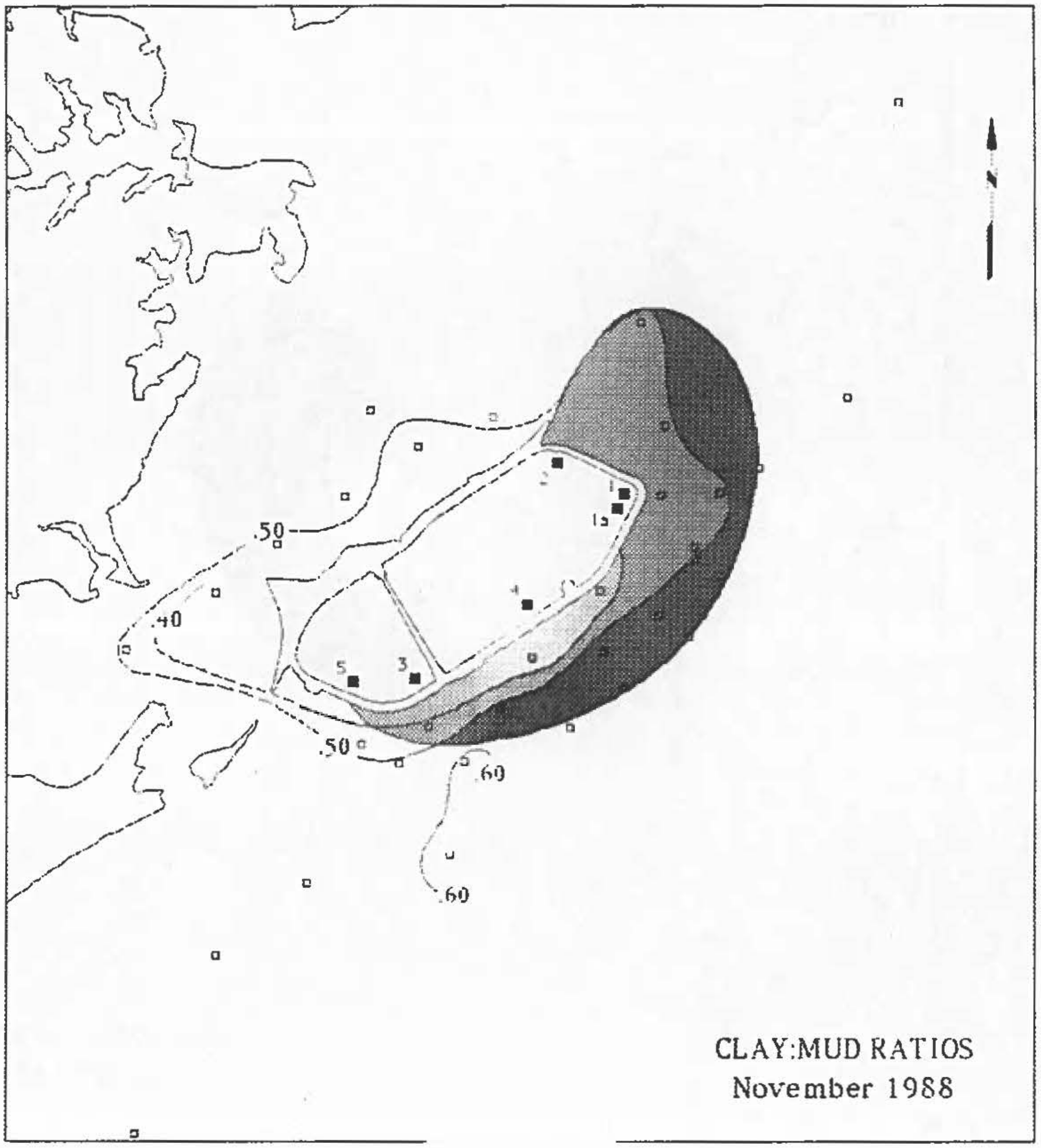
.60
.50
2
1
1a
.60
4
5
3
.40
.50
.60
CLAY:MUD RATIOS
November 1986

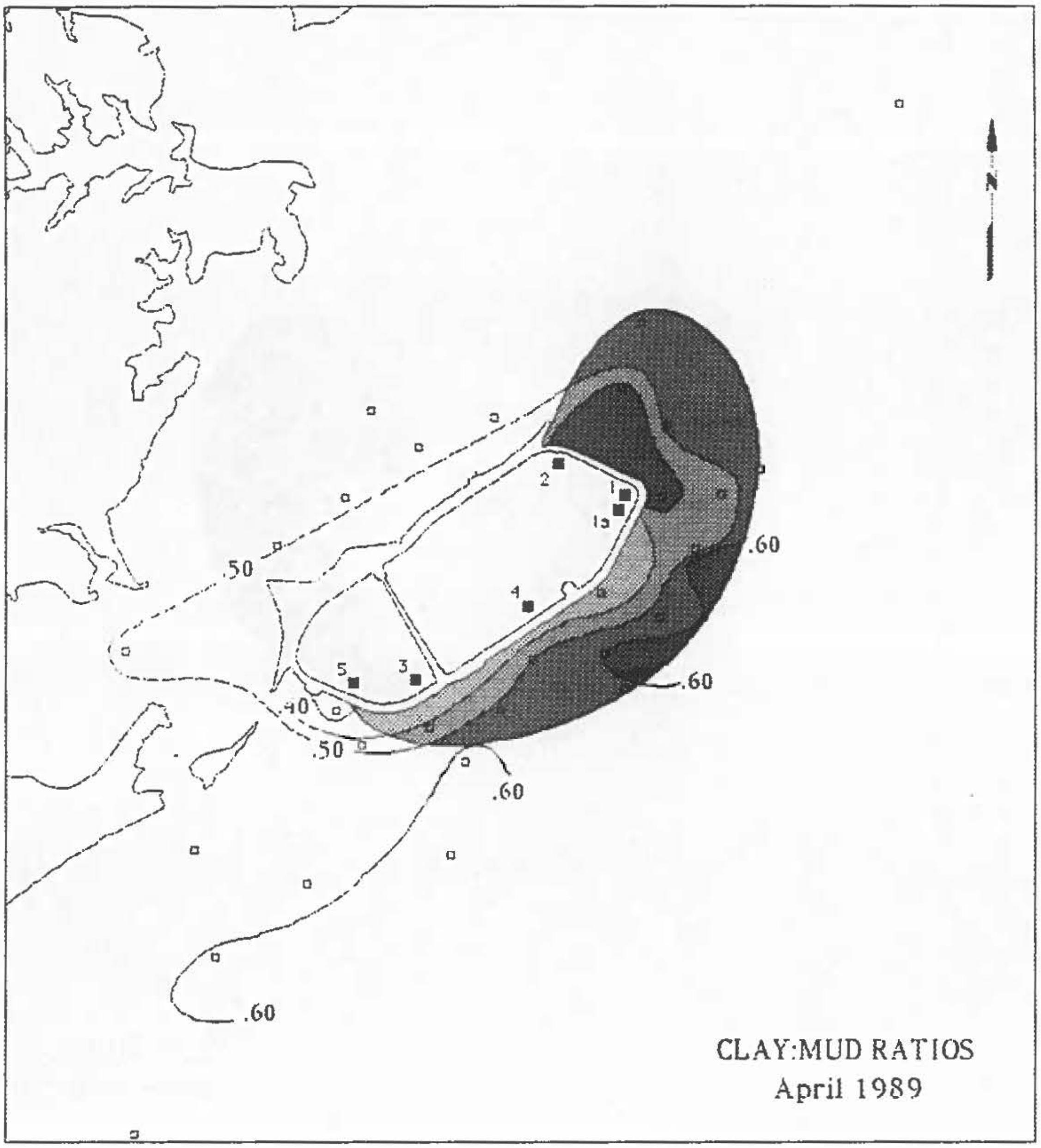

.60
.50
.60
2
1
1a
4
5
3
.50
.60
CLAY:MUD RATIOS
April 1987


.60
.50
.40
2
1
1a
4
5
3
.50
CLAY:MUD RATIOS
November 1987

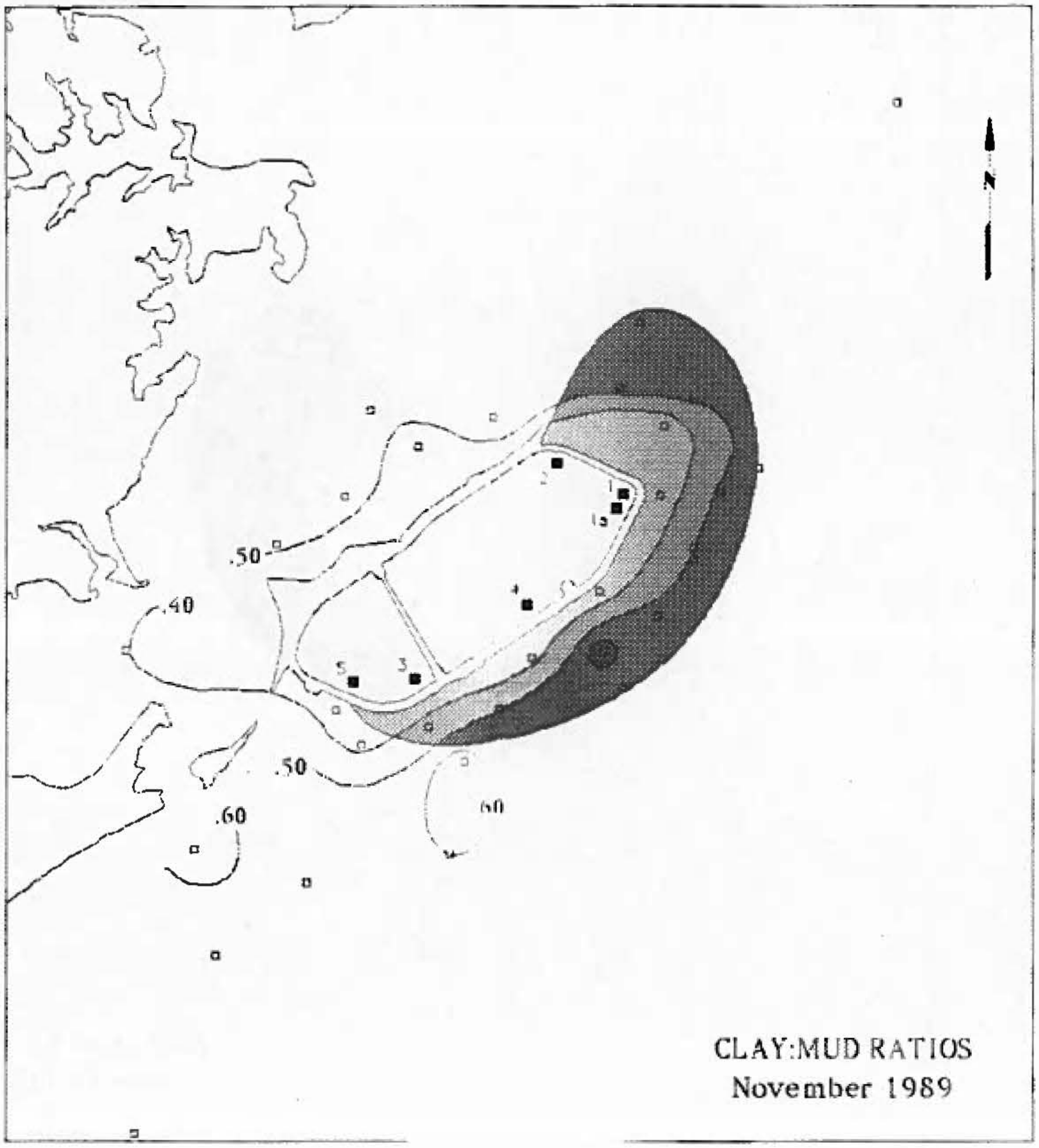


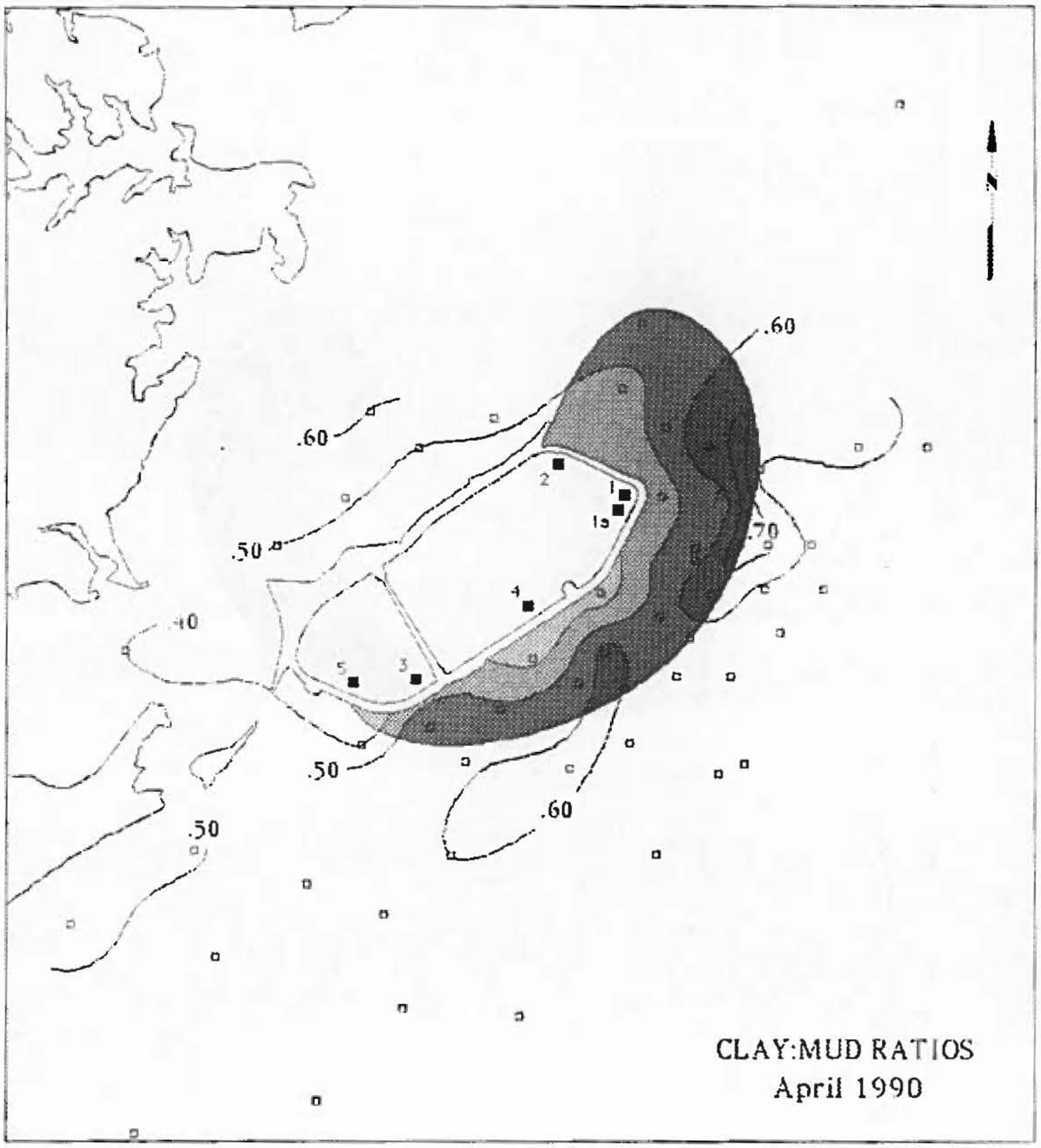
.60
.60
.50
.50
.60
.60
N
CLAY:MUD RATIOS
April 1988


.50
.40
.50
.60
.60
2
1
1s
4
5
3
CLAY:MUD RATIOS
November 1988



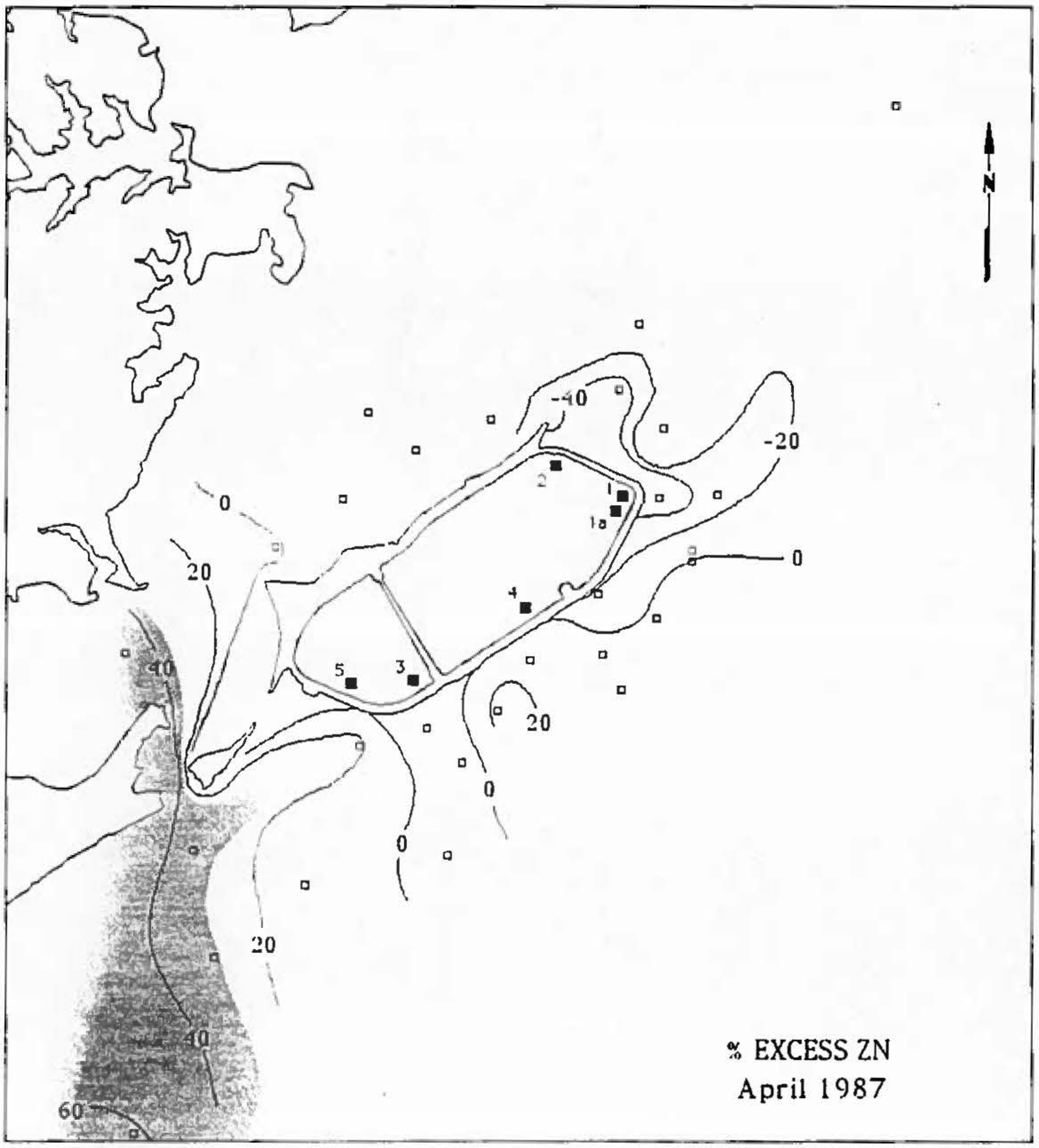
N
2
1
1a
4
5
3
.50
.40
.50
.60
.60
.60
.60
CLAY:MUD RATIOS
April 1989


.50
.40
.50
.60
.60
CLAY:MUD RATIOS
November 1989

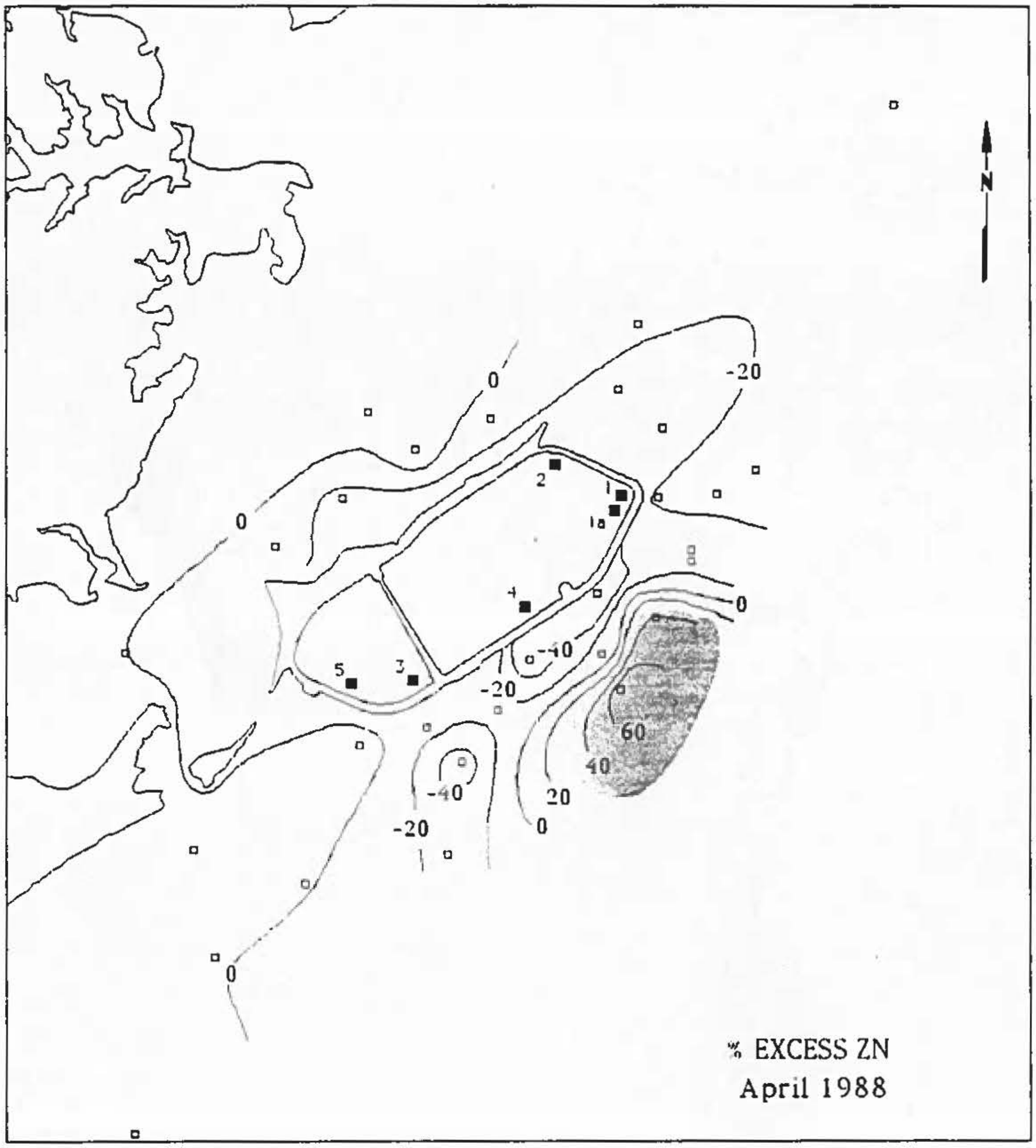

.60
.60
2
1
1a
.70
.50
4
.40
5
3
.50
.60
.50
CLAY:MUD RATIOS
April 1990

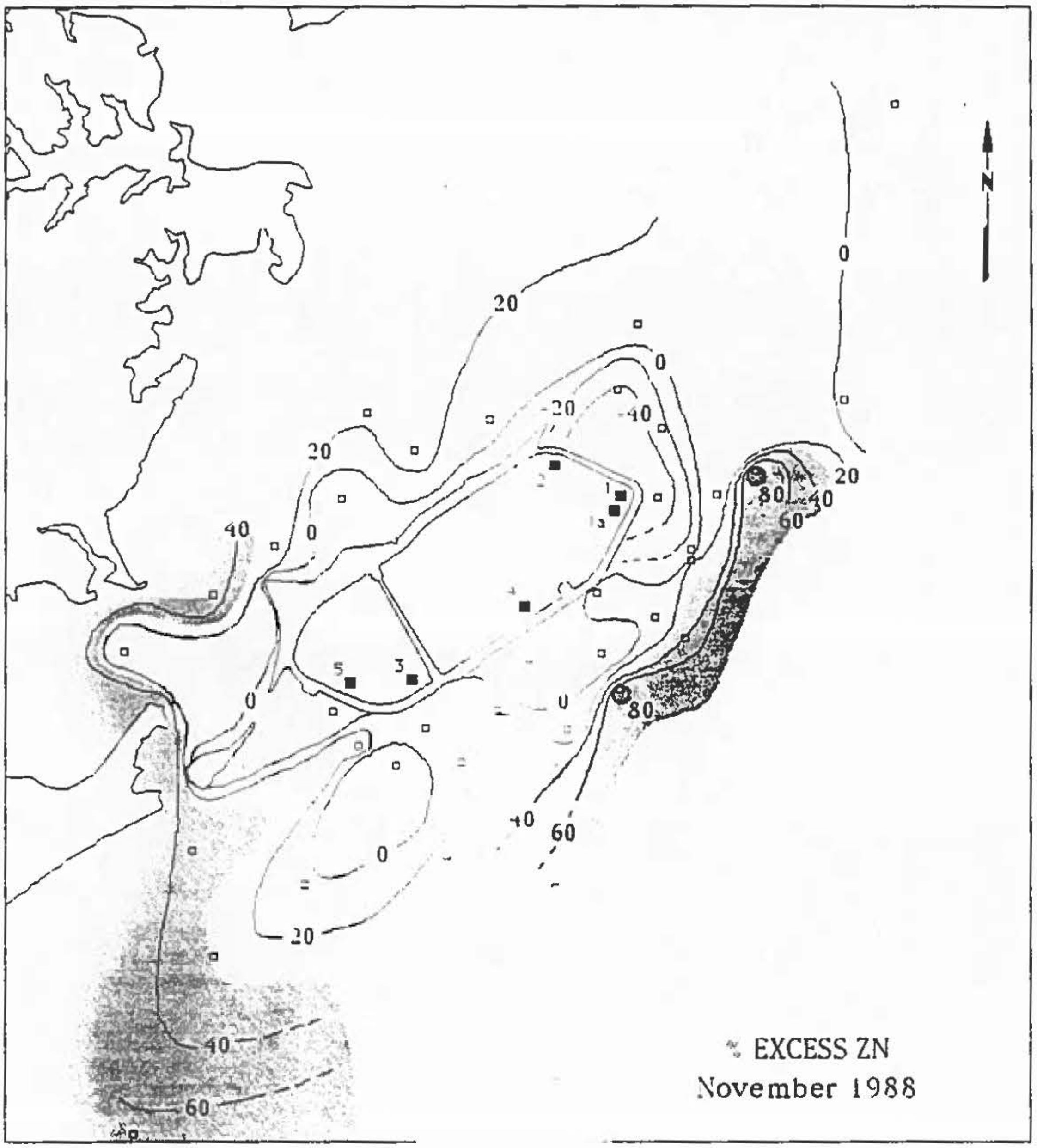
Appendix E

Contour maps of % excess Zn for seven monitoring periods.



N
-40
-20
0
20
0
40
20
0
0
20
40
60
2
1
1a
4
5
3
% EXCESS ZN
April 1987

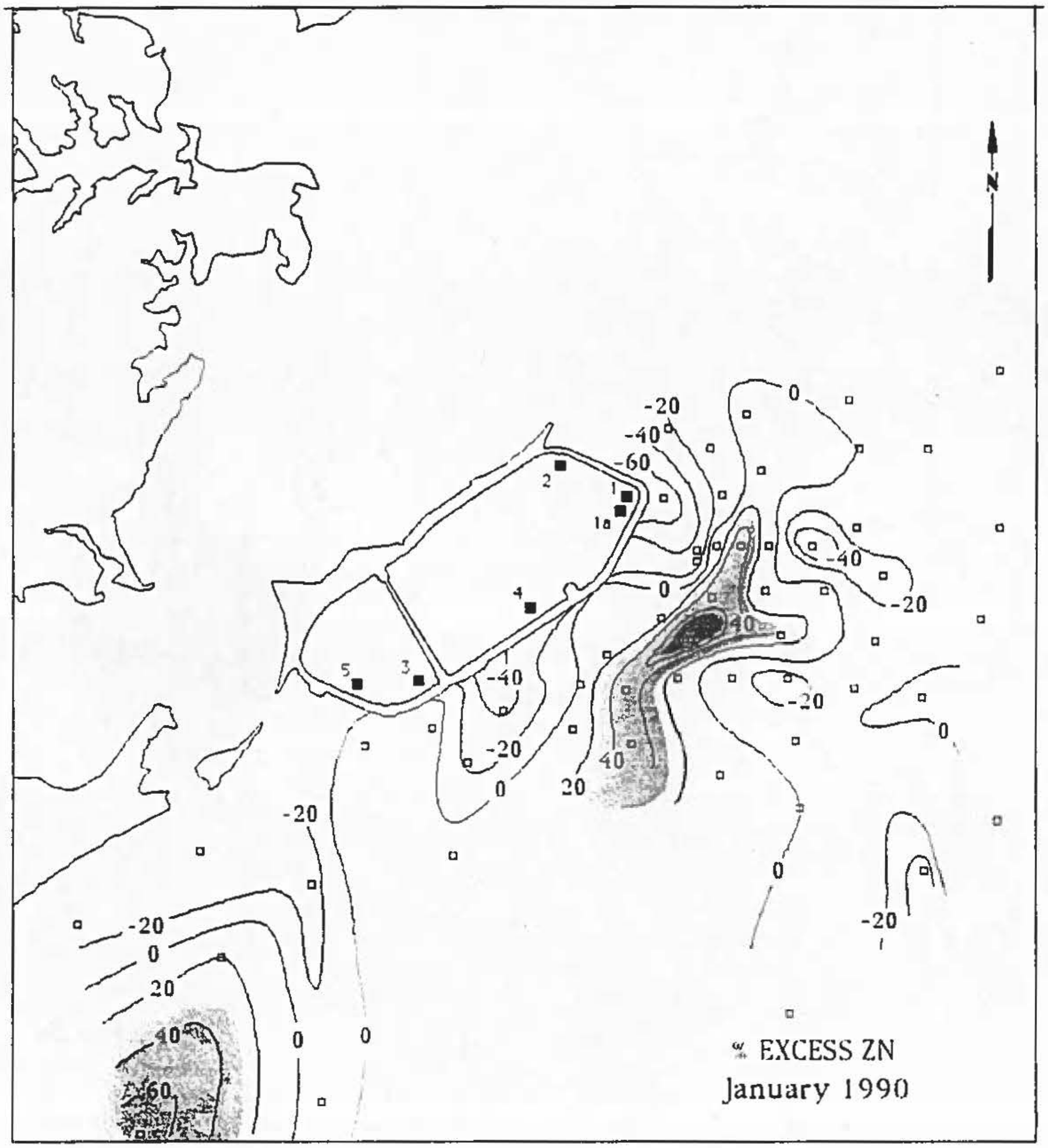

N
0
-20
2
1
1a
0
4
0
-40
5
3
-20
60
40
-40
20
-20
0
0
% EXCESS ZN
April 1988

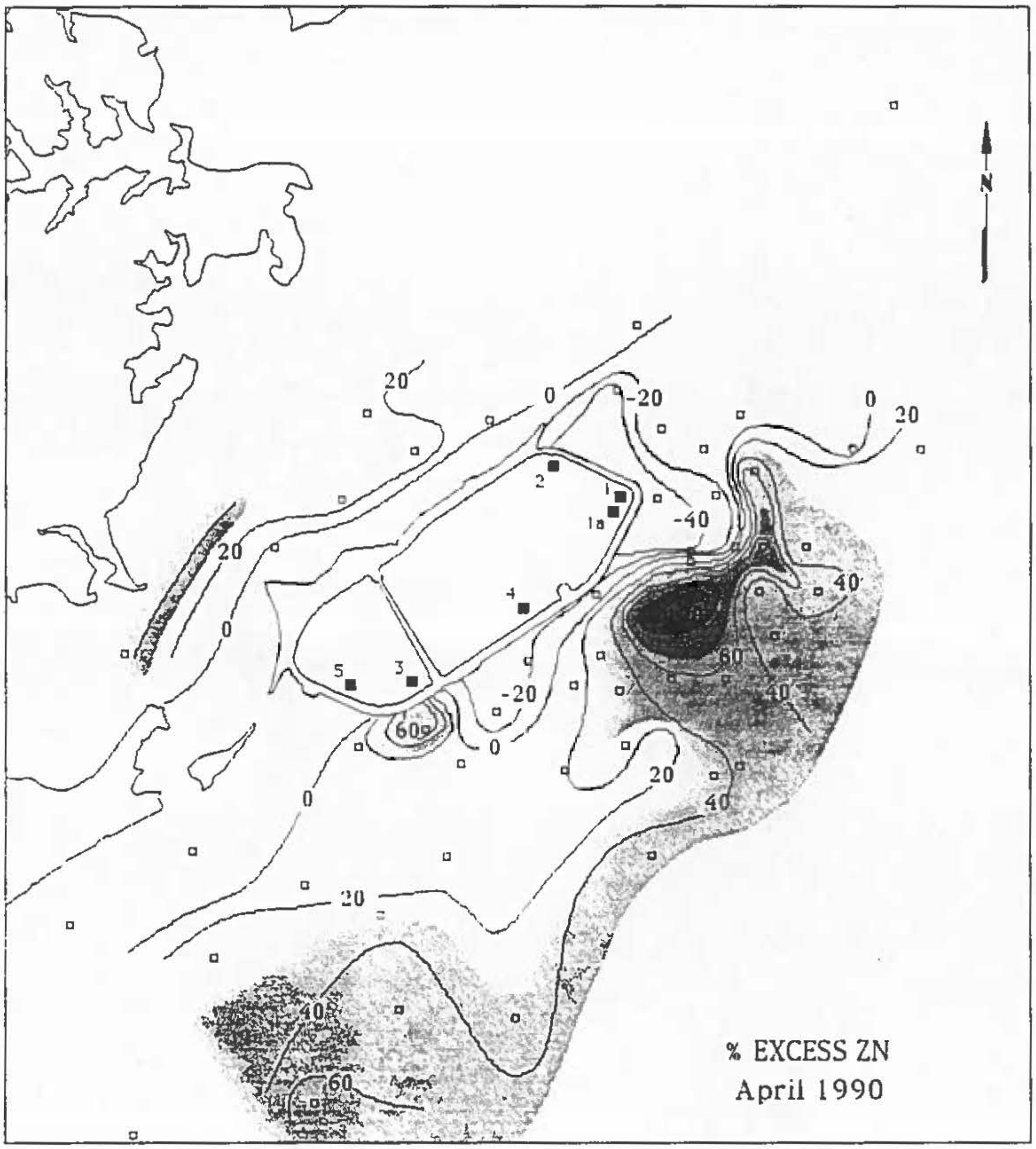


N
0
20
0
-20
-40
20
40
0
80
40
60
20
40
0
0
0
40
60
0
20
40
60
80
% EXCESS ZN
November 1988

N
0
-20
-40
20
40
60
80
2
1
1a
4
5
3
-20
0
20
20
40
60
80
% EXCESS ZN
April 1989

N
20
40
60
80
100
0
2
1
1a
4
5
3
-40
-20
% EXCESS ZN
November 1989

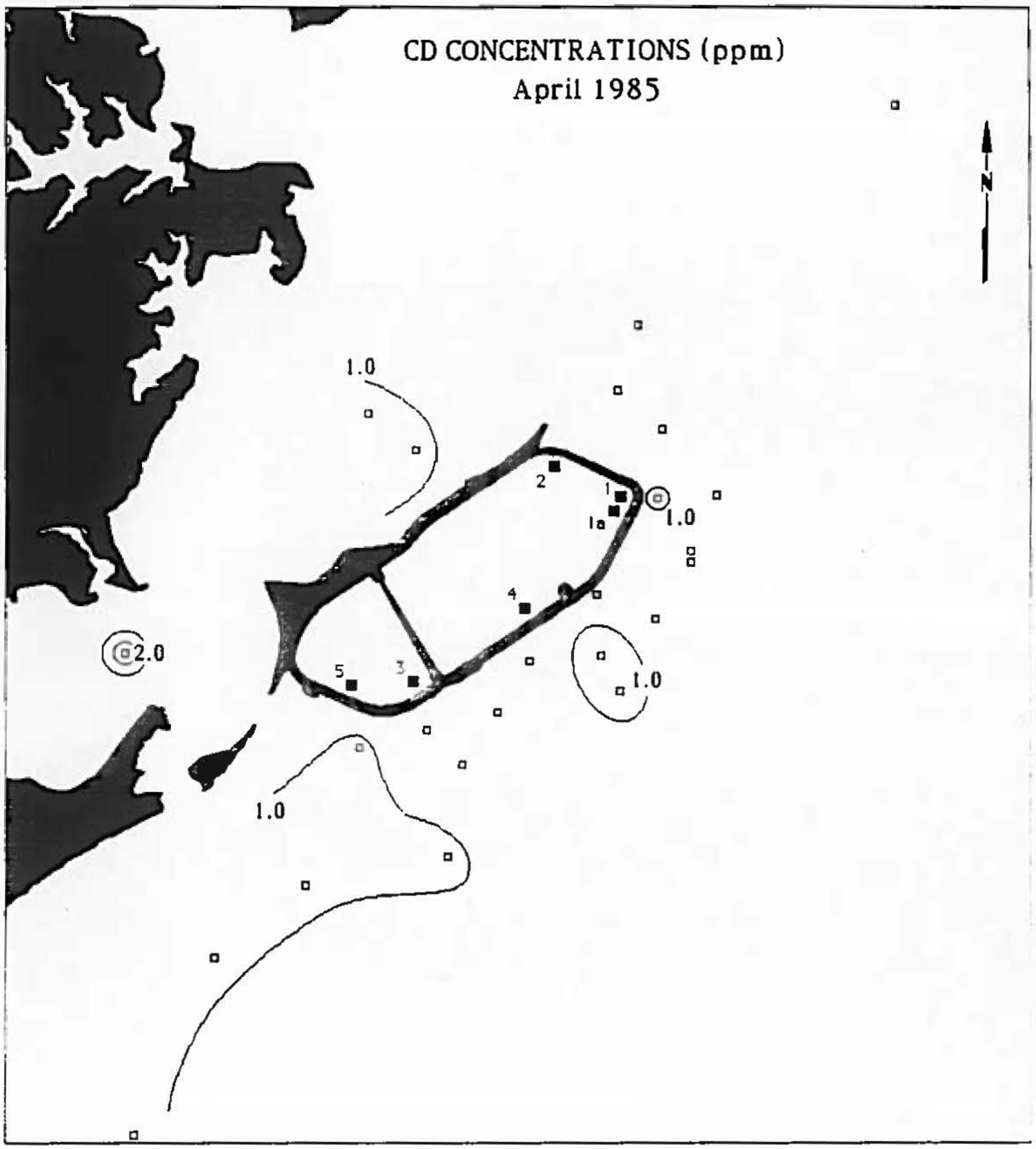

N
% EXCESS ZN
January 1990

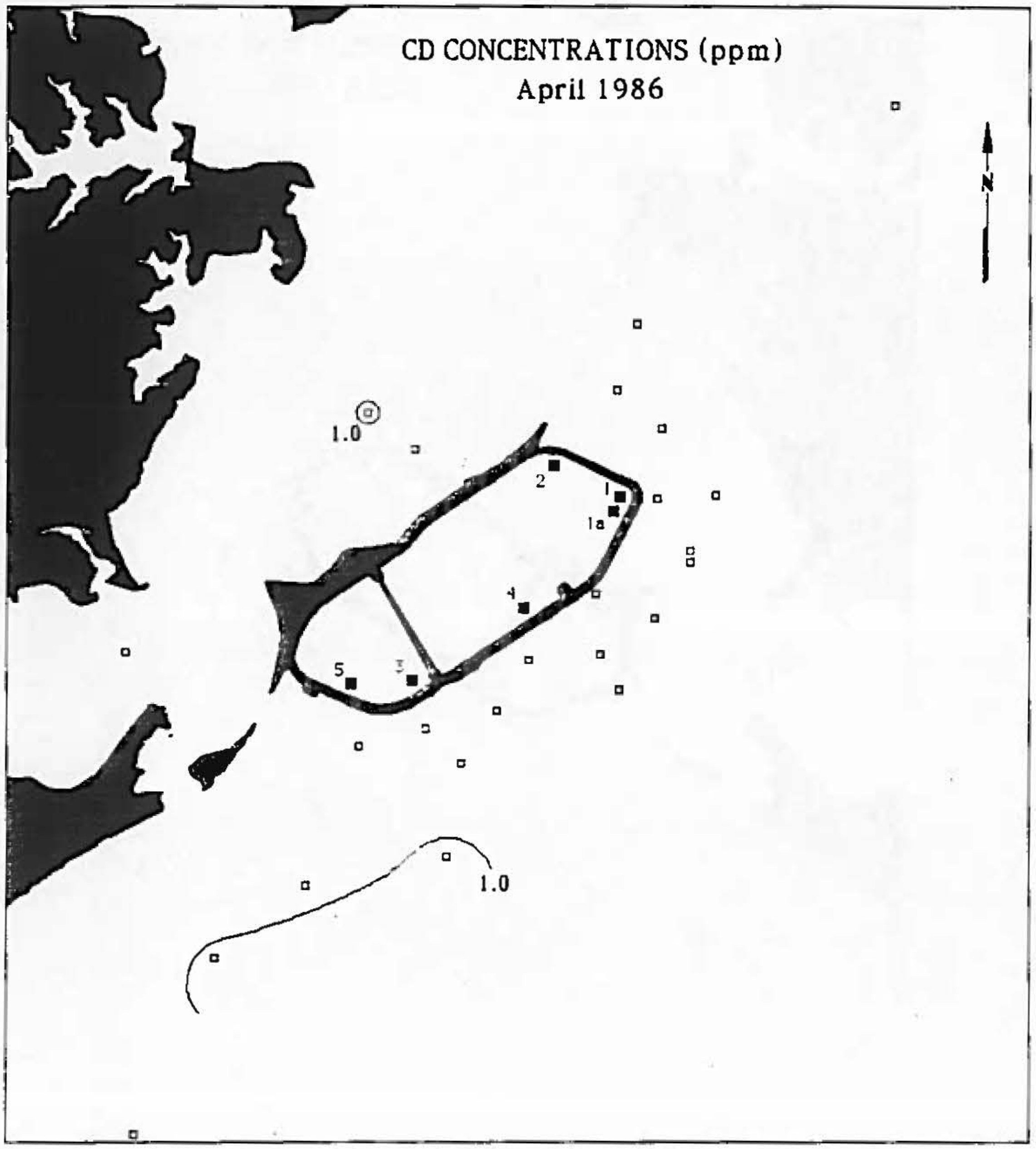


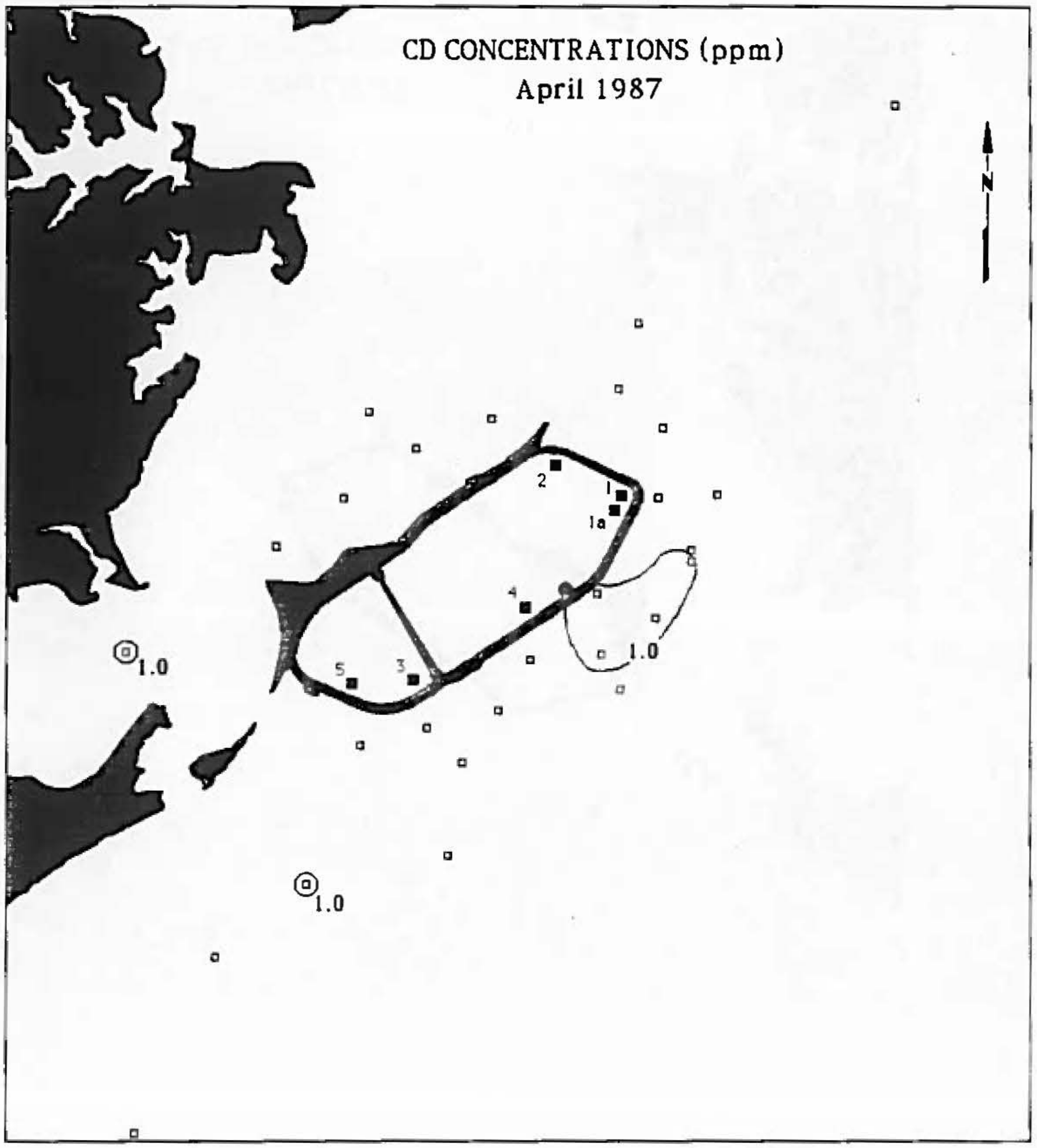
N
20
0
-20
0
20
2
1
1a
-40
20
0
4
40
5
3
60
-20
0
60
40
60
20
0
40
20
40
60
% EXCESS ZN
April 1990

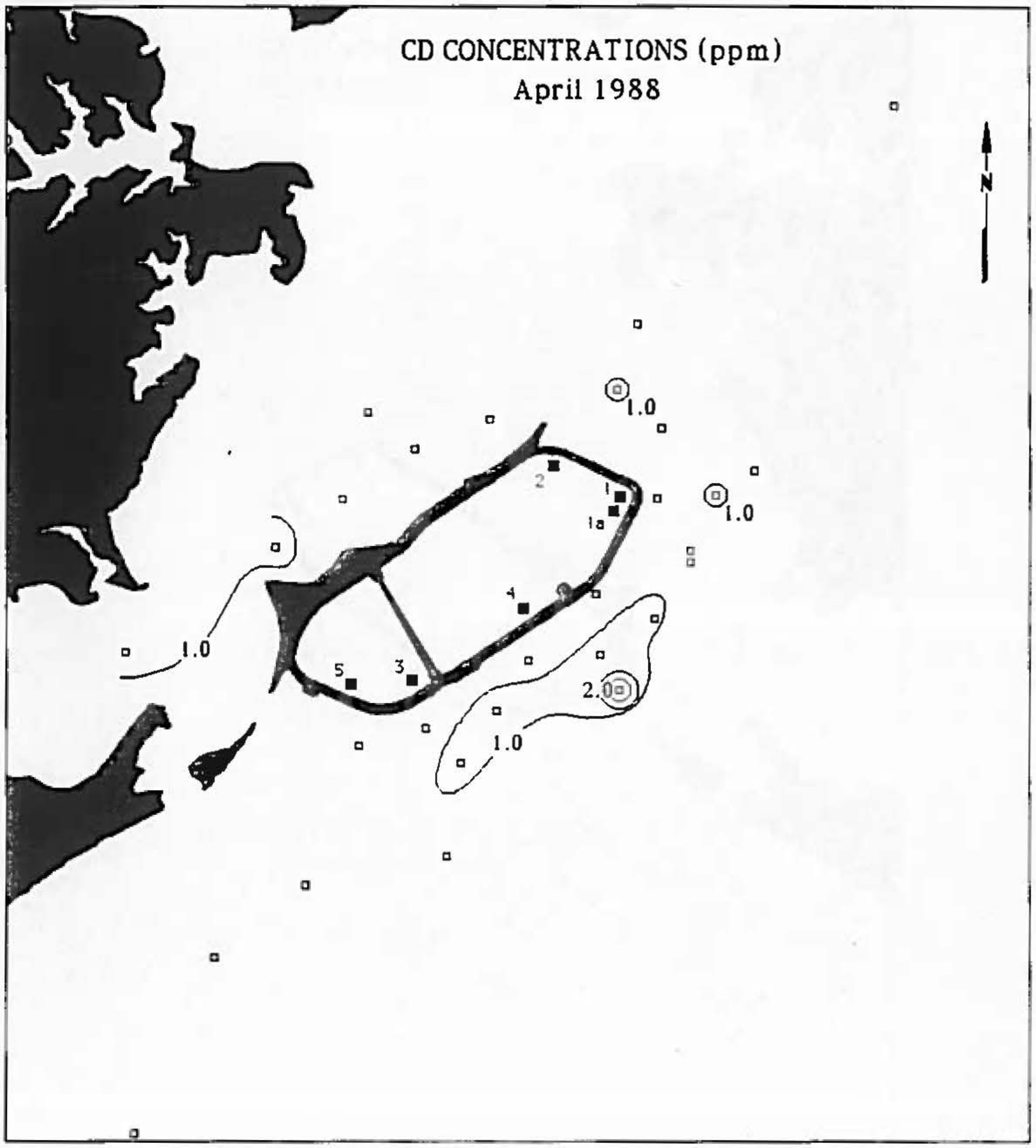
Appendix F

Contour maps of Cd concentrations for six consecutive April cruises (1985-1990).

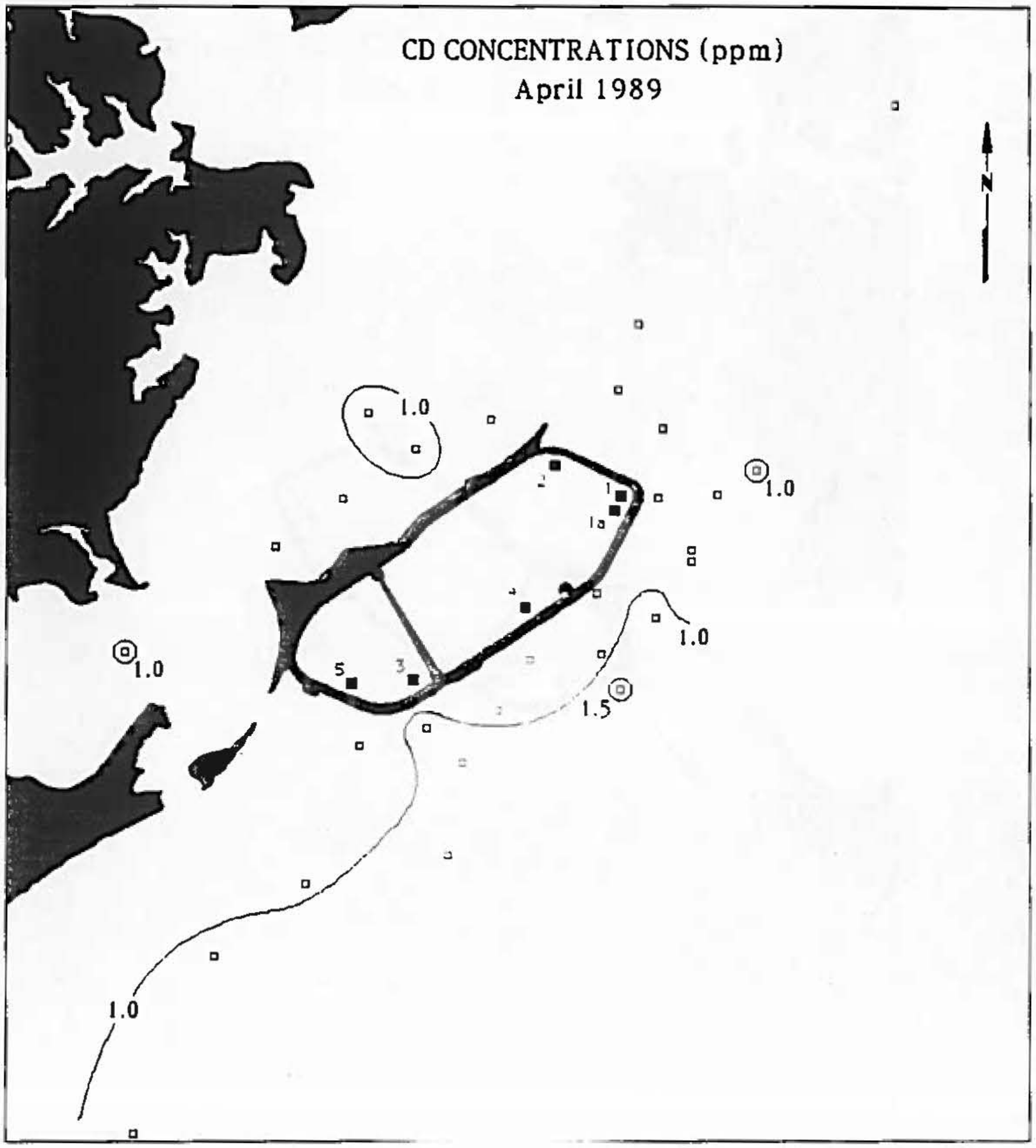

CD CONCENTRATIONS (ppm)
April 1985
N
1.0
2
1
1a
1.0
4
2.0
5
3
1.0
1.0

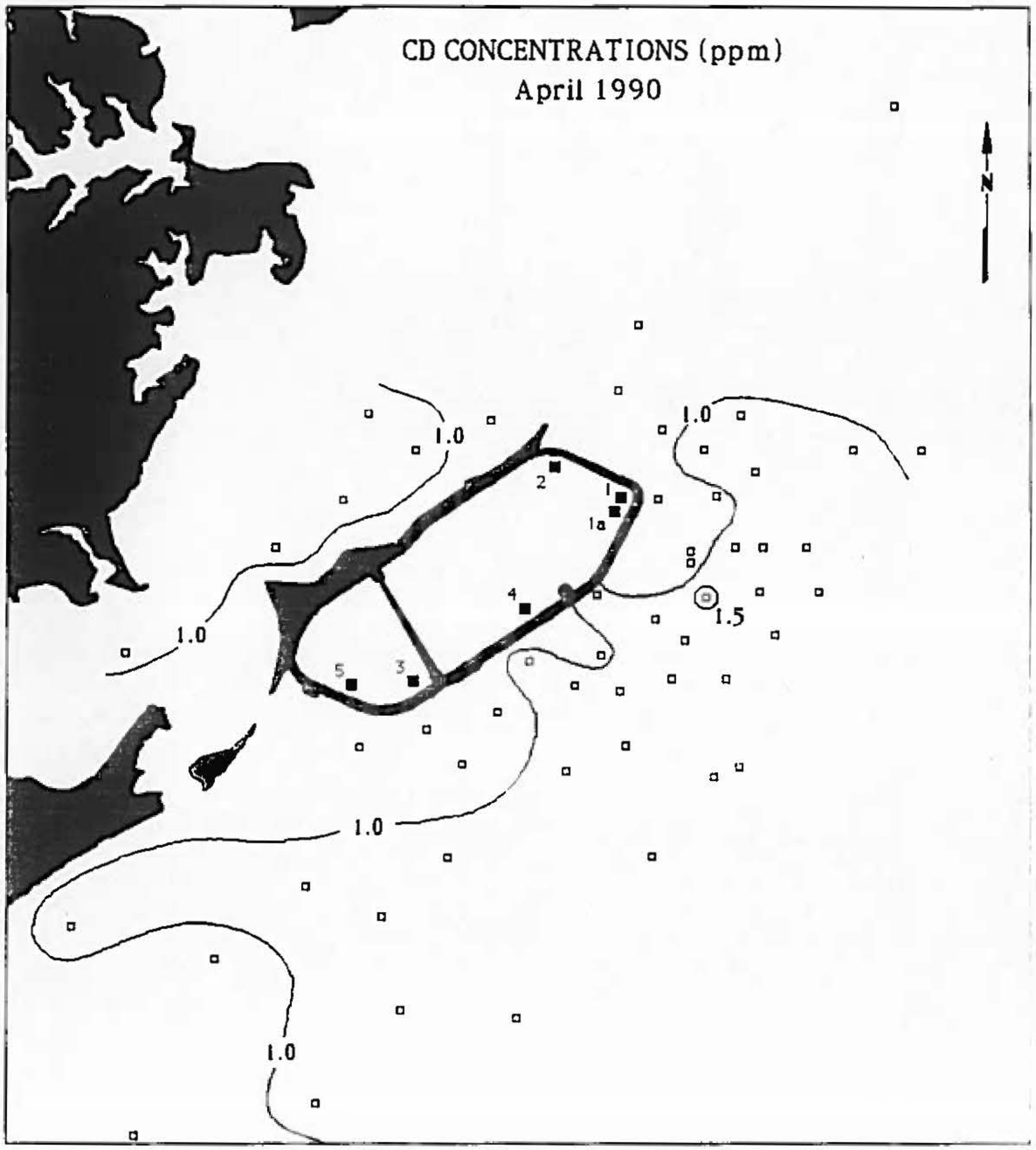

CD CONCENTRATIONS (ppm)
April 1986
N
1.0
2
1
1a
4
5
3
1.0


CD CONCENTRATIONS (ppm)
April 1987
N
2
1
1a
4
5
3
1.0
1.0
1.0



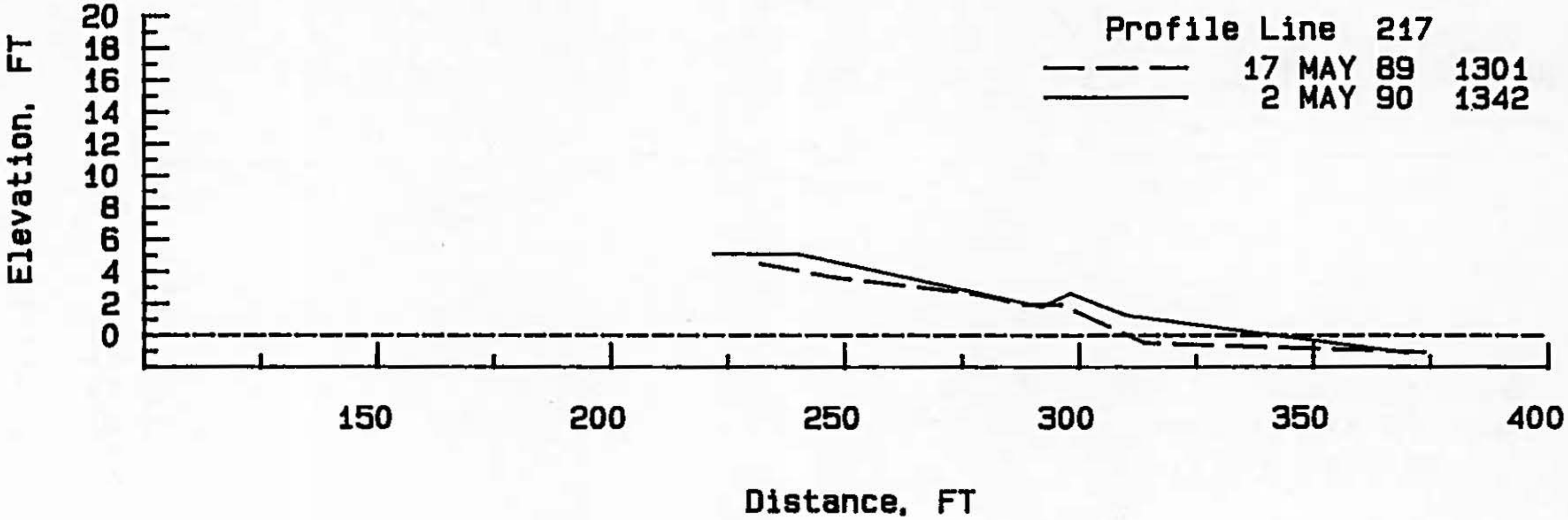
CD CONCENTRATIONS (ppm)
April 1988
N
1.0
1.0
1.0
2.0
1.0
2
1
1a
4
5
3

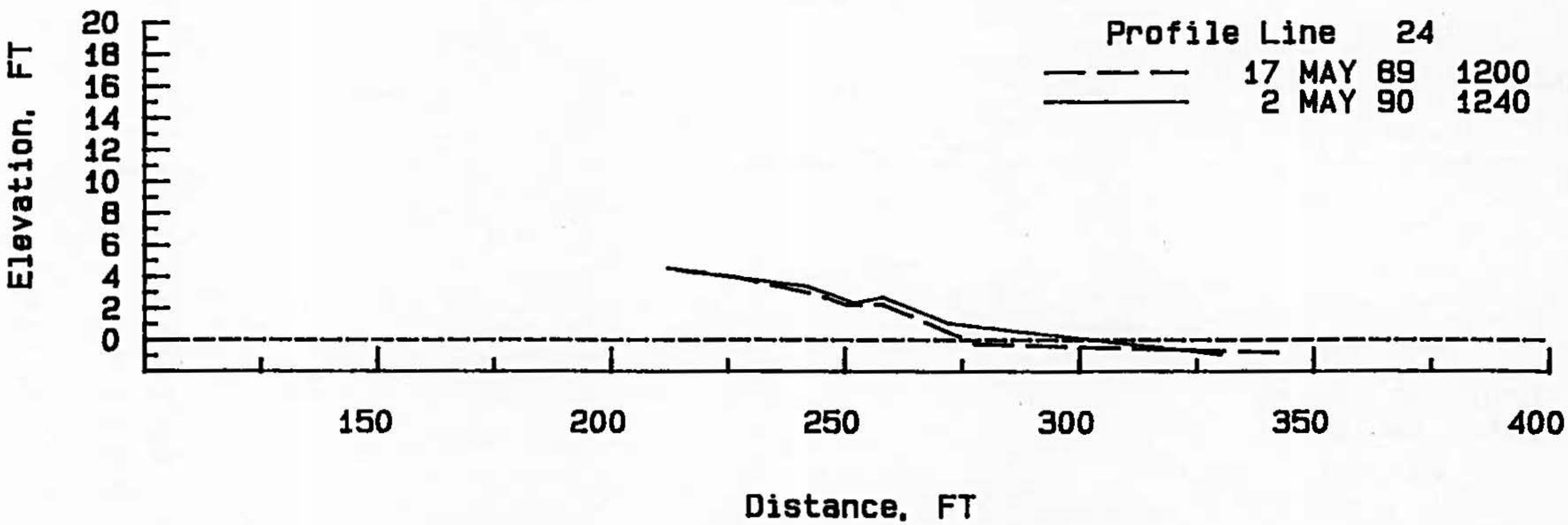

CD CONCENTRATIONS (ppm)
April 1989
N
1.0
2
1
1a
1.0
1.0
5
3
1.0
1.5
1.0

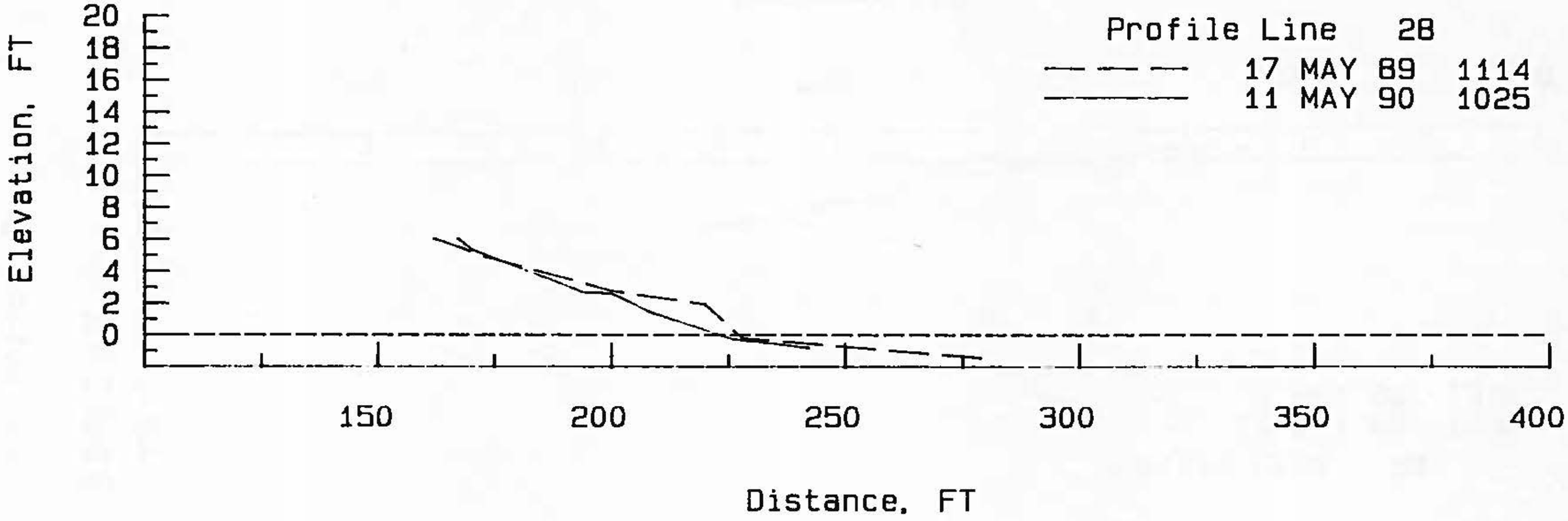

CD CONCENTRATIONS (ppm)
April 1990
N
1.0
1.0
1.0
1.0
1.0
1.0
1.5
1
1a
2
3
4
5

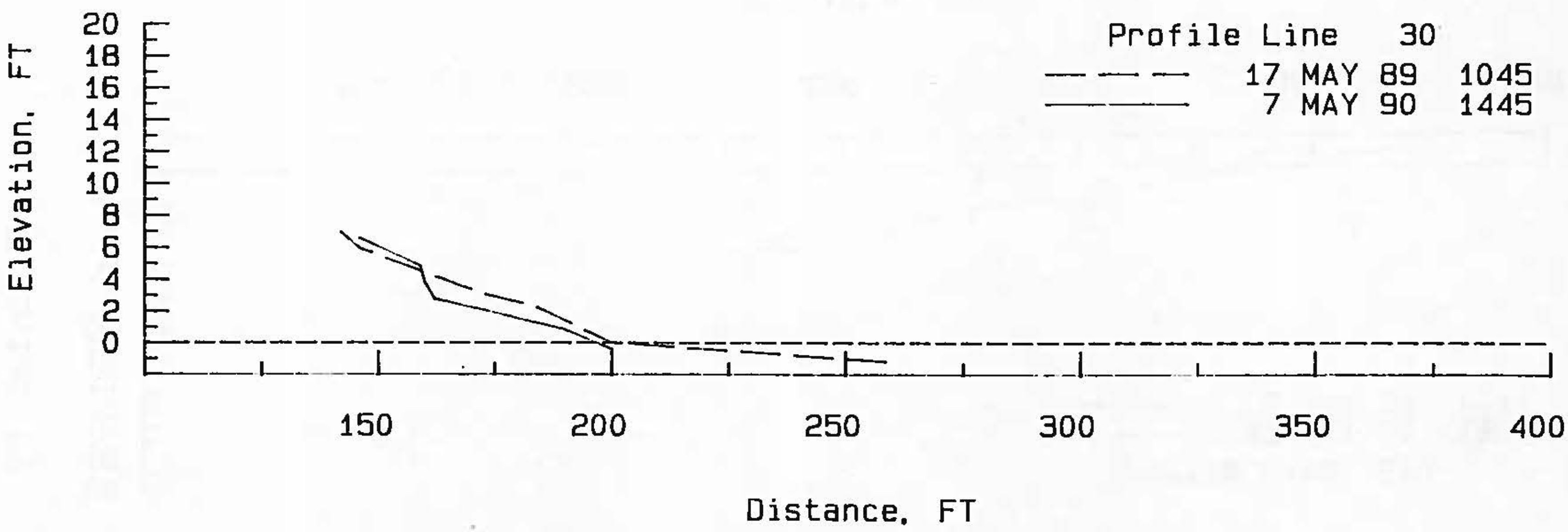
Appendix G

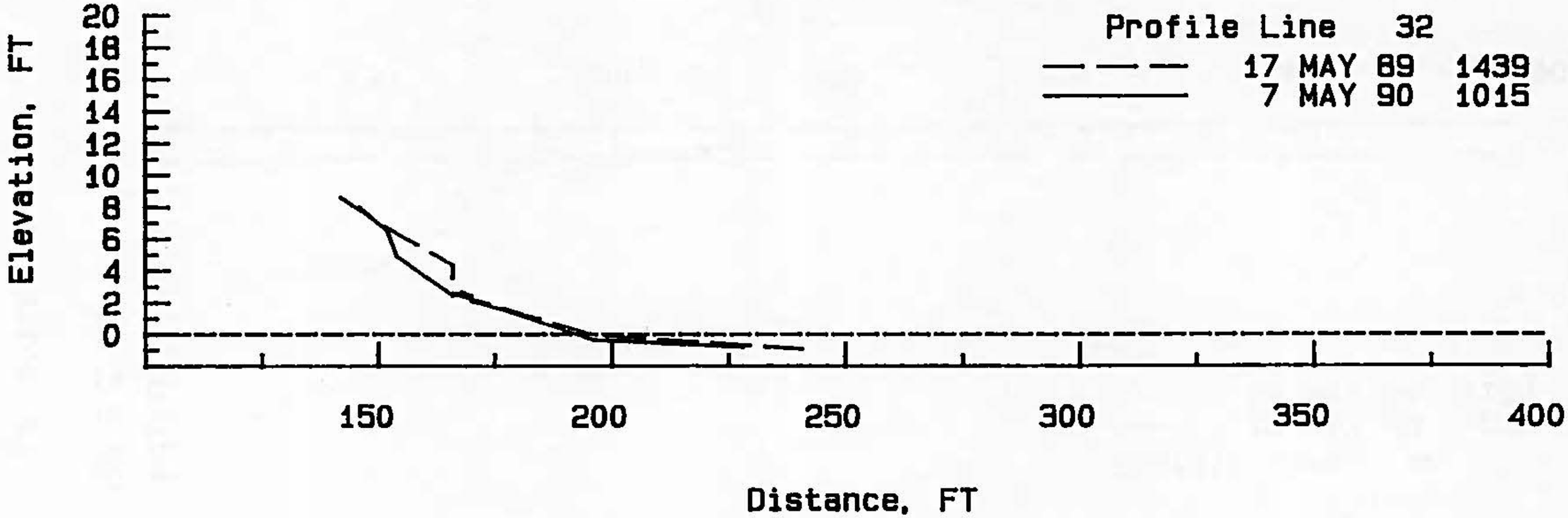
Cross-sectional profiles of the recreational beach.

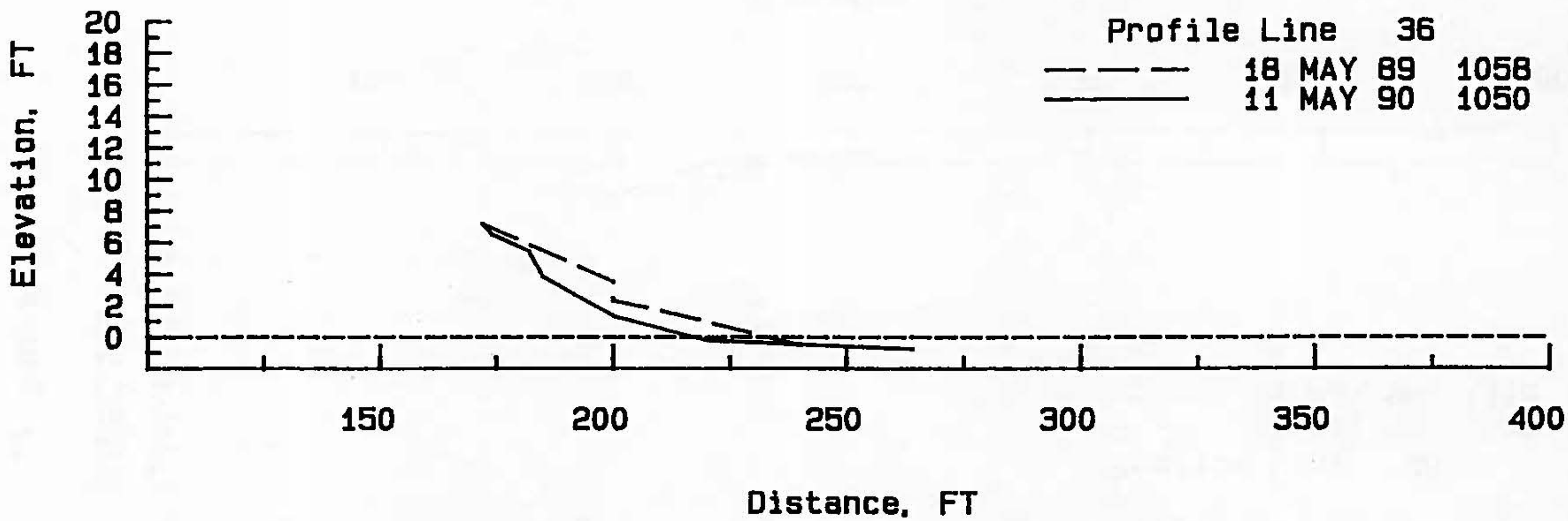

Profile Line 217
17 MAY 89 1301
2 MAY 90 1342
Elevation, FT
20
18
16
14
12
10
8
6
4
2
0
150
200
250
300
350
400
Distance, FT

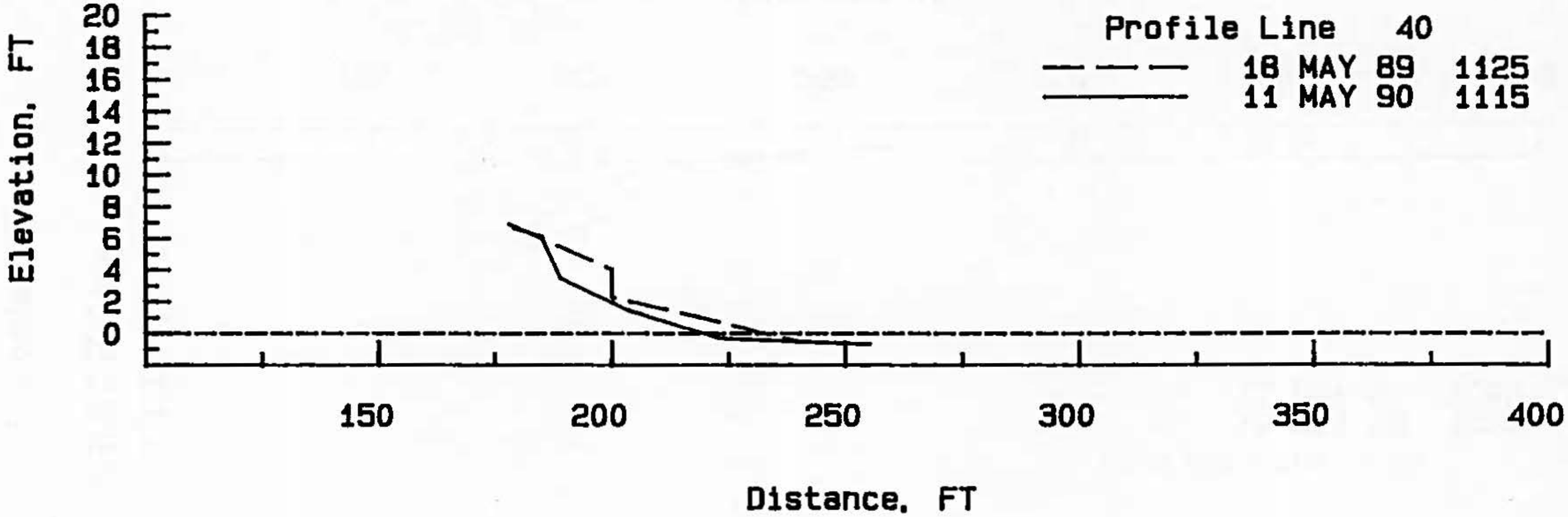

Profile Line 24
17 MAY 89 1200
2 MAY 90 1240
Elevation, FT
20
18
16
14
12
10
8
6
4
2
0
150
200
250
300
350
400
Distance, FT

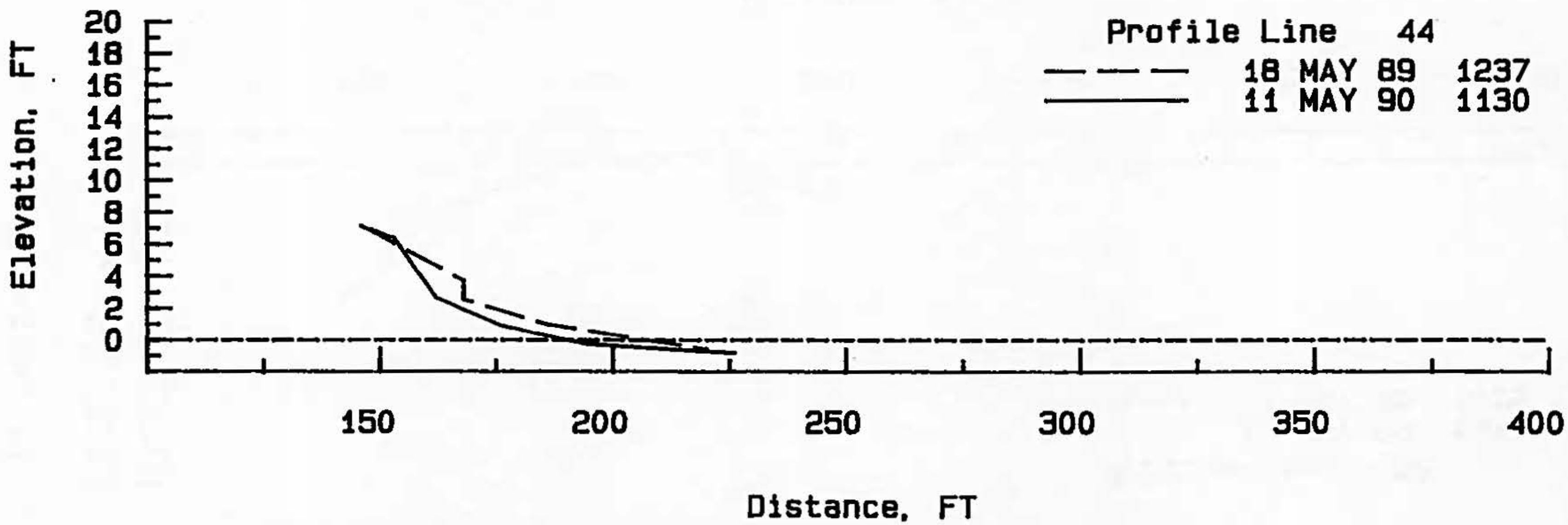

Profile Line 28
17 MAY 89 1114
11 MAY 90 1025
Elevation, FT
20
18
16
14
12
10
8
6
4
2
0
150
200
250
300
350
400
Distance, FT

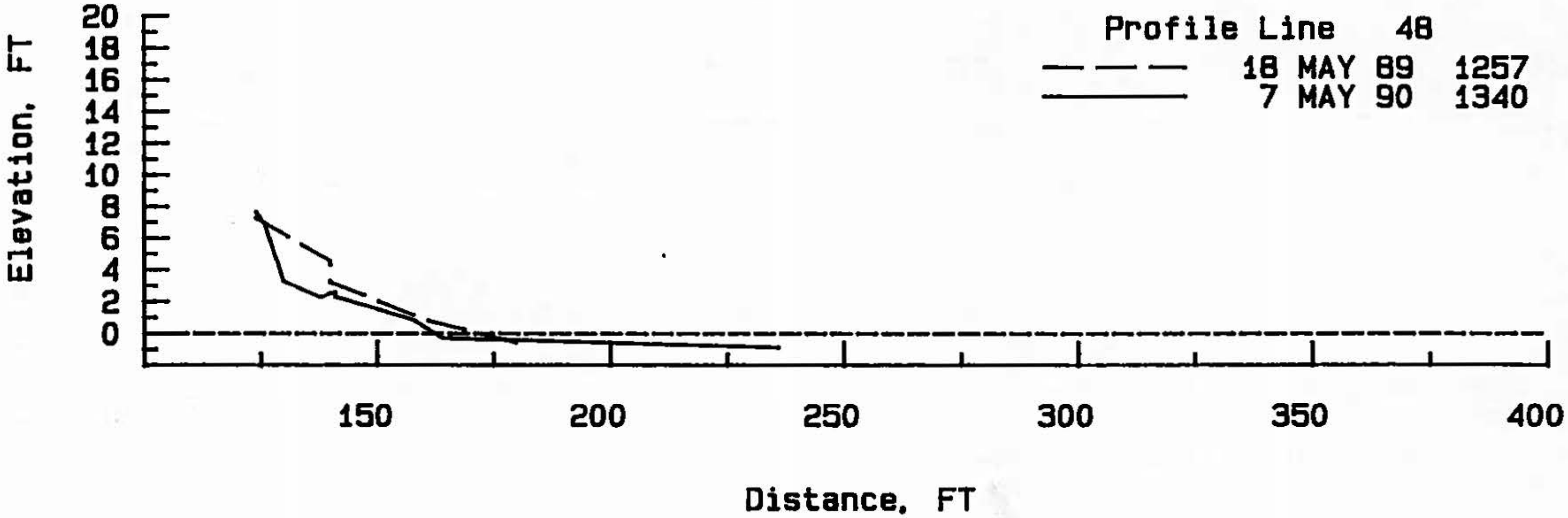

Profile Line 30
17 MAY 89 1045
7 MAY 90 1445
Elevation, FT
20
18
16
14
12
10
8
6
4
2
0
150
200
250
300
350
400
Distance, FT

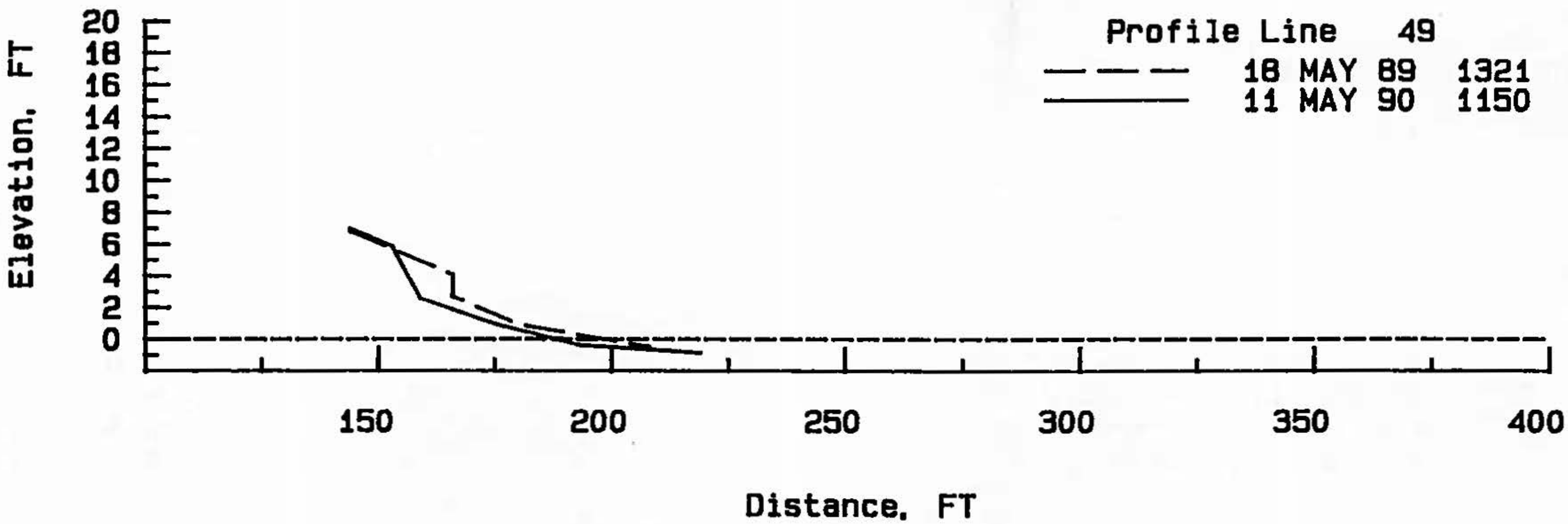

Profile Line 32
17 MAY 89 1439
7 MAY 90 1015
Elevation, FT
20
18
16
14
12
10
8
6
4
2
0
150
200
250
300
350
400
Distance, FT

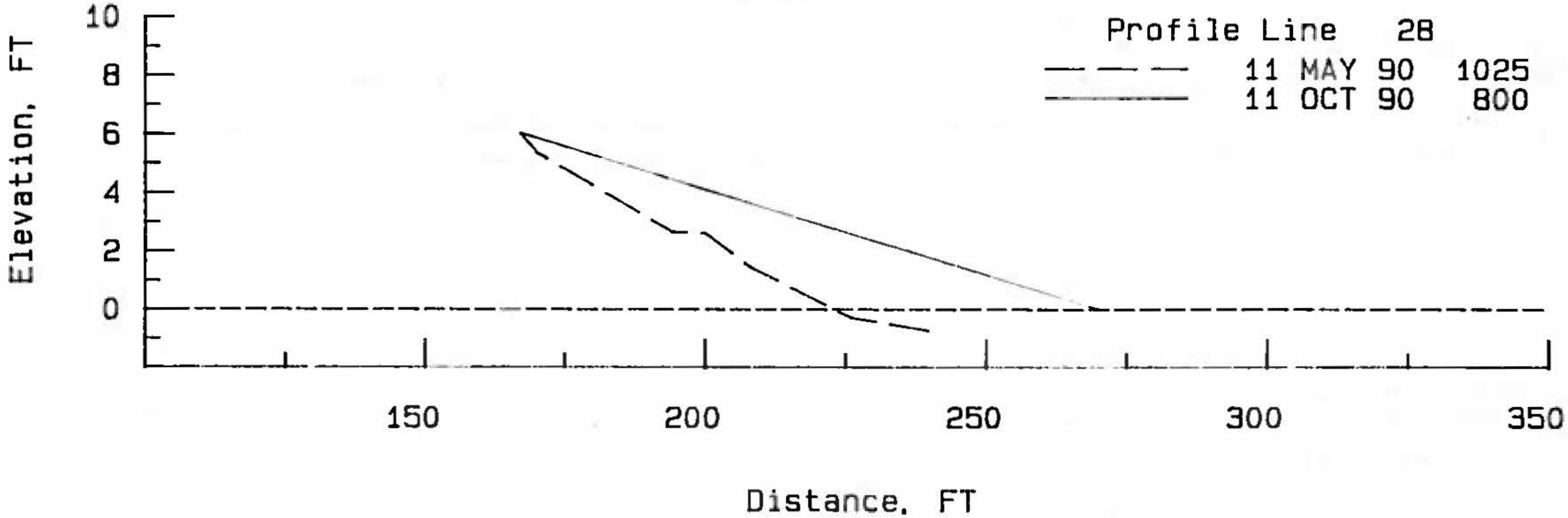

Profile Line 36
18 MAY 89 1058
11 MAY 90 1050
Elevation, FT
20
18
16
14
12
10
8
6
4
2
0
150
200
250
300
350
400
Distance, FT

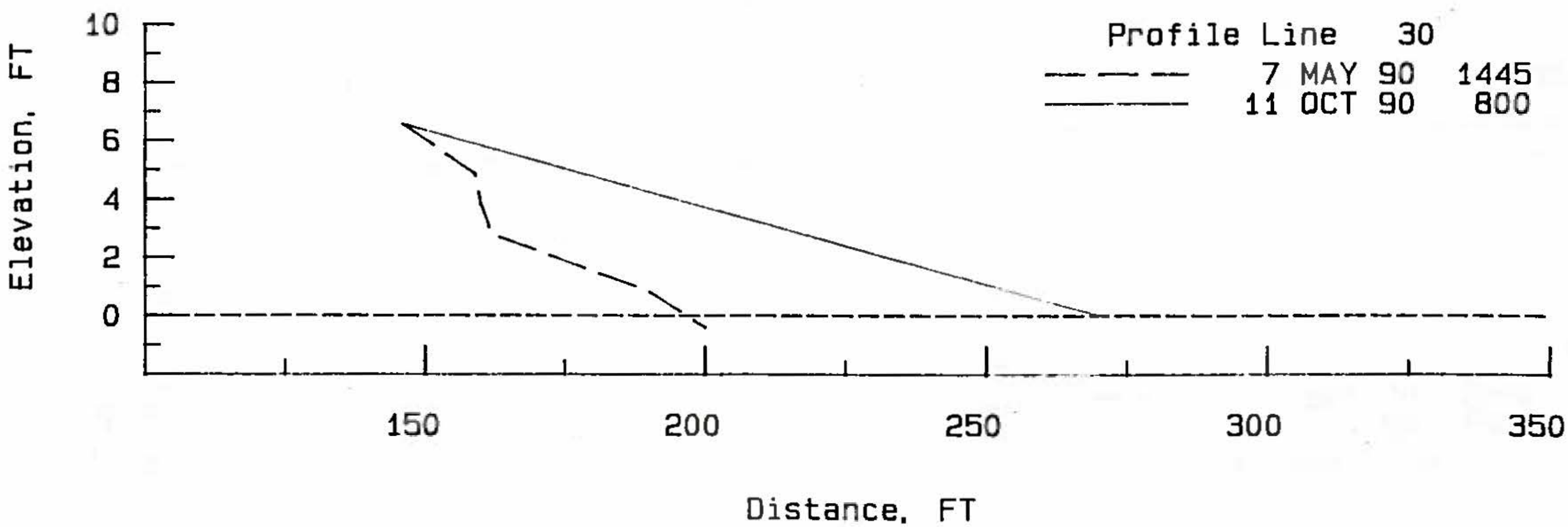

Profile Line 40
18 MAY 89 1125
11 MAY 90 1115
Elevation, FT
20
18
16
14
12
10
8
6
4
2
0
150
200
250
300
350
400
Distance, FT

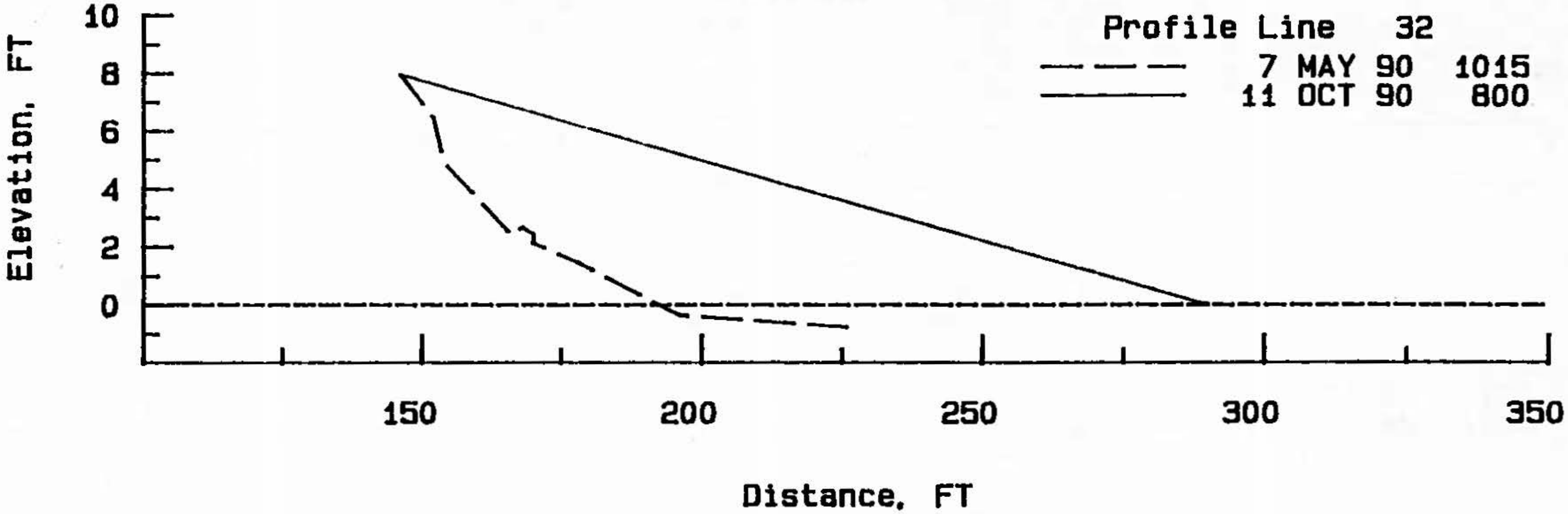

Profile Line 44
18 MAY 89 1237
11 MAY 90 1130
Elevation, FT
20
18
16
14
12
10
8
6
4
2
0
150
200
250
300
350
400
Distance, FT

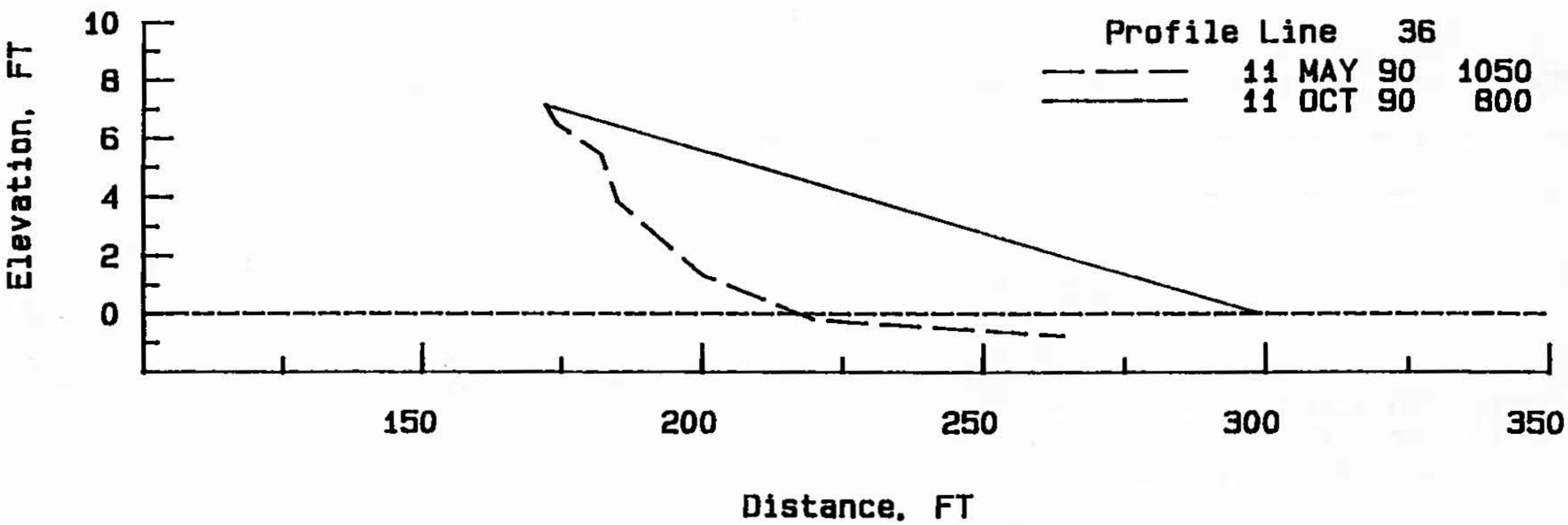

Profile Line 48
18 MAY 89 1257
7 MAY 90 1340
Elevation, FT
20
18
16
14
12
10
8
6
4
2
0
150
200
250
300
350
400
Distance, FT

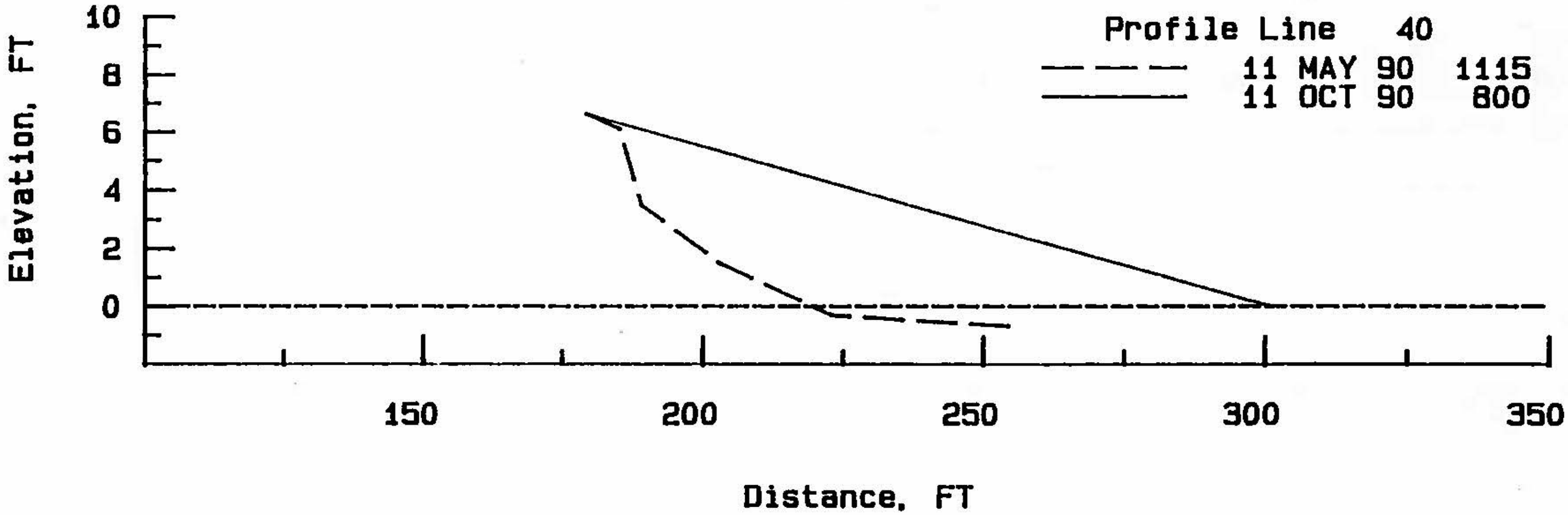

Profile Line 49
18 MAY 89 1321
11 MAY 90 1150
Elevation, FT
20
18
16
14
12
10
8
6
4
2
0
150
200
250
300
350
400
Distance, FT

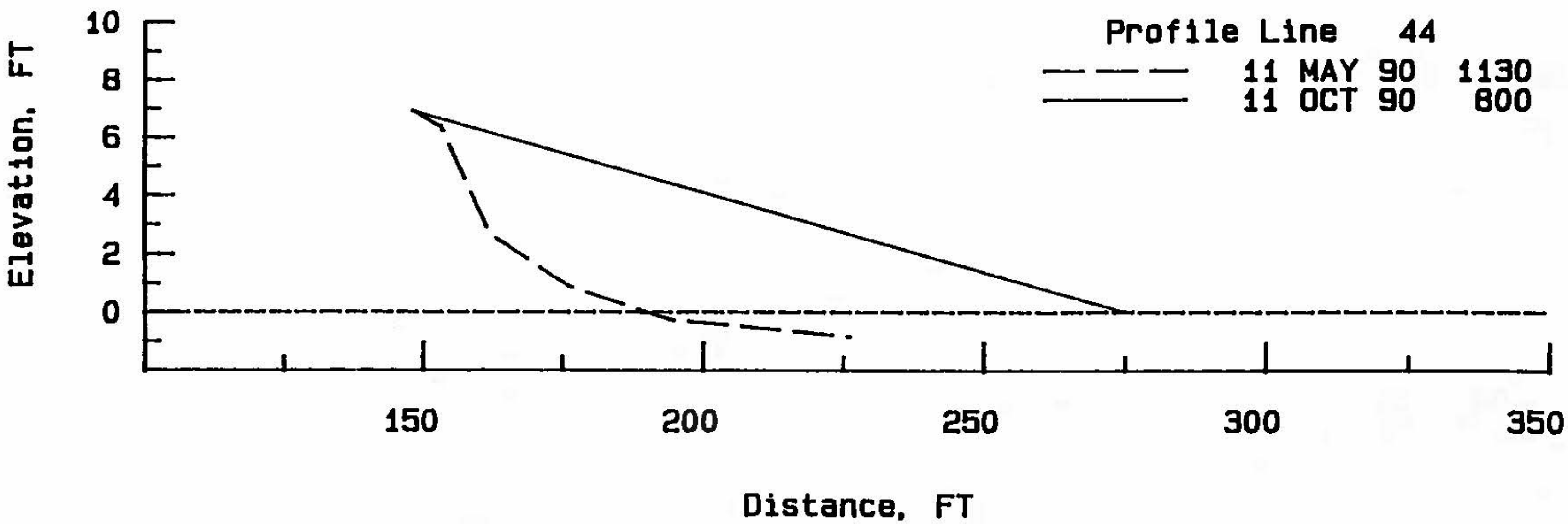

Profile Line 28
11 MAY 90 1025
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT

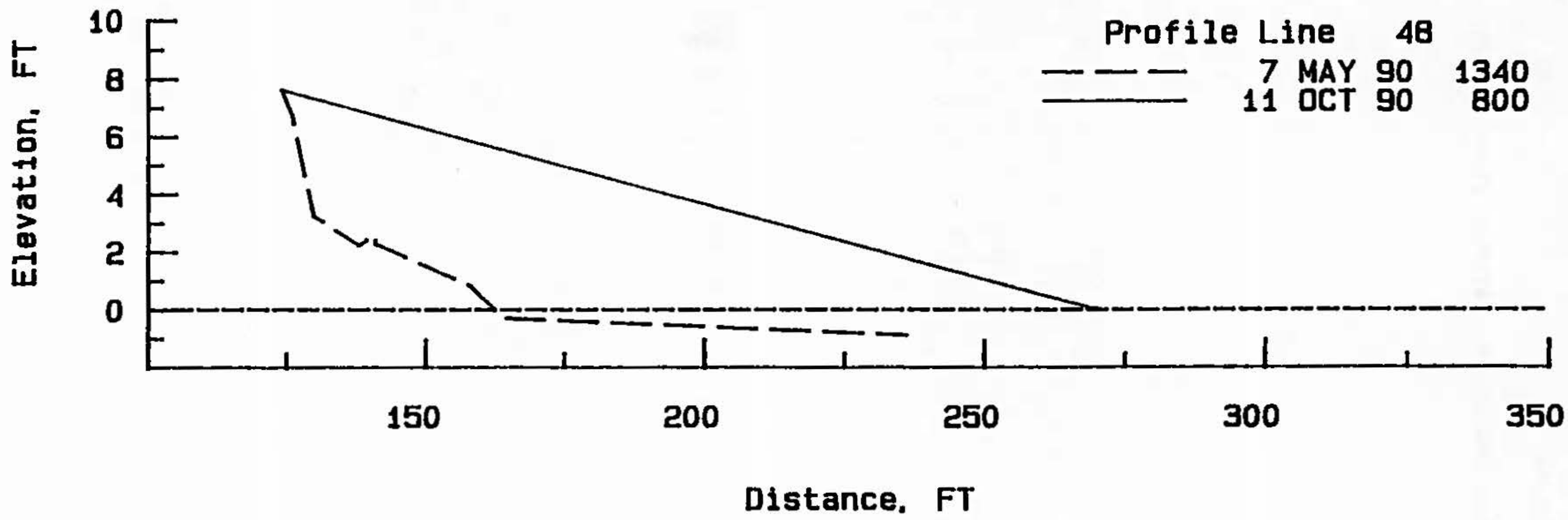

Profile Line 30
7 MAY 90 1445
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT

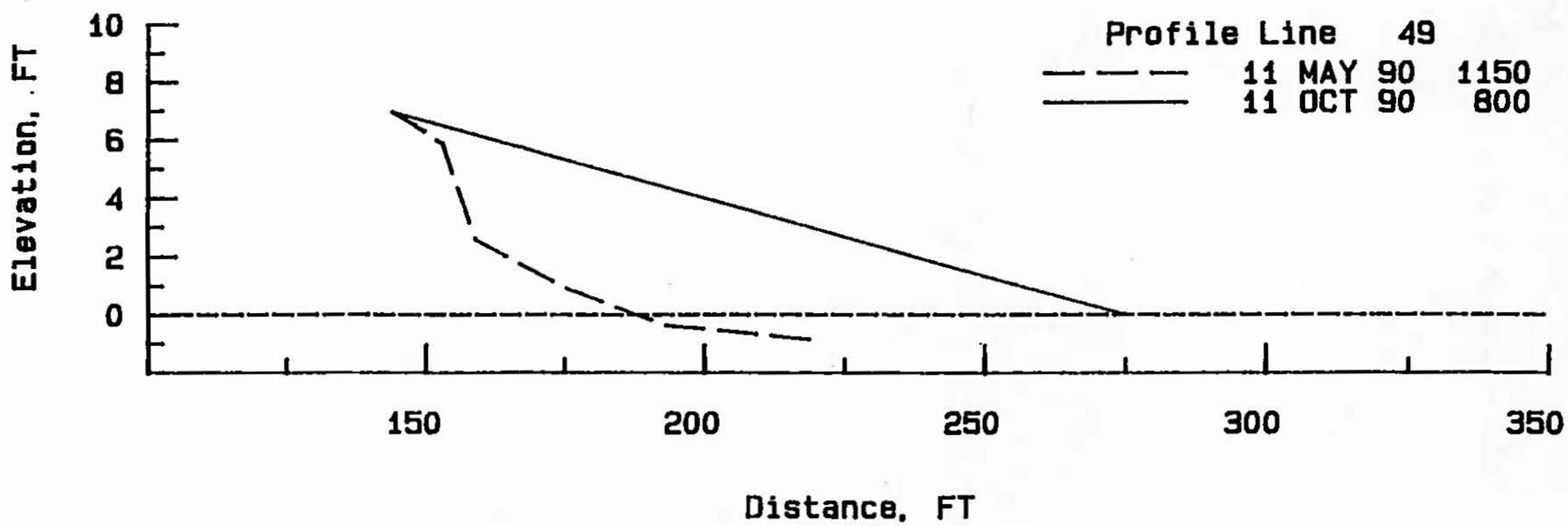

Profile Line 32
7 MAY 90 1015
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT


Profile Line 36
11 MAY 90 1050
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT


Profile Line 40
11 MAY 90 1115
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT

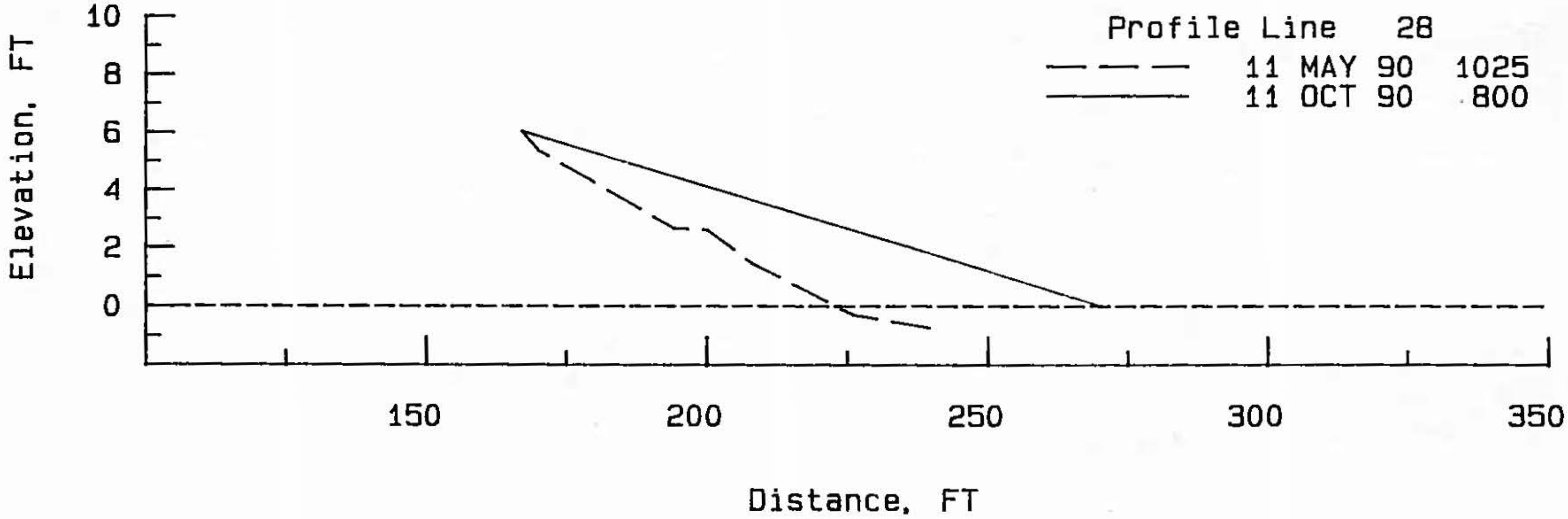

Profile Line 44
11 MAY 90 1130
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT

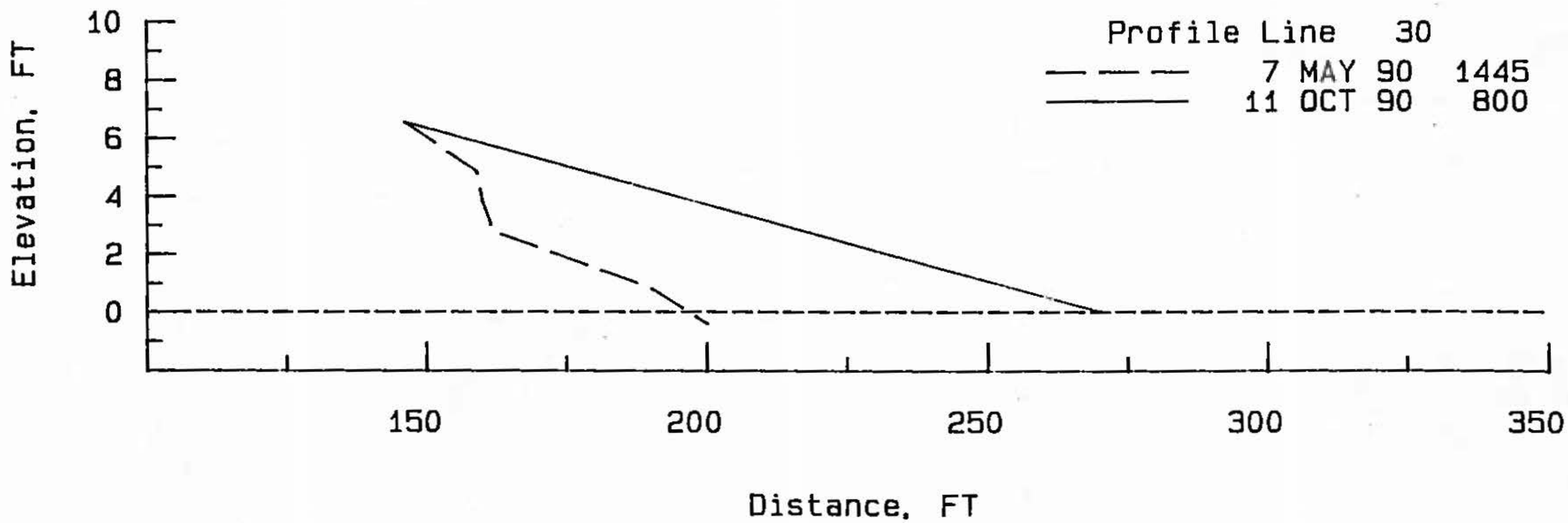

Profile Line 48
7 MAY 90 1340
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT

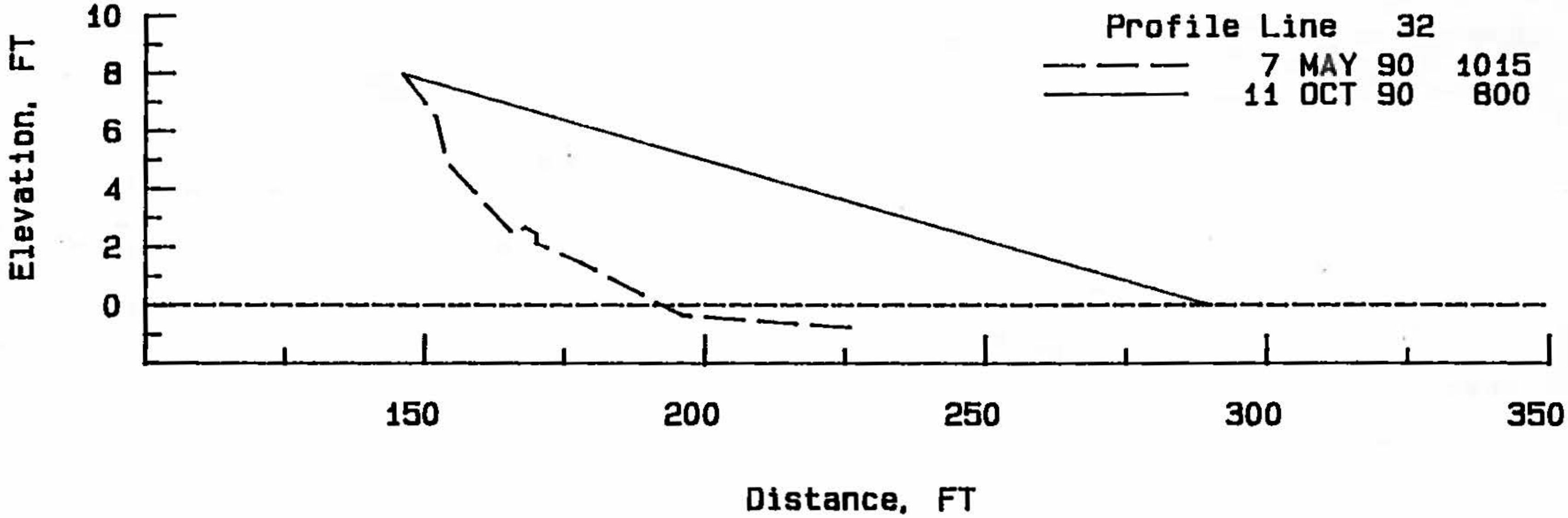

Profile Line 49
11 MAY 90 1150
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT

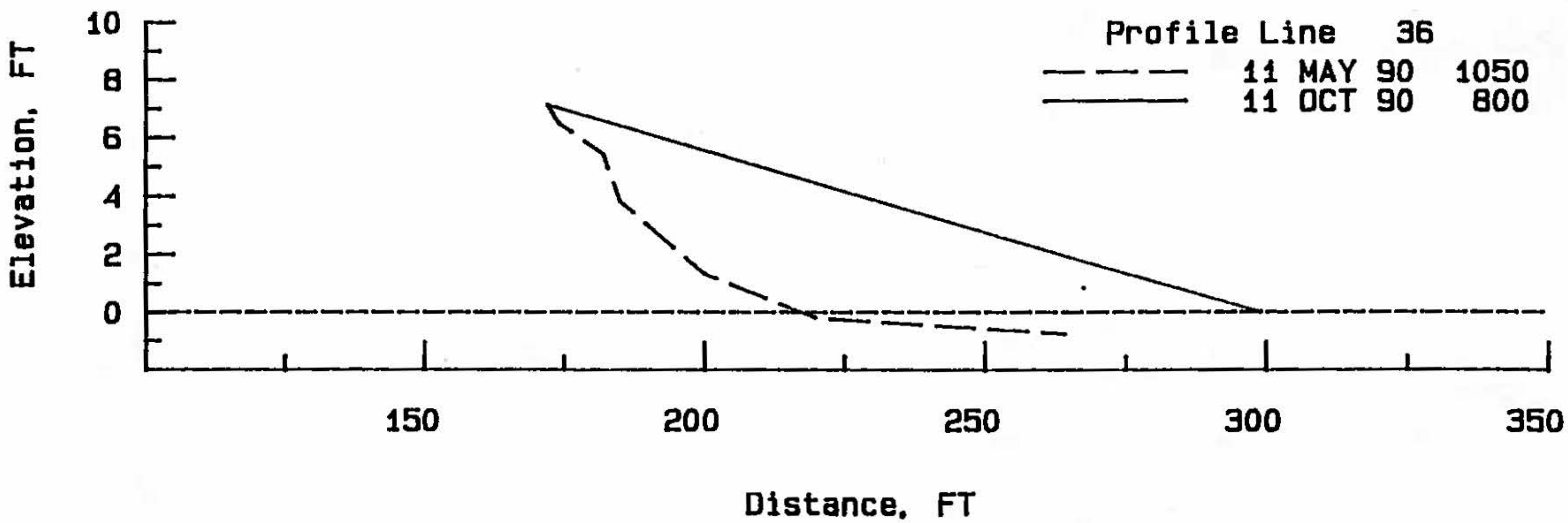
Appendix H

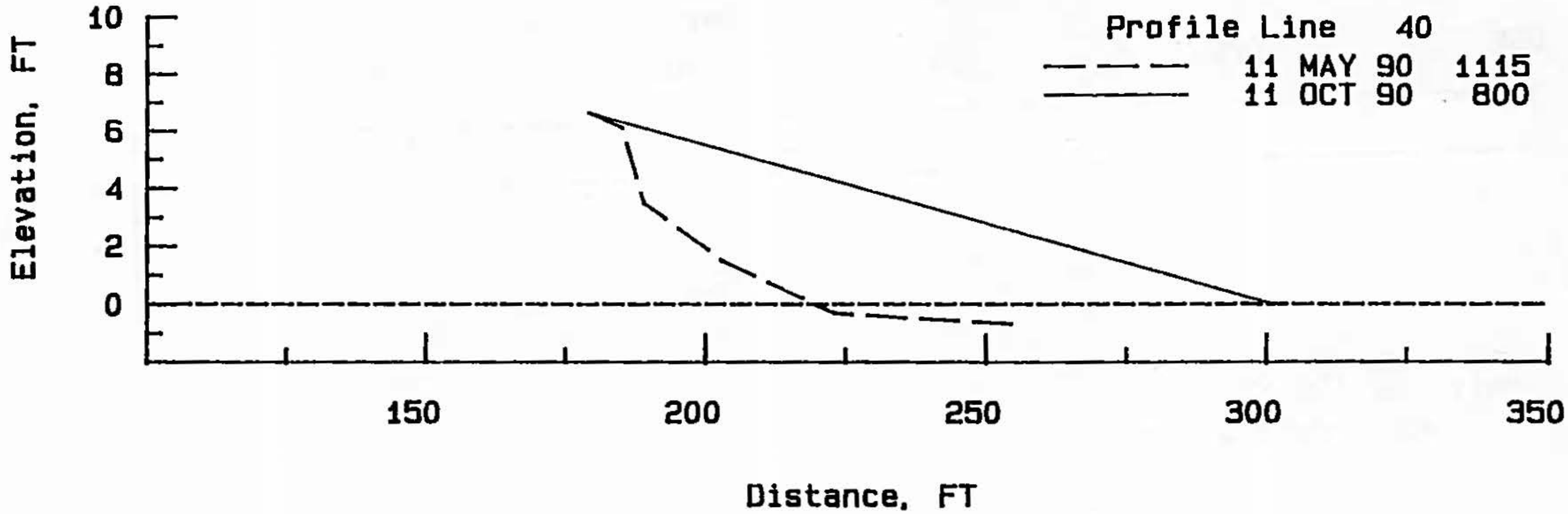
Cross-sectional profiles of the recommended renourished beach.

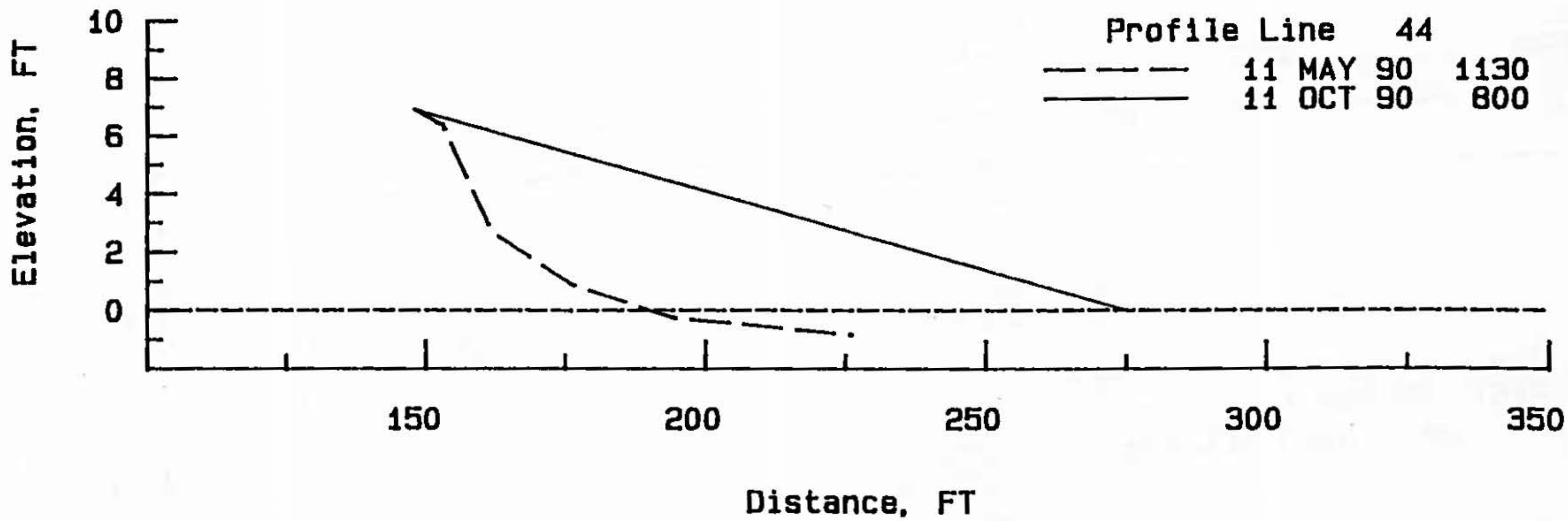

Profile Line 28
11 MAY 90 1025
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT

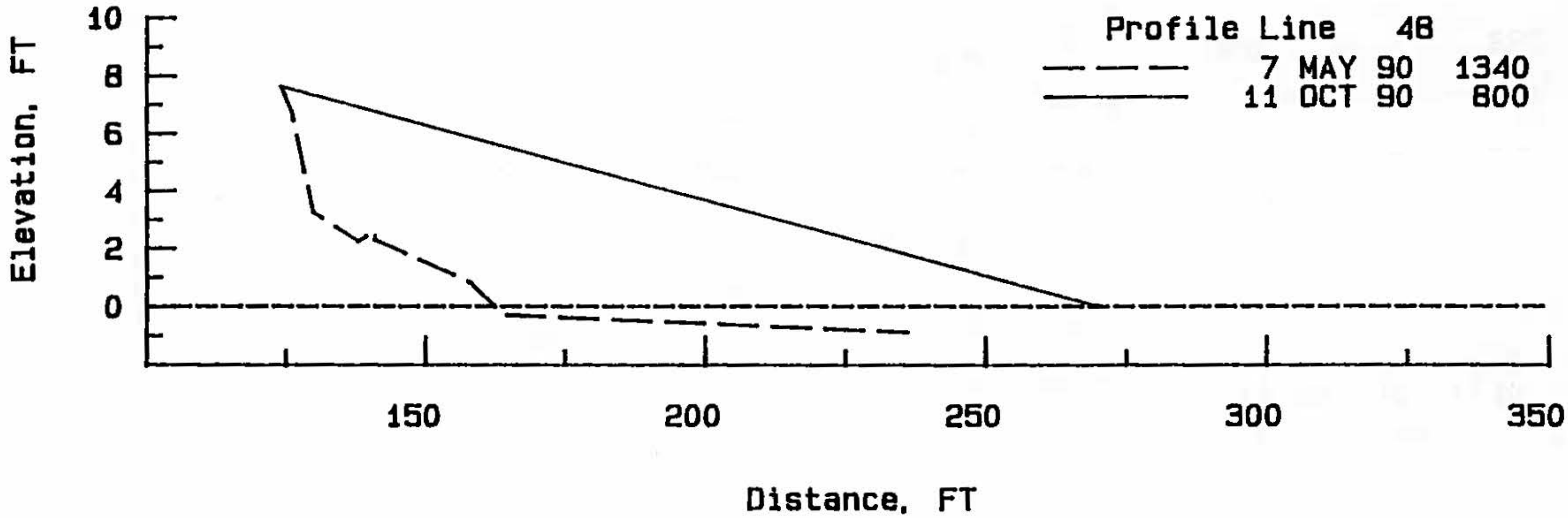

Profile Line 30
7 MAY 90 1445
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT

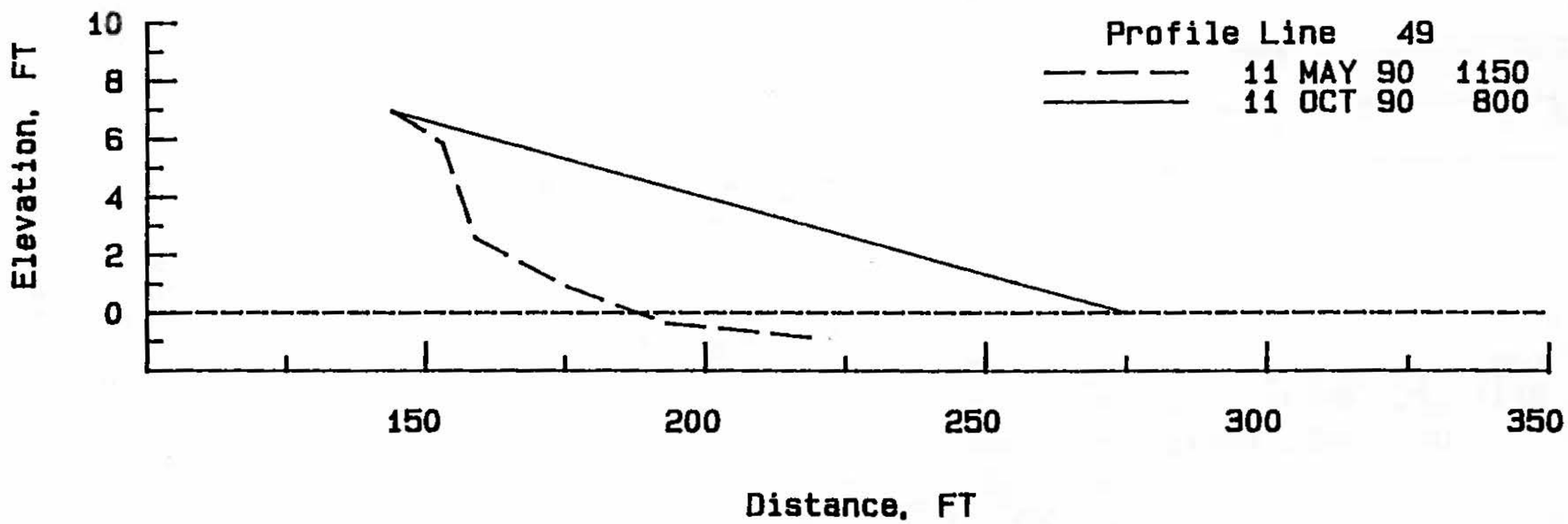

Profile Line 32
7 MAY 90 1015
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT


Profile Line 36
11 MAY 90 1050
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT


Profile Line 40
11 MAY 90 1115
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT


Profile Line 44
11 MAY 90 1130
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT


Profile Line 48
7 MAY 90 1340
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT


Profile Line 49
11 MAY 90 1150
11 OCT 90 800
Elevation, FT
10
8
6
4
2
0
150
200
250
300
350
Distance, FT

Ref. No. [UMCEES]CBL 91-076

Ninth Annual Interpretive Report for Project III: Benthic Studies at the Hart-Miller Island Containment Facility

for

Maryland Department of Natural Resources
Tidewater Administration
580 Taylor Avenue Annapolis, MD 21401

by

Dr. Linda E. Duguay, Principal Investigator
The University of Maryland
Center for Environmental & Estuarine Studies
Chesapeake Biological Laboratory
Solomons, MD 20688-0038

January 1992

ABSTRACT

Benthic invertebrate populations in the vicinity of the Hart-Miller Island Containment Facility were monitored for the ninth successive year to assess any possible effects on these bottom-dwelling organisms from operation of the facility. Organisms living close to the containment dike (called nearfield stations) either within the sediments (infaunal) or upon the concrete and wooden pilings (epifaunal) were collected along with organisms living at some distance from the containment facility (referred to as reference stations) in December 1989 and April and August 1990.

The infaunal samples were collected with a 0.05 m^2 Ponar grab and washed on a 0.5 mm mesh screen. The epifaunal samples were scraped from the pilings, which support a series of piers that surround the containment facility, with a specially designed scraping apparatus. Thirteen infaunal stations were sampled on each cruise (8 nearfield/experimental stations, S1-S8, and 5 reference stations HM 7, 9, 16, 22, 26). Four additional stations were added over the course of the year in areas that were reportedly were substantially enriched in Zn. (8tyh year report). The various infaunal stations include silt-clay stations, oyster shell stations, and sand substrate stations.

A total of 26 benthic infaunal species were collected from these seventeen stations. The most abundant species were the worms, *Scolecolepides viridis*, *Tubificoides gabriellae*, and *Streblospio benedicti*; the crustaceans, *Leptocheirus plumulosus*, *Cyathura polita*, and *Corophium lacustrae*; and the clam *Rangia cuneata*.

Species diversity (H') values were evaluated at each of the infaunal stations at the three sampling periods. The highest diversity value (3.2897) was obtained for one of the Zn enriched stations, G25, in August 1990; whereas, the lowest diversity value (0.0788) also occurred at a Zn enriched station, this time at station G84 in April 1990. For the three sampling dates again as was the case last year, the overall highest diversity values (ten stations with values over 2.0) occurred in December and the lowest overall diversity values (seven stations under 1.0) occurred in April 1990.

The length-frequency distributions of the clams, *Rangia cuneata*, *Macoma balthica*, and *Macoma mitchelli* were examined at the nearfield, reference, and Zn enrichment stations. There was good correspondence in terms of numbers of clams present and the relative size groupings for the three sampling dates. *Rangia cuneata* continues to be the most abundant species for all three groups of stations, followed by *Macoma balthica*. *Macoma mitchelli* remains for the most part the least abundant clam

species. Cluster analysis of the stations over the three sampling periods continues to associate stations primarily in response to bottom type. Variations in recruitment at the different stations explain why some specific stations did not form tight groupings. The clusters were again consistent with studies from previous years and did not indicate any unusual groupings resulting directly from the containment facility. Rank analysis of differences in the mean abundances of ten selected species at stations with silt/clay substrates indicated significant differences only for the reference stations in December and August. No significant differences in means for the combined silt/clay nearfield and reference stations or for the combined silt/clay Zn-enriched and reference stations occurred for any of the sampling periods.

Epifaunal populations were similar to those observed in previous years. Samples were collected at two depths (about 3 ft (1 m) and 6-8 ft (2-3 m), dependent on the station depth). The lower depth is well below the winter ice scour zone. Epifaunal populations persisted throughout the year at all of the locations on the pilings. The epifaunal populations at both the nearfield and reference stations were very similar over all three sampling periods. As previously reported the amphipod, *Corophium lacustre*, was one of the most abundant organisms present at both the reference and nearfield stations at all sampling periods. This year the hydroid, *Cordylophora caspia*, replaced the colonial bryozoan, *Victorella pavida,* as the second most frequently observed species on the pilings. *Cordylophora* was likewise present at both reference and nearfield stations on all sampling periods.

The results of the current monitoring effort once again suggest that only localized and temporary effects on the benthic organisms result from the containment facility. These effects are limited mainly to the area where dredged materials are brought in by the barges to the facility and they are believed to be caused by some scouring of the bottom by the activity of the barges and tug boats. Discharge of effluent from the facility has occurred over the past few sampling years and to date no adverse effects on the benthic populations have been observed. The four benthic infaunal stations added this year in the Zn enriched areas, do not appear to differ in any distinct manner from the original nearfield and reference epifaunal stations. Continued monitoring of the benthic populations in the area is strongly recommended in order to continue to follow any potential changes associated with the existence and operation of the Hart-Miller Island Containment Facility.

INTRODUCTION

The results of the benthic population studies conducted during the ninth consecutive year of the exterior monitoring program in and around the vicinity of the Hart-Miller Island Containment Facility are presented in this report. The containment site, lying within the northern portion of the Chesapeake Bay, experiences seasonal salinity and temperature fluctuations. The region encompasses vast shallow soft-bottom shoals rich in nutrients, which are important to protect because they serve as important breeding and nursery grounds 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. Long term studies of more stable, mesohaline areas further down-Bay found that most macrobenthic species showed significant year-to-year fluctuations in abundance, primarily as a result of slight salinity changes and that spring season was a critical period for the establishment of both regional and long-term distribution patterns (Holland (1985) and Holland et al. (1987)). One would expect even greater fluctuations in the benthic organisms inhabiting the region of the 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, 1989 and Duguay, 1989, 1990) 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 and highly variable regions (Beukema, 1988).

The objectives of the benthic monitoring studies which are were:

1. To monitor the nearfield benthic populations for possible effects of discharged effluent and possible seepage of dredge materials from the containment facility by following changes in population size and species composition over the seasonal cycle.

2. To collect samples of the epibenthic fauna on the pilings along the perimeter of the containment facility to check for any immediate sign of detrimental effects to these organisms as a result of discharge or seepage from the facility.

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

comparisons with the nearfield stations surrounding the containment facility.

4. To expand of the monitoring of benthic populations to include four stations at which the Maryland Geological sedimentary group has been finding elevated levels of Zn (Zn enrichment).

5. To provide selected species of benthic invertebrates and fishes for chemical analysis of organic and metal concentrations by an outside laboratory (Martel, Inc.), in order to ascertain various contaminant levels in organisms and to follow if there is any possible bioaccumulation occurring.

METHODS AND MATERIALS

Three cruises were conducted during the ninth monitoring year on December 4-5 1989, April 5-6, 1990 and August 6-7, 1990. The location of all the sampling stations (infaunal - reference, nearfield, and Zn enrichment; and the epifaunal - reference and nearfield) are shown in Figure 1 with their CBL designations. The stations were located in the field by means of the LORAN-C navigational system of the ship. Latitude and longitude of each station and the state identification numbers can be found in the *Ninth Year Data Report*. The state designation numbers are also listed in Table 6 of this report. Three replicate grabs were taken with a 0.05 m^2 Ponar grab at the regular 13 benthic infaunal stations (S1-S8, and HM 7, 9, 16, 22, 26) at each sampling period. Four additional stations were added over the course of the year which corresponded to stations at which elevated levels of Zn had been reported by the Maryland Geological Survey sedimentary group. Station G25 was added in December 1989, G84 and HM12 were added in April 1990, and the fourth station G5 was added in August 1990. All of the samples were washed individually on a 0.5 mm screen and fixed in 10% formalin/seawater on board the ship. Back in the laboratory the samples were again washed on a 0.5mm sieve and then transferred to 70% ethyl alcohol. The samples were then sorted and each organism was removed, identified, and enumerated. Measurements of length-frequency were made on the three most abundant mollusks. A qualitative sample was scraped from the pilings at the epifaunal stations (R2-R5, see Figure 1) by a specially designed piling scraping device constructed of aluminum. The scrape samples were treated in a similar manner 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, 2 - abundant or common, to

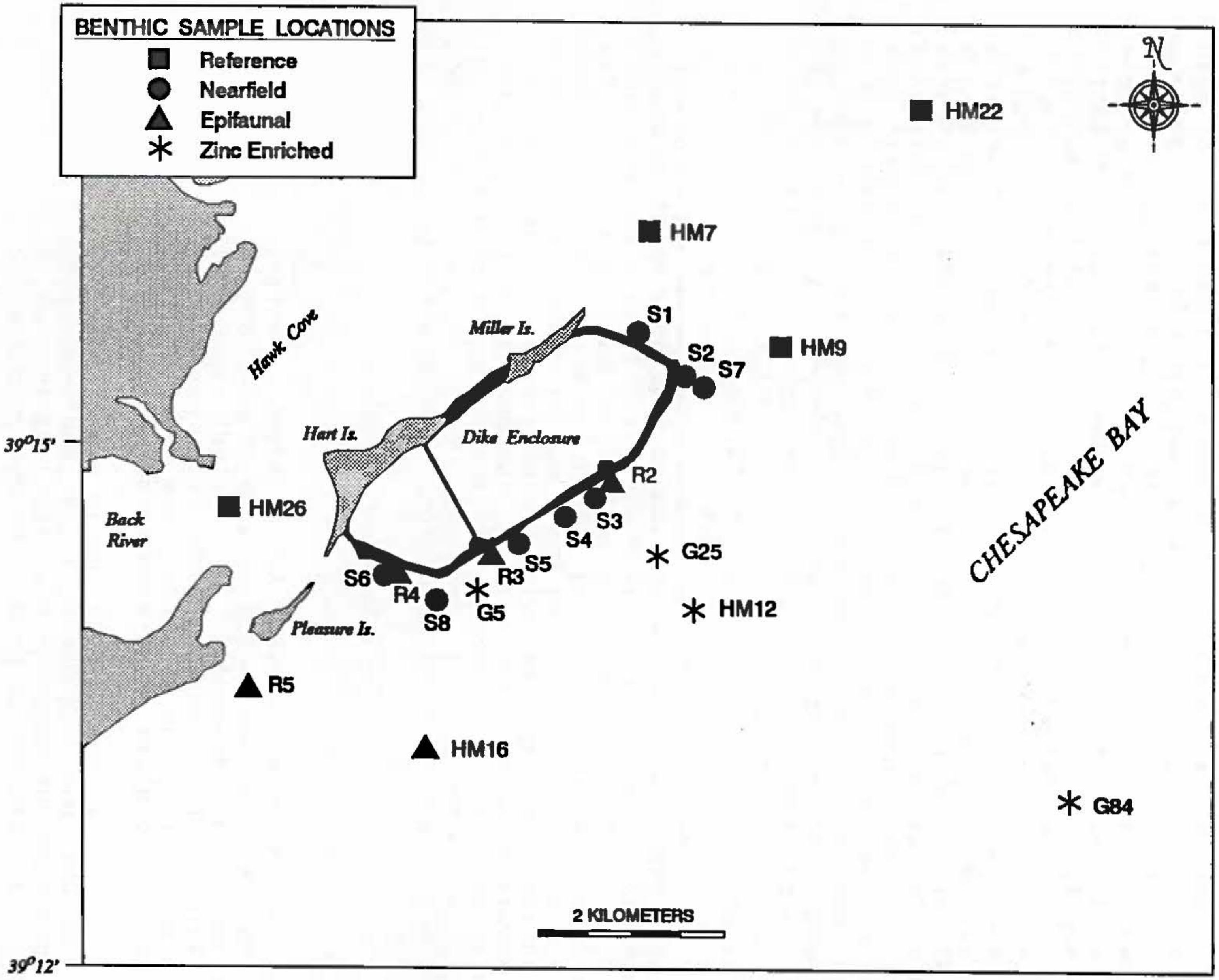


FIGURE 1. BENTHIC INFAUNAL AND EPIFAUNAL SAMPLING STATION LOCATIONS FOR THE 9TH YEAR OF BENTHIC MONITORING AT HART MILLER ISLANDS CONTAINMENT FACILITY. UNIVERSITY OF MARYLAND, CHESAPEAKE BIOLOGICAL LAB DESIGNATIONS.

3 - present. Station depths were recorded from the ship's fathometer. Water temperature and salinity were measured from surface water samples collected through the vessel's seawater intake hoses. Temperature was determined with a hand-held mercury thermometer (range of -20 to 110°C) to the nearest 0.5°C. Salinity was determined with an AO Goldberg hand-held salinometer to the nearest part per thousand (ppt - O/OO) .

The quantitative infaunal sample data was analyzed by a series of statistical tests. A method of rank analysis was again used to determine the dominance factor (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 ten most abundant species, between the slit/clay - nearfield, reference, and Zn enriched stations separately. Then, the reference and nearfield or Zn enriched stations were added together and retested.

RESULTS AND DISCUSSION

Since the beginning of the benthic survey studies in 1981, a small number of species have been the dominant members of the benthic invertebrate populations collected at the various nearfield and reference sites in the vicinity of the facility. The most abundant species this year were the annelid worms, *Scolecolepides viridis*, *Tubificoides gabriellae*, *Streblospio benedicti*; the crustaceans, *Leptochierus plumulosus* and *Cyathura polita*; and the clam, *Rangia cuneata* (see Tables 3, 4, and 5). Variations in the range and average number of *S. viridis*, *L. plumulosus*, and *R. cuneata* at the reference stations since the initial sampling in August 1981 are presented in Table 1. The populations of these three species have remained relatively stable over the monitoring period, and this particular monitoring year increases were observed in all three species. The largest increase was observed for the clam, *Rangia cuneata*.

The major variations observed in dominant or most abundant species occur primarily as a result of the different bottom types (Table 2). Soft bottoms are preferred by the annelid worms, *S. viridis*, *T. gabriellae, and S. benedicti*, as well as the crustaceans, *L. plumulosus* and *C. polita*. The most common inhabitants of the predominately old oyster shell substrates are more variable, often with the barnacle, *Balanus improvisus*, and the worm, *Nereis succinea,* among the dominant organisms. However, this year the dominant organisms were similar for all of the bottom types sampled. Sudden freshwater inflows during the spring spawning period have frequently favored the recruitment success of *R. cuneata* in different study years. During the sixth monitoring year high influxes of young recruits into the population were observed at several stations during our August 1987 sampling which was reflected in high densities of small individuals in both the December 1987 and April 1988 samples. A similar influx was observed in our August 1990 samples, particularly at HM7, HM26 and S4, S6 and G5. If high salinities (>10 °/oo) occur and persist throughout the winter, then large mortalities of *Rangia* clams have been reported to occur (Cain, 1975). This does not seem to have been the case during the seventh and eighth monitoring years, as a fairly substantial number of larger clams were present in both August 1988 and in August 1989. However, this year there were very few large *Rangia* clams in August 1990.

Station HM26, at the mouth of the Back River, has the most diverse annelid worm fauna, with seven different species present in December. The most abundant worm (annelid) at this station for December was *Tubificoides sp.* with levels of 2,847 individuals per m^2 (Table 3). *Scolecolepides viridis* was the most abundant worm at HM26 in April with 1,147 individuals/m^2; whereas, in August, *Tubificoides* was again the most abundant worm with 627 individuals/m^2, and *Scolecolepides* was second with 333 individuals/m^2.

The worm, *S. viridis*, and the crustacean, *C. polita*, occurred most frequently at all three sets of stations, the nearfield, reference, and Zn-enriched. *C. polita* was absent only in April at station G84, and *S. viridis* was present at all stations on all sampling dates. 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/clay (Tables 3, 4, and 5). Over the course of the benthic monitoring studies, the worm, *S. viridis* has frequently alternated with the

TABLE 1. Relative abundances (#/m2) of three of the most abundant species of benthic organisms which occur at the Hart-Miller Island Reference stations over the 9 year study period from August 1981 to August 1990.

	Aug., Nov. 1981	Feb., May, Aug., Nov. 1982	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	Dec. 1988 Apr., Aug. 1989	Dec. 1989 Apr., Aug. 1990
Scolecolepides viridis										
Range/m2	0-1825	0-286	0-264		11-153	7-1287	13-447	0-657	20-3420	27-9393
Avg./m2	229	121	69	546	92	398	179	178	998	2012
Leptochierus plumulosus										
Range/m2	0-2960	0-5749	7-6626		20-441	7-1293	7-3312	0-3693	0-2474	67-2820
Avg./m2	832	1459	2259	614	272	308	1111	398	327	829
Rangia cuneata										
Range/m2	0-46	0-99	0-135		0-75	0-273	13-3007	0-2267	0-580	13-12420
Avg./m2	9	9	22	455	27	102	687	359	123	1587

TABLE 2: A list of the 3 numerically dominant benthic organisms collected from each bottom type on each sampling date during the ninth year of monitoring studies at the Hart-Miller Island containment facility.

STATION	December 1989	April 1990	August 1990
NEARFIELD SOFT BOTTOM (S3,4,5,6,8)			
	Corophium lacustre	Scolecolepides viridis	Rangia cuneata
	Polydora ligni	Leptochierus plumulosus	Leptochierus plumulosus
	Scolecolepides viridis	Tubificoides gabriellae	Scolecolepides viridis
NEARFIELD SHELL BOTTOM (S2,7)			
	Streblospio benedicti	Scolecolepides viridis	Corophium lacustre
	Rangia cuneata	Corophium lacustre	Polydora ligni
	Leptochierus plumulosus	Leptochierus plumulosus	Scolecolepides viridis
REFERENCE SOFT BOTTOM (HM7,16,22)			
	Leptochierus plumulosus	Scolecolepides viridis	Rangia cuneata
	Tubificoides gabriellae	Leptochierus plumulosus	Leptochierus plumulosus
	Streblospio benedicti	Cyathura polita	Cyathura polita
REFERENCE SHELL BOTTOM (HM9)			
	Streblospio benedicti	Scolecolepides viridis	Leptochierus plumulosus
	Scolecolepides viridis	Leptochierus plumulosus	Rangia cuneata
	Leptochierus plumulosus	Rangia cuneata	Cyathura polita
BACK RIVER REFERENCE (HM26)			
	Tubificoides gabriellae	Scolecolepides viridis	Rangia cuneata
	Streblospio benedicti	Tubificoides gabriellae	Tubificoides gabriellae
	Leptochierus plumulosus	Leptochierus plumulosus	Scolecolepides viridis
ZINC ENRICHED SOFT BOTTOM (G25)**			
	Streblospio benedicti	Scolecolepides viridis	Cyathura polita
	Cyathura polita	Leptochierus plumulosus	Rangia cuneata
	Monoculodes edwardsi	Cyathura polita	Scolecolepides viridis

**Only zinc enriched station for which data was available for all three sampling dates.

TABLE 3: Number of benthic organisms per m squared found at the Reference Stations for the ninth year monitoring study (December 1989 - August 1990) for the Hart-Miller Island Benthic Study.

SPECIES NAME	SPECIES#	HM7 (XIF 6388)			HM9 (XIF 5297)			HM16 (XIF 3325)			HM22 (XIG 7689)			HM26 (XIF 5145)			TOTALS ALL STATIONS ALL DATES
		Dec	Apr	Aug	Dec	Apr	Aug	Dec	Apr	Aug	Dec	Apr	Aug	Dec	Apr	Aug	
RHYNCHOCOELA (ribbon worms)																	
Micrura leidyi	2						20	27	7	13	7		13	47		13	147
ANNELIDA (worms)																	
Heteromastus filiformis	3	27	13	73		20	53	93	33	33	47	47	20	7	33	33	532
Nereis succinea	5	7			87	7		20		7				13			141
Eteone heteropoda	8													40			40
Polydora ligni	9						87						7	7		67	168
Scolecolepides viridis	10	27	1813	100	260	7913	247	193	2867	80	87	4147	53	60	9393	333	27573
Streblospio benedicti	11	433			480			60			60			1340		13	2386
Limnodrilus hoffmeisteri	13																0
Tubificoides gabriellae.	14	267	27	40	120	107	53	953	33	100	53	40	20	2847	1147	627	6434
Capitella capitata	15																0
MOLLUSCA (mollusks)																	
Ischadium recurvus	16																0
Congeria leucophaeta	17				7		47										54
Macoma balthica	19							280		133					47	20	480
Macoma mitchelli	20	7		7		7		7	40		20			87	120	47	342
Rangia cuneata	21	67	167	10820	153	253	353	173	13	200	247	[illegible]	253	127	453	12420	25699
Hydrobia sp	23			440			53			7			13			40	553
ARTHROPODA (crustaceans)																	
Balanus improvisus	27				27		13										40
Balanus subalbidus	28																0
Leucon americanus	29																0
Cyathura polita	30	140	167	133	7	187	253	326	213	273	33	60	100	87	173	173	2325
Cassidinidea lunifrons	31																0
Edotea triloba	33		7	13	7		7					7			33	33	107
Gammarus palustris	35																0
Leptocheirus plumulosus	36	2813	733	1047	193	267	387	2820	933	860	167	307	1053	1027	460	627	13694
Corophium lacustre	37	27	13		67	67	7	53	7	20	7	80		80	13		441
Gammarus daiberi	38																0
Gammerus tigrinus	39										13						13
Melita nitida	40	533		67	7		7	7		33							654
Chirodotea almyra	41						7									20	27
Monoculodes edwardsi	42	40	13	7	33	40	20	60	20		7	13	33		7		293
Chironomid sp.	43	113					7	40			60			120			340
Rithropanopeus harrisi	44				13	7	7								7		34
Stylochus ellipticus	48																0
TOTAL NUMBERS		4501	2953	12747	1461	8875	1628	5112	4166	1759	.808	4701	1565	5889	11886	14466	82517

Calc from Grab sum of 1863

TABLE 4: Number of benthic organisms per m squared (m2) found at the Nearfield Stations for the ninth year studies (1989-1990) around the Hart-Miller Island containment facility.

SPECIES NAME	#	S1			S2			S3			S4		
		XIF5710			XIF5406			XIF4811			XIF4715		
		Dec	Apr	Aug	Dec	Apr	Aug	Dec	Apr	Aug	Dec	Apr	Aug
RHYNCHOCOELA (ribbon worms)													
Micrura leidyi	2	20		13	13			27		7	13		13
ANNELIDA (worms)													
Heteromastus filiformis	3	13		33	20		27	67	193	80			
Nereis succinea	5	40		7	167	13	33				40		
Eteone heteropoda	8	7						7					
Polydora ligni	9	33		7			7220			13	13		
Scolecolepides viridis	10	427	36460	513	193	12173	1207	373	11907	480	1120	3113	333
Streblospio benedicti	11	1507		13	840			180			213	13	
Limnodrilus hoffmeisteri	13												
Tubificoides gabriellae	14	947	7	467	367	400	400	193	127	73	107	67	
Capitella capitata	15												
MOLLUSCA (mollusks)													
Ischadium recurvus	16						20						
Congeria leucophaeta	17	13			7	20	393			7			
Macoma balthica	19	7							20		19	40	
Macoma mitchelli	20	107						20		7			27
Rangia cuneata	21	907	13	400	240	27	47	187	387	860	80	53	1567
Hydrobia sp.	23			293			27						13
ARTHROPODA (crustaceans)													
Balanus improvisus	27				133	420	653						
Balanus subalbidus	28												
Leucon americanus	29												
Cyathura polita	30	193	13	180	133	13	273	93	87	40	273	140	160
Cassidinidea lunifrons	31				20	113	53			7			
Edotea triloba	33			80					7	13		7	13
Gammarus palustris	35												
Leptocheirus plumulosus	36	1713	127	1160	540	87	13	620	1147	60	407	1073	427
Corophium lacustre	37	10780	93	13	367	920	20013	113	20		193	33	
Gammarus daiberi	38												
Gammarus tigrinus	39		7										
Melita nitida	40	33		13	13	27	40			7			13
Chirodotea almyra	41	7								13			
Monoculodes edwardsi	42	27	53	27	7			107	33	27	73	47	
Chironomid sp.	43		7										
Rithropanopeus harrisi	44					93	140				7		
Stylochus ellipticus	48												
TOTAL NUMBERS		16781	36780	3219	3060	14306	30559	1987	13928	1694	2558	4586	2566

TABLE 4 CONTINUED: Number of benthic organisms per m squared (m2) found at the Nearfield Stations for the ninth year studies (1989-1990) around the Hart-Miller Island containment facility.

SPECIES NAME	#	S5 Dec	S5 Apr	S5 Aug	S6 Dec	S6 Apr	S6 Aug	S7 Dec	S7 Apr	S7 Aug	S8 Dec	S8 Apr	S8 Aug	TOTALS ALL STATIONS ALL DATES
RHYNCHOCOELA (ribbon worms)														
Micrura leidyi	2			33	20		27	7					13	206
ANNELIDA (worms)														
Heteromastus filiformis	3	13	7		27	20	33	7	47	167	7	13		774
Nereis succinea	5	293			53			53			33			732
Eteone heteropoda	8				53									67
Polydora ligni	9	2340	7				7	20		2800	140			12600
Scolecolepides viridis	10	380	2687	33	447	6540	133	147	39687	873	133	2633	67	122059
Streblospio benedicti	11	933			500			207			447			4853
Limnodrilus hoffmeisteri	13													0
Tubificoides gabriellae	14	467	60	20	720	627	227	180	67	120	33	73	20	5769
Capitella capitata	15													0
MOLLUSCA (mollusks)														
Ischadium recurvus	16				7									27
Congeria leucophaeta	17	87						47		340				914
Macoma balthica	19	7				160	40							293
Macoma mitchelli	20				267	113	73	13	7			33	20	687
Rangia cuneata	21	253	27	73	53	113	3640	413	193	793	47	13	93	10479
Hydrobia sp.	23						33			160			7	
ARTHROPODA (crustaceans)														
Balanus improvisus	27	13						7	7	113				1346
Balanus subalbidus	28													0
Leucon americanus	29													0
Cyathura polita	30	360	347	167	107	153	193	73	7	293	447	80	247	4072
Cassidinidea lunifrons	31													193
Edotea triloba	33				13	27	7			20				187
Gammarus palustris	35													0
Leptocheirus plumulosus	36	47	567	587	487	967	1033	87	627	247	53	1200	900	14176
Corophium lacustre	37	7933	113	13	200	220	13	100	93	5113	2120	33		48496
Gammarus daiberi	38													0
Gammarus tigrinus	39	13												20
Melita nitida	40			73		7	13			40		27	33	339
Chirodotea almyra	41					7	7			7				
Monoculodes edwardsi	42		20		40	60			53			13		587
Chironomid sp.	43													7
Rithropanopeus harrisi	44	7								87	7			341
Stylochus ellipticus	48													0
TOTAL NUMBERS		13146	3835	999	2994	9014	5479	1361	40788	11173	3467	4118	1400	229798

TABLE 5: Number of benthic organismsnisms per m squared (m2) found at the Research Station for the nineth year monitoring stud (December 1989 - August 1990) for the Hart-Miller Island benthic studies.

SPECIES NAME	#	G5 X1F4426 Dec	Apr	Aug	G25 X1F4712 Dec	Apr	Aug	G84 X163570 Dec	Apr	Aug	HM12 X164104 Dec	Apr	Aug	TOTALS ALL STATIONS ALL DATES
RHYNCHOCOELA (ribbon worms)														
Micrura leidyi	2	NS	NS	20	20		87	NS			NS		47	174
ANNELIDA (worms)														
Heteromastus filiformis	3	NS	NS		60	20	27	NS	7	327	NS	47	87	575
Nereis succinea	5	NS	NS		33		7	NS			NS			40
Eteone heteropoda	8	NS	NS					NS						0
Polydora ligni	9	NS	NS				53	NS			NS		87	140
Scolecolepides viridis	10	NS	NS	153	33	8553	93	NS	40287	220	NS	6360	273	55972
Streblospio benedicti	11	NS	NS		173			NS		13	NS		13	199
Limnodrilus hoffmeisteri	13	NS	NS					NS						0
Tubificoides gabriellae.	14	NS	NS	87	33	87	27	NS	7	80	NS	140	27	488
Capitella capitata	15	NS	NS					NS						0
MOLLUSCA (mollusks)														
Ischadium recurvus	16	NS	NS					NS						0
Congeria leucophaeta	17	NS	NS					NS			NS		33	33
Macoma balthica	19	NS	NS	13			13	NS	40	240	NS	67	47	420
Macoma mitchelli	20	NS	NS	53				NS		13	NS			66
Rangia cuneata	21	NS	NS	7140	47	73	120	NS	20	27	NS	493	553	8473
Hydrobia sp.	23	NS	NS	20			7	NS		13	NS		13	53
ARTHROPODA (crustaceans)														
Balanus improvisus	27	NS	NS				107	NS			NS		13	120
Balanus subalbidus	28	NS	NS					NS			NS			0
Leucon americanus	29	NS	NS					NS			NS			0
Cyathura polita	30	NS	NS	180	133	320	133	NS	7	373	NS	233	160	1539
Cassidinidea lunifrons	31	NS	NS					NS			NS			0
Edotea triloba	33	NS	NS	7		7		NS			NS	33	7	54
Gammarus palustris	35	NS	NS					NS			NS			0
Leptocheirus plumulosus	36	NS	NS	587	47	687	80	NS	140	1360	NS	67	333	3301
Corophium lacustre	37	NS	NS			120		NS	7	13	NS	7		147
Gammarus daiberi	38	NS	NS					NS			NS			0
Gammerus tigrinus	39	NS	NS					NS			NS			0
Melita nitida	40	NS	NS	20				NS		13	NS			33
Chirodotea almyra	41	NS	NS					NS			NS			0
Monoculodes edwardsi	42	NS	NS		67	60	7	NS	73		NS	73		280
Chironomid sp.	43	NS	NS					NS			NS			0
Rithropanopeus harrisi	44	NS	NS			7	13	NS			NS			20
Stylochus ellipticus	48	NS	NS					NS			NS			0
TOTAL NUMBERS		NS	NS	8280	646	9934	774	NS	40588	2692	NS	7520	1693	72127

TABLE 6: Salinity (in 0/00), temperature (in OC), and depth (in ft.) data for the benthic sampling stations on the different collection dates during the ninth year of sampling.

CBL	STATE	DECEMBER 89			APRIL 90			AUGUST 90		
STA. ID	STA. #	SAL. 0/00	TEMP. oC	DEPTH FT.	SAL. 0/00	TEMP. oC	DEPTH FT.	SAL. 0/00	TEMP. oC	DEPTH FT.
R1	XIF4811	*NS	NS	NS	NS	NS	NS	NS	NS	NS
R2	XIF4813	**NR	NR	3/6	NR	NR	3/8	5	27	3/8
R3	XIF4514	NR	NR	3/8	NR	NR	3/8	NR	NR	3/8
R4	XIF4518	NR	NR	3/8	NR	NR	3/8	NR	NR	3/8
R5	XIF3638	NR	NR	3/8	NR	NR	3/8	4	26	3/8
S1	XIF5710	NS	NS	6	2	9	6	4	27	11
S2	XIF5406	0	1	8	2	9	11	4	27	11
S3	XIF4811	0	1	12	2	9	14	4	27	15
S4	XIF4715	1	2	12	2	9	13	6	27	13
S5	XIF4420	1	2	16	0.5	9	20	6	27	19
S6	XIF4327	0	2	8	0.5	8.5	9	6	26.5	10
S7	XIG5405	0	1	10	2	9	13	4	27	12
S8	XIF4124	1	2	12	0.5	8.5	14	6	27	15
HM7	XIF6388	0	1	10	2	9	11	4	27	10
HM9	XIF5297	0	1	9	2	9	17	4.5	27	16
HM16	XIF3325	0	2	14	0	8	16	6	26.5	16
HM22	XIG7689	1	1	10	2	9	12	6	27	11
HM26	XIF5145	0	1	13	2	9	13	3	27	15
HM12	XIF5805	NS	NS	NS	0.5	9	15	6	27	15
G5	XIF4221	NS	NS	NS	NS	NS	NS	6	27	16
G25	XIF4405	1	2	14	0.5	9	15	6	27	15
G84		NS	NS	NS	2	9	17	7	27	18

*NS= NOT SAMPLED **NR= NOT RECORDED

crustaceans, *C. polita* and *L. plumulosus*, as the foremost dominant species. It appears that slight modifications in the salinity patterns during the important seasonal recruitment period in late spring play an important role in determining the dominance of these species. The crustaceans, *C. polita* and *L. plumulosus*, become more abundant during low salinity years, while *S. viridis* prefers slightly higher salinities. This particular year *S. viridis* reached even higher total densities than last year's high numbers, primarily due to a very large population (39,687 individuals/m^2) at station S7 in April (see Table 4). This particular year *L. plumulosus* was ahead of *C. polita* in terms of overall abundance at all three sets of stations (see Tables 3, 4, 5) and was present at all stations on all dates sampled. The isopod crustacean, *Cyathura*, was also present at all stations on all sampling dates. *Cyathura* appears to be very tolerant of physical and chemical disturbances and repopulates areas such as dredged material piles more quickly than other crustacean 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 rates and often reach high densities of individuals (Wells, 1961). The total number of individual organisms collected at the various reference, nearfield, and Zn enriched stations are comparable and ranged for the most part between 1000 and 5000 individuals/m^2. The highest recorded values occurred at stations S7 and G84 (40,000+ individuals/m^2) as a result of high concentrations of the worm *S. viridis*. The lowest recorded values occurred at station G25 in December and August (646 and 744 individual/m^2, respectively) followed by station HM22 (808 individual/m^2) in December and S5 (999 individual/m^2) in August. There did not appear to be any consistent pattern in terms of the highs and lows at the reference or nearfield stations. However, April values were generally above December and August, reflecting maximum recruitment at this time. The predominant benthic populations at the three sets of stations -- nearfield, reference, and Zn enriched areas -- are similar. They consist of detrital feeders, which have an ample supply of fine substrates in this region of the Chesapeake Bay and particularly around the containment facility itself (Wells et al., 1984).

Surface salinity and temperature were recorded at all infaunal stations on all sampling dates (Table 6). In December salinity ranged from 0-1 O/OO; whereas, in April the salinity varied between 0 and 2 O/OO. In August, salinity ranged from 4-7 O/OO. The April values were similar to the last two years when salinities were 1 O/OO in April 87 and 1-2 O/OO in April 88. The December values were somewhat lower than the previous two years, when salinities were 2-6 O/OO. The August values were again within the same range as the previous three years. Temperature was likewise comparable to the three most recent previous study years, with the August temperature again somewhat below the high temperatures recorded in August 1988 of 29-30°C and the values of 27 to 29°C in August 1987.

Species diversity values must be interpreted carefully in analyzing benthic data from the upper Chesapeake Bay. Generally, high diversity values reflect a healthy, stable fauna with the numbers 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, we have observed that 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 7, 8, 9. Again this year, the highest species diversity values for 10 of the original 13 stations occurred during the winter sampling cruise in December. Highest diversity values for the three remaining of the original stations (S1, HM9, HM16) occurred during the August cruise, along with all four of the Zn enriched stations. Highest diversity values occurring in the summer had been postulated in the First Interpretive Report (Pfitzenmeyer et al., 1982) and was the usual case in the early reports. The lowest species diversity values occurred in April, and again they were substantially below previous values recorded in April with no stations above 2.0000 compared with 2 stations above 2.0 in 1989 and 10 stations above 2.00 in 1988. Perhaps these reduced diversity values for April are responsible for the continued reduction in diversity observed in the subsequent August samples.

The largest number of species recorded for any station was 18 at station S1 in December and HM9 in August, followed by 16 at S2 in August. The lowest number of species, 8, was recorded in August at the nearfield station (S5). These rankings for the highest and lowest number of species differed from the previous three years when the highest number of species occurred at HM26 and the lowest number of species occurred at the original sand substrate station S1. We did slightly relocate S1 due to shoaling in the area of the original station, and it is most likely that it has been relocated into a silt/clay area. We will undertake grain size analysis at this station during our next sampling period to ascertain if this is the reason for the shift. An alternate or additional change in the sediment characteristics of the area may be a result of the increased discharge of effluent

TABLE 7. Number of species and the total number of individuals collected in three grab samples (0.05m2 each) at the infaunal stations for DECECEMBER 1989 Bottom substrate, species diversity (H1) and dominance factor (S.I.) are also shown. Data for the ninth year of Benthic monitoring studies at at the Hart-Miller Island containment facility.

STATION	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H1)	DOMINANCE FACTOR S.I.
NEARFIELD					
S1	Sand	18	2517	1.8878	0.43815
S2	Shell	15	459	3.0513	0.15225
S3	Silt/Clay	12	298	2.9508	0.16898
S4	Silt/Clay	13	386	2.6328	0.24217
S5	Silt/Clay	15	1972	1.9650	0.40465
S6	Silt/Clay	15	449	3.0615	0.14941
S7	Shell	14	204	3.0430	0.16008
S8	Silt/Clay	11	520	1.9033	0.41090
REFERENCE					
HM 7	Silt/Clay	13	603	1.7019	0.50848
HM 9	Shell	14	219	2.8740	0.18175
HM16	Silt/Clay	15	767	2.2276	0.34939
HM22	Silt/Clay	13	121	2.9848	0.16932
BACK RIVER REFERENCE					
HM26	Silt/Clay	14	883	2.1432	0.31780
ZINC ENRICHED					
G5	NOT SAMPLED				
G25	Silt/Clay	10	97	2.9990	0.15294
G84	NOT SAMPLED				
HM12	NOT SAMPLED				

TABLE 8. Number of species and the total number of individuals collected in three grab samples (0.05m2 each) at the infaunal stations for APRIL 1990 Bottom substrate, species diversity (H1) and dominance factor (S.I.) are also shown. Data for the ninth year of Benthic monitoring studies at the Hart-Miller Island containment facility.

STATION	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H1)	DOMINANCE FACTOR S.I.
NEARFIELD					
S1	Sand	9	5517	0.0913	0.98270
S2	Shell	12	2146	0.9596	0.72994
S3	Silt/Clay	10	2089	0.8796	0.73882
S4	Silt/Clay	10	688	1.4037	0.51702
S5	Silt/Clay	9	575	1.4460	0.52245
S6	Silt/Clay	13	1352	1.5493	0.54440
S7	Shell	10	6118	0.2326	0.94706
S8	Silt/Clay	10	618	1.3848	0.49426
REFERENCE					
HM 7	Silt/Clay	9	443	1.5859	0.44516
HM 9	Shell	11	1331	0.7710	0.79772
HM16	Silt/Clay	10	625	1.3432	0.52640
HM22	Silt/Clay	9	739	0.9930	0.71499
BACK RIVER REFERENCE					
HM26	Silt/Clay	12	1783	1.2131	0.63709
ZINC ENRICHED					
G5	NOT SAMPLED				
G25	Silt/Clay	10	1490	0.8776	0.74758
G84	Silt/Clay	9	6088	0.0788	0.98529
HM12	Silt/Clay	10	1128	0.9999	0.72121

TABLE 9. Number of species and the total number of individuals collected in thr grab samples (0.05m2 each) at the infaunal stations for AUGUST 1990 Bottom substrate, species diversity (H1) and dominance factor (S.I.) are also shown. Data for the ninth year of Benthic monitoring studies at the Hart-Miller Island containment facility.

STATION	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H1)	DOMINANCE FACTOR S.I.
NEARFIELD					
S1	Sand	15	483	2.7041	0.20392
S2	Shell	16	4584	1.5367	0.48716
S3	Silt/Clay	15	254	2.1312	0.34472
S4	Silt/Clay	9	385	1.7232	0.42118
S5	Silt/Clay	8	150	1.9581	0.38551
S6	Silt/Clay	15	822	1.6763	0.48066
S7	Shell	15	1676	2.4093	0.28621
S8	Silt/Clay	9	210	1.7249	0.45211
REFERENCE					
HM 7	Silt/Clay	11	1912	0.9184	0.72872
HM 9	Shell	18	244	3.0669	0.15829
HM12	Silt/Clay	14	254	2.8621	0.18811
HM16	Silt/Clay	12	264	2.4029	0.28776
HM22	Silt/Clay	10	235	1.6589	0.48436
BACK RIVER REFERENCE					
HM26	Silt/Clay	14	2170	0.9543	0.74155
ZINC ENRICHED					
G5	Silt/Clay	11	1242	0.8835	0.74960
G25	Silt/Clay	14	116	3.2897	0.11861
G84	Silt/Clay	12	404	2.2743	0.30461
HM12	Silt/Clay	14	254	2.8621	0.18811

from the spillways in this region. At any rate it would appear to be a positive effect with an increase in the number of invertebrates species occurring in the vicinity of station S1.

Three species of clams, *Rangia cuneata*, *Macoma balthica*, and *Macoma mitchelli*, were measured to the nearest mm in shell length to determine if any size/growth differences were noticeable between the reference and nearfield stations and to compare the clams collected in the Zn enriched areas with the other two areas (see Figures 2, 3, 4). The most abundant clam again this year was *R. cuneata*. Last year there was a large number of *Rangia* collected in August 1989 in the smallest size class (0-5 mm) A large number of this small size class was still present in the December 1989 samples. The number of small size *Rangia* declined slightly but persisted through April as the predominant size class. In August a major set was again recorded with over 1,000 clams/m^2 for all three sets of stations (nearfield, reference, and Zn enriched). In December 1989 and April 1990 there were still substantial numbers of clams in the 21-35 mm size class. However, these larger clams disappeared in August 1990, concomitant with the appearance of the large cohort of small sized *R. cuneata* in the 0-5 mm size range. The disappearance of the larger sized individuals in August (>25 mm) was indicative of poor survival of this group over the summer period. There were no observable differences in the overall numbers of *Rangia* found at the nearfield or reference sites, as well as at the Zn enriched sites. This year the overall numbers of *Rangia* in all three sets of samples in August exceeded our previous high values, which were reported for August 1987, when a high of 600-700 individuals were collected. The large cohort of small (0-5 mm) individuals collected in August 1990 indicated that, unlike 1988, when no new spring set and grow up occurred, that the ninth year seemed to be more favorable for *Rangia* recruitment which appears to be strongly influenced by variations in salinity in this region (Duguay, 1989).

The next most abundant clam during the ninth year, as was the case for the three previous years, was *M. balthica*. In December, the *M. balthica* population (see Figure 3) was dominated by the 16-20 mm size classes, with over 25 individuals present at the reference stations. There were very few *M. balthica* recorded in December at the nearfield stations and none recorded at the single Zn enriched station sampled (G25). However, in April there appeared to be a settlement of small individuals in the three smallest cohorts (0-6 mm sizes) at the nearfield stations, as well as in the smallest cohort (0-2 mm) for the reference and Zn enriched stations. The reduced numbers of *M. balthica* in December 1990 are in keeping with the lower number of specimens recorded at the nearfield (1) and reference (10) stations last August 1989. In April 1990, there was a

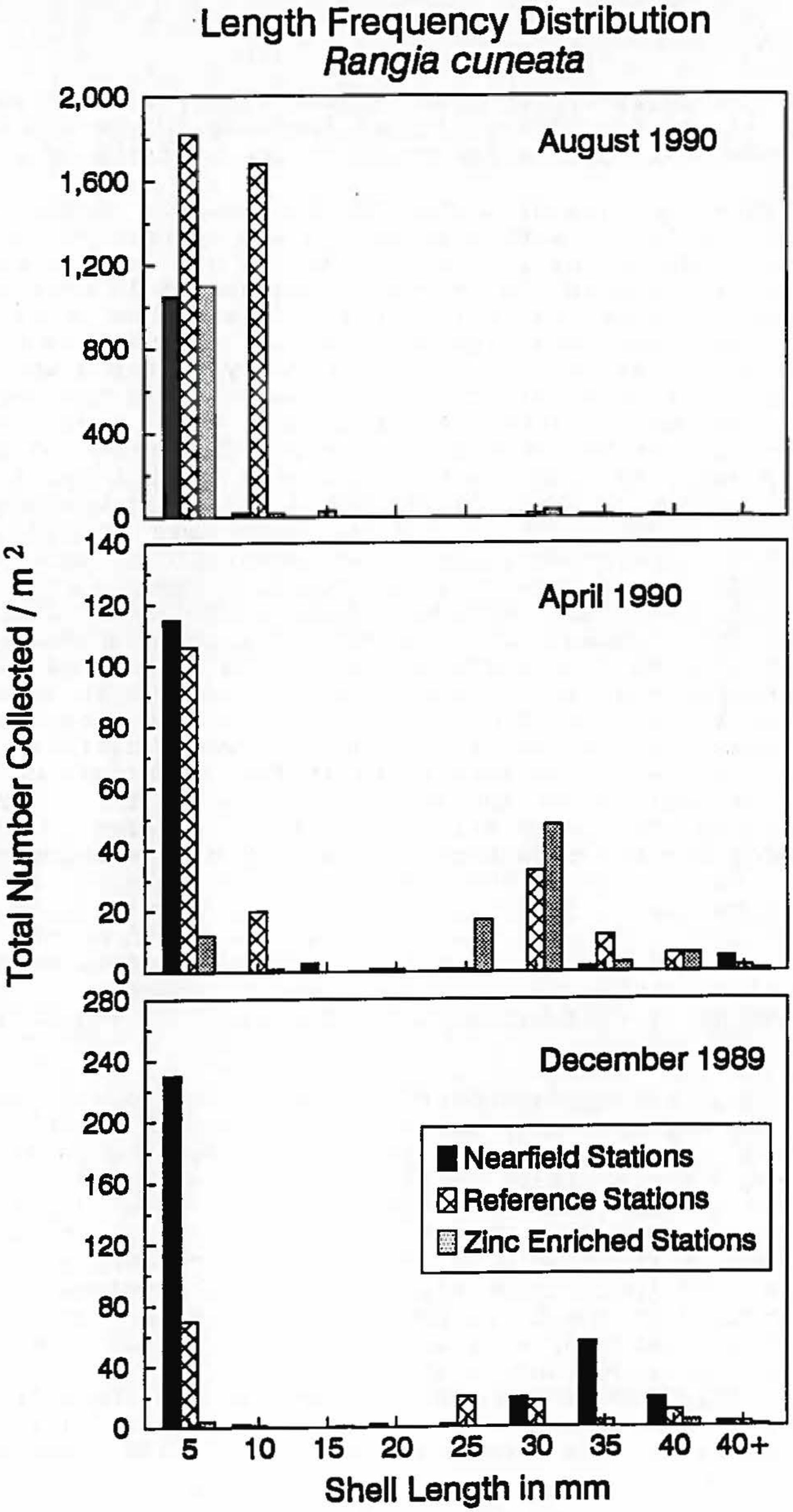


FIGURE 2. LENGTH FREQUENCY DISTRIBUTION OF THE CLAM, RANGIA CUNEATA, DURING THE NINTH YEAR OF BENTHIC MONITORING STUDIES AT THE HART MILLER ISLANDS CONTAINMENT FACILITY.

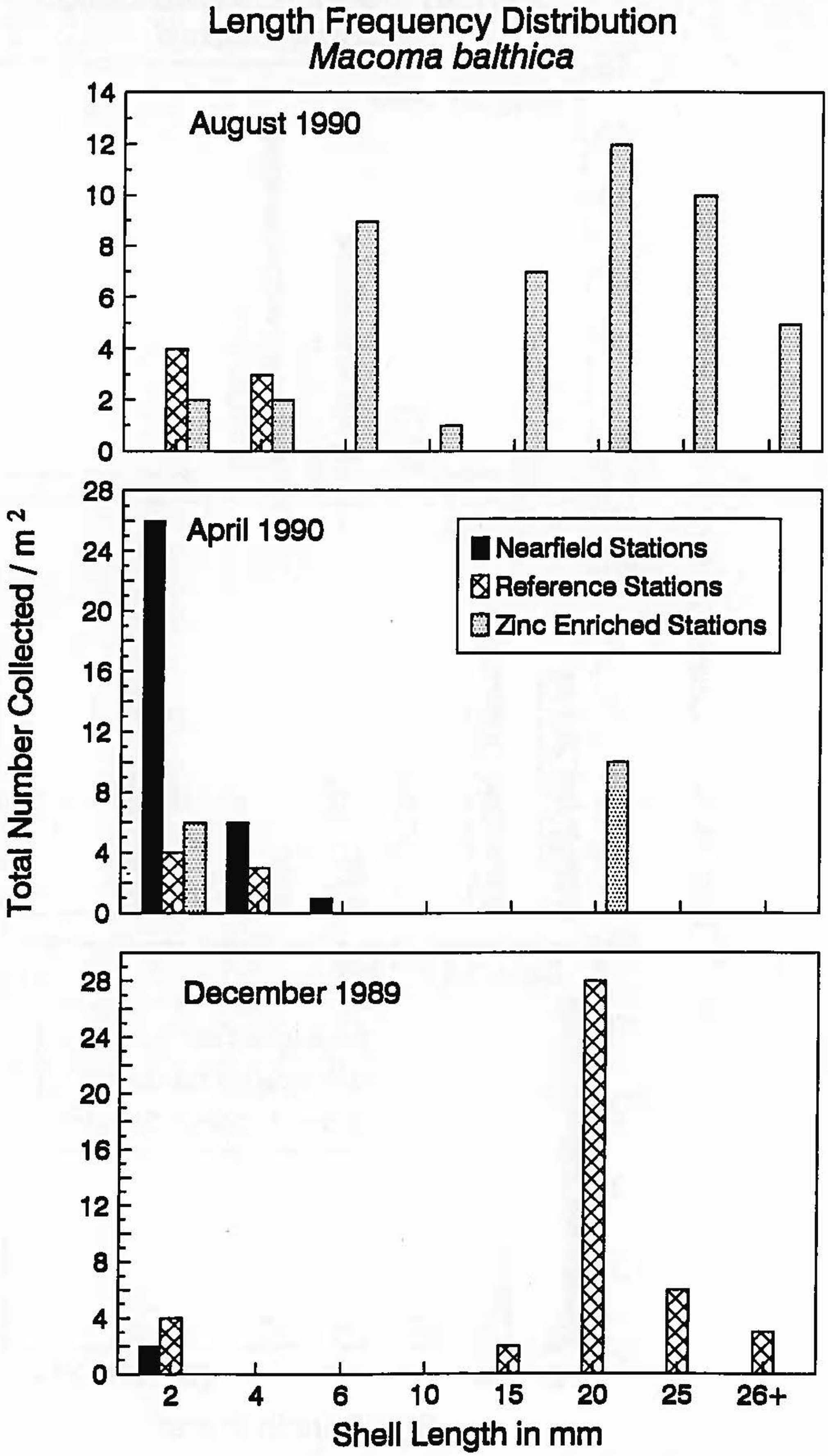


FIGURE 3. LENGTH FREQUENCY DISTRIBUTION OF THE CLAM, MACOMA BALTHICA, DURING THE NINTH YEAR OF BENTHIC MONITORING STUDIES AT THE HART MILLER ISLANDS CONTAINMENT FACILITY.

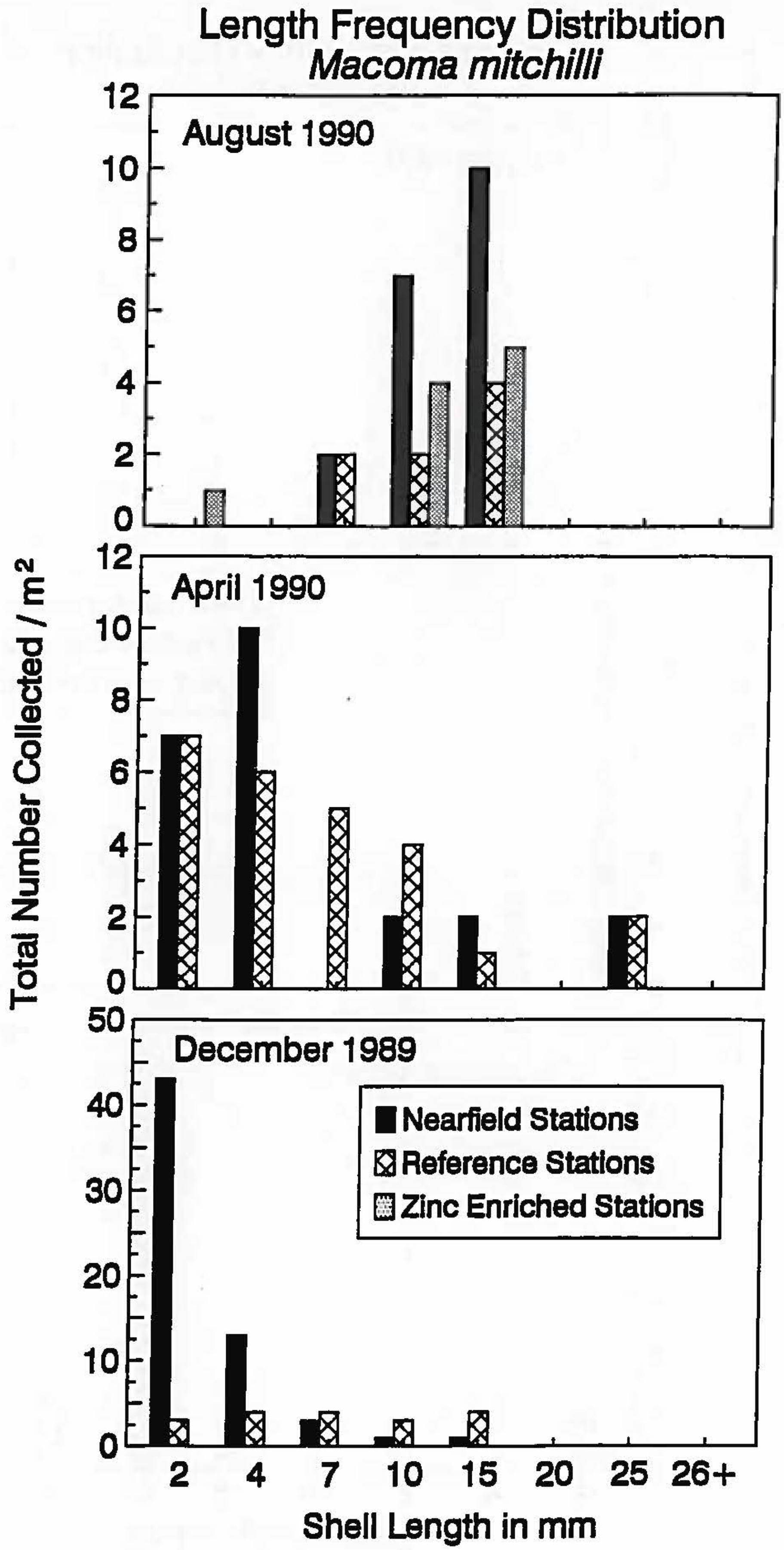


FIGURE 4. LENGTH FREQUENCY DISTRIBUTION OF THE CLAM, <u>MACOMA MITCHILLI</u>, DURING THE NINTH YEAR OF BENTHIC MONITORING STUDIES AT THE HART MILLER ISLANDS CONTAINMENT FACILITY.

decrease in the numbers of larger *M. balthica* at the reference stations; however, there was also an increase in the numbers of small individuals in the range of 0-6 mm. The largest increase in numbers of small individuals at this time was at the nearfield stations, going from about 2 to 25 clams. The population changes suggest reproduction and subsequent die off of the large sized individuals. In August 1990, no *M. balthica* were found at the nearfield stations; however, the numbers of clams at the reference stations remained about the same. This decline in numbers of *M. balthica* in August had also been observed during the 7th and 8th monitoring years when a major reduction in numbers at the nearfield stations had been reported versus a more moderated drop at the reference stations. This greater decline in numbers of *M. balthica* at the nearfield stations may reflect the heavy barge traffic which has occurred closer in to the containment facility during the summer months. The Zn enriched areas for which we do not have a complete set of data over the three sampling dates had the highest number of *M. balthica* in August, when all four of the stations were sampled. There was a fairly even distribution of *M. balthica* at these Zn enriched stations with about 2-10 clams in each of the size ranges.

The length frequency distribution and abundance pattern of the third clam, *M. mitchelli* was somewhat similar to that observed in the previous two years. *M. mitchelli* had in general a lower abundance than either of the other two species however in December there was a large number (40) of small individuals (0-2mm) at the nearfield stations compared with fairly even distribution of all of the size classes at the reference stations in both December and April. In August the larger size classes (5-15 mm) predominated, and a few individuals were encountered in the smallest size class (1-4 mm) only at the Zn enriched stations. The reduction in small clams in August may possibly reflect grow up over the April to August period. As was reported last year, there was again no particular difference between the overall numbers at the nearfield versus the reference stations. The decline in the number of *M. mitchelli* in this region of the Bay from highs in some size classes of 35 individuals in 1987 to no more than 5 individuals in any size class during the eighth year of sampling in 1989 seems to have reversed. The slight increase in total numbers of *M. mitchelli* indicates more favorable conditions for this particular species. This was the first year that we have data for the Zn enriched stations, and August is the only period that we sampled at all four stations. We found that *M. mitchilli* was present at two of the 4 stations ((G5 and G84) and in comparable numbers to those observed for both the nearfield and reference stations. As had been reported for the previous three years, (Duguay et al., 1989, Duguay 1989, and Duguay 1990), there has been a slight shift in relative dominance to greater numbers of *M. balthica* than *M. mitchelli* over the past few years.

Cluster analysis was again employed 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 5, 6, and 7 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 has clearly indicated a faunal response to bottom type (Pfitzenmeyer, 1985). Thus, any unusual grouping of stations tends to suggest changes are occurring due to factors other than bottom type, and further examinations of these stations are required. Most of the time experience and familiarity with the area under study can help to explain the differences. However, when they cannot be explained, then extraneous factors must be investigated.

The basic grouping of stations for the December 1989 sampling period is presented in Figure 5. There is an initial joining of two groups of nearfield and reference stations (S2 and HM9 - both shell stations; and S7, a shell station, with HM22, a silt/clay station). The next stations to fall in were three soft-bottom/silt-clay stations S3, S4, and G25. The final stations to join the dendrogram were S5, S8, S1 and HM26. HM26 had also formed the outer end of the cluster in the previous December (1988). HM26, the station located near Back River is frequently one of the final stations to join the dendrogram. The clustering of stations observed for December is similar to that observed in previous reports (Duguay et al., 1989, Duguay, 1989, and Duguay 1990) and an indication that no anomalous changes are occurring at the nearfield stations.

In April 1990 (Figure 6), the basic grouping consisted of a number of smaller clusters of stations, such as sand station S1 with G84, a mixture of sand and silt clay; the silt clay stations S8 and HM16, as well as shell station HM9 with silt clay station HM22. The exact stations forming the inner groupings differed from those in December. A series of silt clay stations fell in with the two inner groupings. As in December one of the final stations to join the dendrogram was HM26 along with shell stations S2 and S7 and the silt/clay station S6.

The summer sampling period represents a season of continued 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. As we had observed in April, there were a series of small inner clusters, though not exactly the exact same

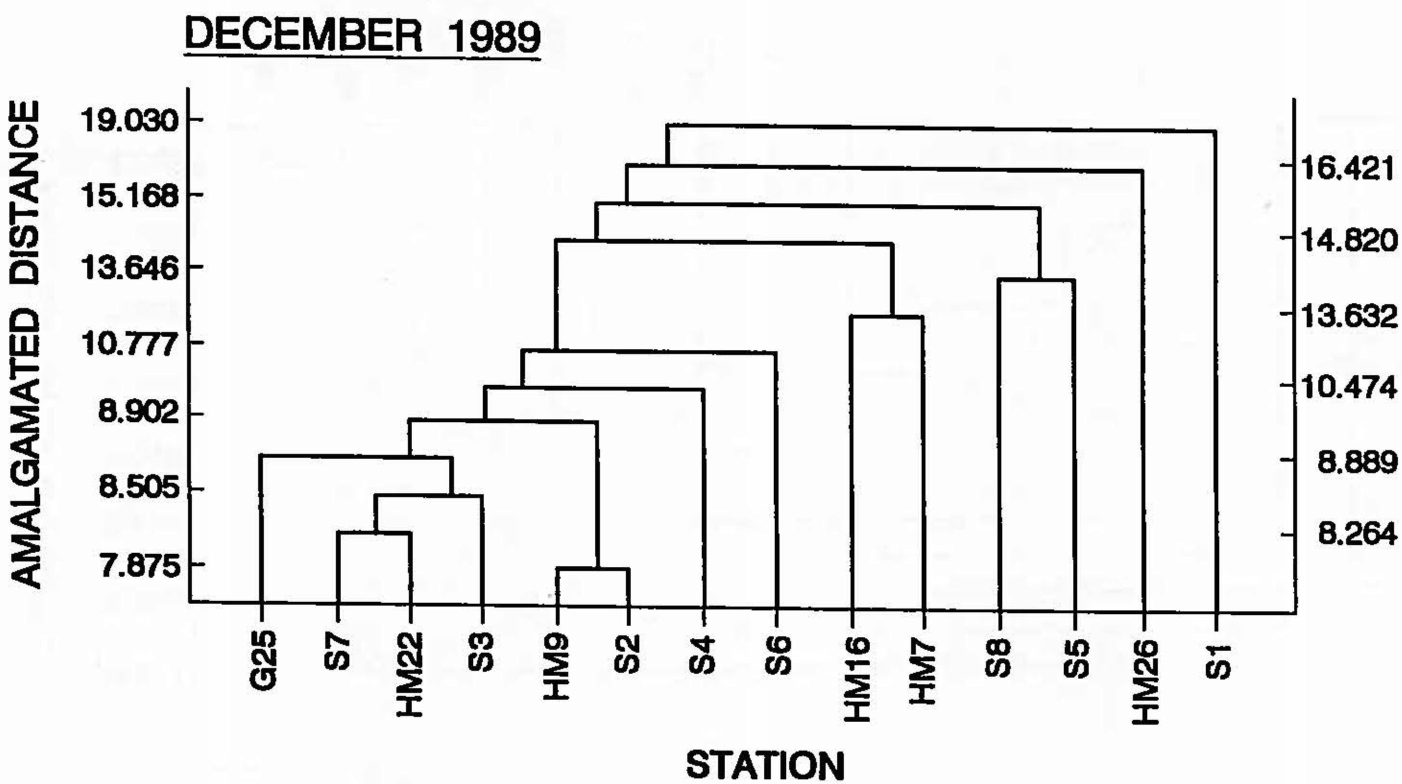


FIGURE 5. CLUSTER ANALYSIS FOR ALL OF THE HART MILLER ISLAND STATIONS SAMPLED IN DECEMBER 1989 DURING THE 9TH YEAR OF BENTHIC MONITORING.

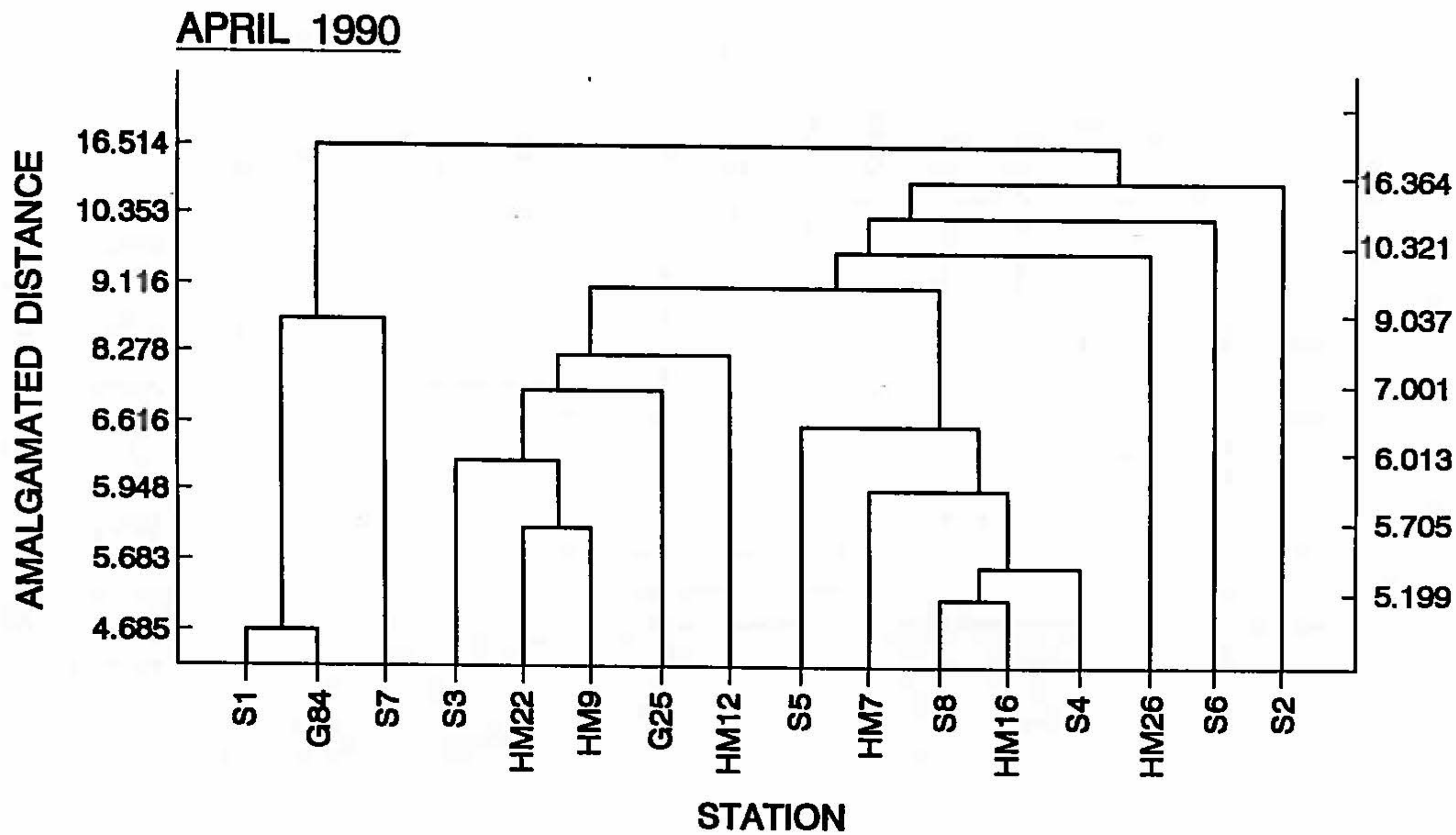


FIGURE 6. CLUSTER ANALYSIS FOR ALL OF THE HART MILLER ISLAND STATIONS IN APRIL 1990 DURING THE 9TH YEAR OF BENTHIC MONITORING.

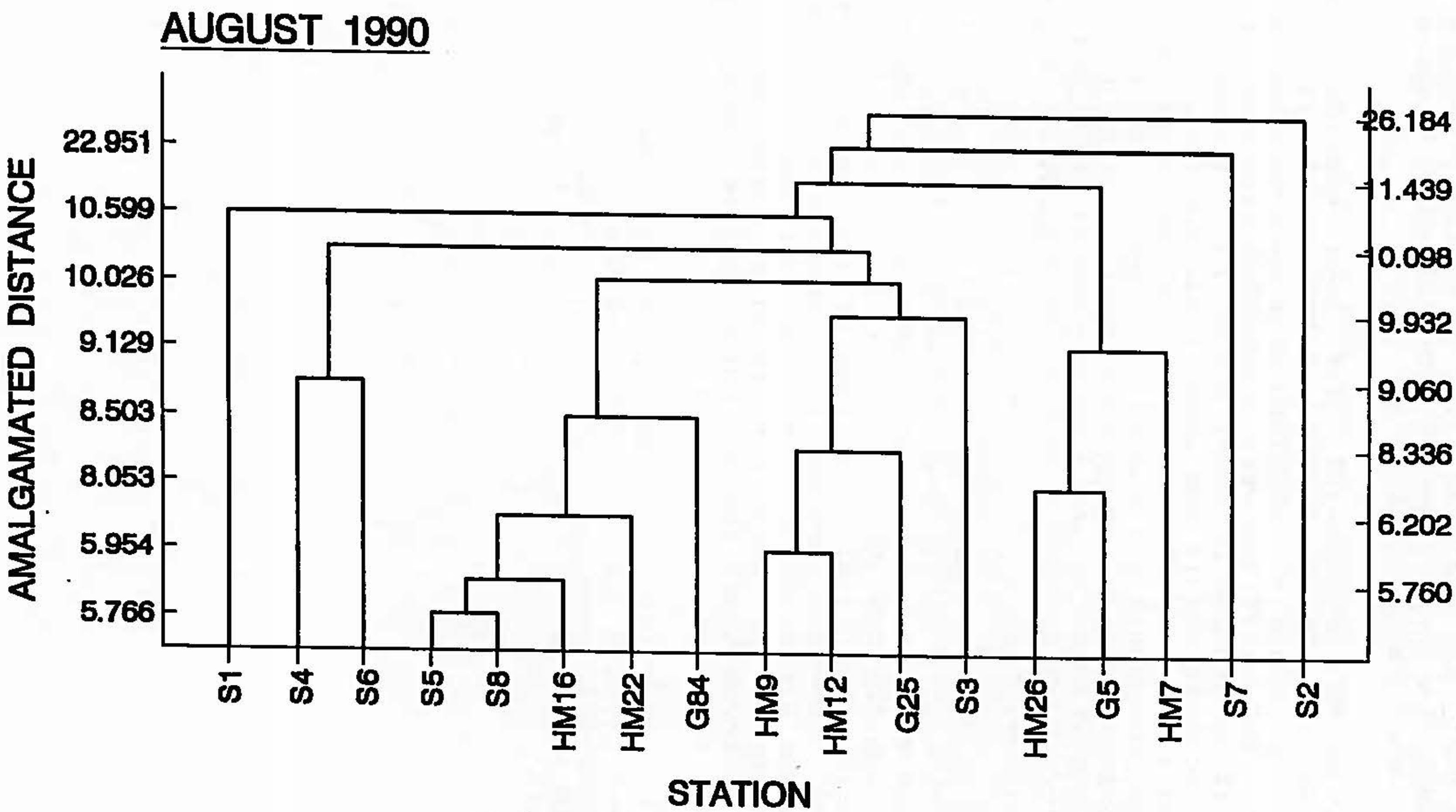


FIGURE 7. CLUSTER ANALYSIS FOR ALL OF THE HART-MILLER ISLAND STATIONS SAMPLED IN AUGUST 1990 DURING THE 9TH YEAR OF BENTHIC MONITORING.

ones. The three inner clusters consisted of (1) - silt/clay stations S5, S8, and HM16; (2) by shell station HM9 associated with silt/clay station HM12, G25, and S3; and (3) silt/clay stations HM26, G5, and HM7. All four of the reference stations fell within the inner clusters. The outermost members of the cluster were S1 along with S2 and S7.

The clusters formed over these three sampling dates, represented previously observed normal groupings for the reference and nearfield stations with no unusually isolated stations. These clusters were consistent with earlier studies and primarily grouped stations according to bottom type and general location within the study area. The Zn enriched stations clustered along with the nearfield and reference stations and indicated no unusually isolated stations. If the benthic invertebrates in this region were being affected by some adverse or extraneous force it would appear in the groupings. No such indications were found during the three sampling periods reported in this study.

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 homogeneous subsets. The results of these tests for the three different sampling dates are presented in Tables 10, 11 and 12.

In December 1989, the stations sorted themselves out into six subsets (Table 10). S1, which had the highest population density for this sampling date, formed a subset on its own. Four nearfield stations, S2 through S5, formed the second subset, and

TABLE 10. The Student-Neuman-Keuls test of significance for stations sampled in December 1989. Subsets show groupings of stations different at ($P<0.05$). Stations in a vertical column and row are significantly different from others. Ninth year of benthic monitoring studies at Hart and Miller Island.

DECEMBER 1989

SUBSET	STATION NUMBERS												
1	S1												
2		S2	S3	S4	S5								
3				S4	S5	S6	S7						
4						S6	S7	S8					
5								S8	HM16	HM22	HM9		
6									HM16	HM22	HM9	HM7	HM26	G25

ANALYSIS OF VARIANCE

SOURCE	D.F	SUM OF SQ.	MEAN SQ.	F. RATIO	F.PROB
BETWEEN GROUPS	12	61175	5097.	33.4	0
WITHIN GROUPS	26	3969	152.3		
TOTAL	38	65136			

TABLE 11. The Student-Neuman-Keuls test of significance among mean number of individuals for stations sampled in April 1990. Subsets show groupings of different stations (P<0.05). Stations in a separate vertical row and column are significantly different from others. Ninth year of benthic monitoring studies at Hart and Miller Islands.

APRIL 1990

SUBSET	STATION NUMBERS															
1	S1	S2	S6	S3	S4	S5										
2							S7	HM9	S8	HM26	HM16	HM7	HM22	HM12		
3										HM26	HM16	HM7	HM22	HM12	G25	
4																G84

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F RATIO	F PROB.
BETWEEN GROUPS	15	3489804	232653	25.01	0
WITHIN GROUPS	32	297635	9300		
TOTAL	47	3787429			

TABLE 12. The Student-Neuman-Keuls test of significance among mean number of individuals per station for stations sampled in August 1989. Subsets show groupings of different stations (P<0.05). Stations in a seperate vertical row and column are significantly different from others. Ninth year of benthic monitoring studies at Hart and Miller Islands.

AUGUST 1990

SUBSET	STATION NUMBERS															
1	S1	S2	S3	S6	S7	HM9	S4	S5	HM16	HM22	S8	HM7	HM12	G5	HM26		
2		S2	S3	S6	S7	HM9	S4	S5	HM16	HM22	S8	HM7	HM12	G5	HM26	G25	G84

ANALYSIS OF VARIANCE

SOURCE	D F	SUM OF SQUARES	MEAN SQUARES	F. RATIO	F. PROB.
BETWEEN GROUPS	16	698914.1	43682.1	2.6806	0.0077
WITHIN GROUPS	34	554055.8	16295.8		
TOTAL	50	1252969.9			

the third subset was made up by adding two nearfield stations (S6, S7) and dropping two other stations (S2 and S3). The fourth subset dropped station S4 and S5 and added station S8. The fifth subset consisted of S8, along with three of the reference stations. The sixth and final subset dropped station S8 and consisted of the five reference stations (HM26, HM22, HM16, HM9, HM7) and the single Zn enriched station (G25).
This arrangement was in keeping with previous analyses made for December 1985-88 (Pfitzenmeyer and Tenore, 1987; Duguay et al., 1989; Duguay, 1989; and Duguay, 1990, respectively), which identified essentially two primary groups of stations - the nearfield and the reference stations. Within the two groupings, the stations are interrelated, and, occasionally, S7 and S8 do overlap with the reference stations.

In April, four subsets were evident (Table 11). The first subset was comprised of nearfield stations S1-S6. The second subset consisted of nearfield stations S7 and S8, along with all five reference stations and the new Zn enriched station HM12. The third subset dropped S7 and S8 along with HM9 and added one more of the Zn enriched stations G25. The fourth and last subset was comprised only of the final Zn enriched station G84, located across the Bay, which had the greatest abundance of organisms on this sampling date. As in December, the reference stations and nearfield stations formed relatively discernible groups and the Zn enriched stations appear to group along with the reference stations.

The analysis of the August 1990 data resulted in the occurrence of two very large subsets (15 and 16 stations in each) comprising almost all of the total 17 stations in each of them. The occurrence of large subsets is quite similar to the pattern observed for last August. However, at that time, there were four large subsets comprised of 10 of the 13 sampled stations, compared with this seasons two larger subsets. The only differences between this years two subsets is that subset 1 did not include two Zn enriched stations G25 and G84, and subset two added these two stations and dropped station S1. The analysis of variance for this sampling period resulted in no significant differences between or within groups.

The results of running Friedman's non-parametric test for differences in the means of samples (for ranked abundances of 10 selected species), taken only at the silt/clay stations for the nearfield, reference, and Zn enriched stations, are presented in Table 13. Significant differences ($p<0.05$) were found only at the reference stations away from the island during both the December and August sampling periods. During the December period, station HM22 had a low number of total individuals, being about 9-10 times lower than the other two stations in the survey; whereas, in August station HM7 had a 10 fold higher population than either of the other two due to a very large set of the clam,

TABLE 13. Results of Friedman's non-parametric test for differences in the abundances of (10) selected species betwen stations with silt/clay substrates for the eighth year of Benthic monitoring studies at th Hart-Miller Island containment facility. (Silt/clay stations are: NEARFIELD STAS.- S3,S4,S5,S6,S8; REFERENCE STAS.- HM7,HM16,HM22; ZINC ENRICHED STAS. - G5,G25,G84,HM12.

	SOURCE	D.F.	CHI-SQUARED	CHI-SQUARED (0.05)
DEC 1989				
	NEARFIELD	4	6.82	9.48
	REFERENCE	2	13.35**	5.99
	ZINC ENRICHED	--	--	--
	NEARFIELD & REFERENCE	7	7.44	14.06
	ZINC ENRICHED & REFERENCE	3	5.19	7.81
APR 1990				
	NEARFIELD	4	7.54	9.48
	REFERENCE	2	2.60	5.99
	ZINC ENRICHED	2	1.40	5.99
	NEARFIELD & REFERENCE	7	10.88	14.06
	ZINC ENRICHED & REFERENCE	5	5.19	11.07
AUG 1989				
	NEARFIELD	4	4.02	9.48
	REFERENCE	2	10.35**	5.99
	ZINC ENRICHED	3	6.03	7.81
	NEARFIELD & REFERENCE	7	8.62	14.06
	ZINC ENRICHED & REFERENCE	6	11.70	12.09

**SIGNIFICANT DIFFERENCE AT THE 0.05 LEVEL.

Rangia cuneata. In April, no significant differences were observed for the three reference stations with silt/clay bottom type (HM16, HM7, and HM22). Likewise, no significant differences were found for the nearfield or Zn enriched stations on any of the sampling dates, either on their own or when combined with the reference stations.

Table 14 provides the data for the epifaunal samples from a series of pilings surrounding the facility and one located in the Pleasure Island boat channel. Samples this year were again limited to depths of about 3 feet (1.0 to 1.3 m) and 6-8 ft (2-3 m) below the surface to avoid the region of ice scour in the upper levels of the pilings, where the fauna becomes depauperate in winter. Thus a reasonably well developed fauna occurred on all three sampling dates. There were no obvious major differences between the upper and lower samples. The densities and distribution of the various epifaunal species on both the nearfield pilings (R2-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 four study years (Pfitzenmeyer and Tenore, 1987; Duguay et al., 1989; Duguay, 1989; and Duguay, 1990). The amphipod, *Corophium lacustre,* again was one of the most abundant and widespread species (Pfitzenmeyer and Tenore, 1987, Duguay et al., 1988, and Duguay, 1989). It was the most abundant organism at all stations on all dates with the single exception of the lower depth in April at the nearfield stations when the barnacle, *Balanus subalbidus*, was the most abundant species. The hydroid, *Cordylophora caspia*, was present at all stations on all sampling dates and along with the bryozoan *Victorella*, was often ranked second in abundance at a majority of the stations. Other abundant organisms consisted of the worm, *Polydora*, the barnacles, *Balanus subalbidus* or *B. improvisus* and the bryozoan, *Membranipora*. *Corophium* is a small amphipod crustacean which 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. The two colonial forms of the bryozoan *Victorella* and the hydroid *Cordylophora* once again reached their greatest abundance in August, which most likely reflects their maximal reproductive and growth season.

Table 15 lists the fish collected, as well as the total numbers collected during 5 minute otter trawls at a series of stations (shown in Figure 8) on each of the sampling dates. A total of 14 different types of fish were collected, and the most abundant species was spot in August 1990. The fish were collected primarily for analysis of tissue levels of metal and organic contaminants in yellow and white perch. These results are presented in Analytical Services section of this report.

TABLE 14. Benthic species listed in descending order of density found on the piers and pilings surrounding the containment facility and at a reference piling at 1m and 2-3m depth for the three sampling periods for the Ninth Year Benthic sampling study at Hart-Miller Island.

	STATIONS R2-R4 DEPTH (M)		REFERENCE STATION R5 DEPTH (M)	
DEC 1989				
	1.0 m	2-3 m	1.0 m	2-3 m
	Corophium	Corophium	Corophium	Corophium
	Stylochus	Nereis	Victorella	Victorella
	Cordylophora	Membranipora	Polydora	Polydora
	Polydora	Polydora	Cordylophora	Membranipora
	Victorella	Stylochus	Nereis	Cordylophora
	Membranipora	Cordylophora	Membranipora	Stylochus
APR 1990				
	1.0 m	2-3 m	1.0 m	2-3 m
	Corophium	B. subalbidus	Corophium	Corophium
	Cordylophora	Cordylophora	Cordylophora	Membranipora
	B. subalbidus	Gammarus	B. subalbidus	Cordylophora
	G. tigrinus	Corophium		Nereis
	Congeria	Congeria		Victorella
	Membranipora	Nereis		B. subalbidus
AUG 1990				
	1.0 m	2-3 m	1.0 m	2-3 m
	Corophium	Corophium	Corophium	Corophium
	Victorella	Victorella	Victorella	Victorella
	Cordylophora	Cordylophora	Cordylophora	Cordylophora
	B. subalbidus	B. subalbidus	B. subalbidus	B. subalbidus
	Membranipora	B. improvisus	B. improvisus	Congeria
				Rithropanopeus

TABLE 15: Total number and common name of fish collected in 5 minute trawls at the stations depicted in Figure 8 during the 9th year of Benthic monitoring studies in the vicinity of Hart and Miller Islands.

	DECEMBER 1989				APRIL 1990				AUGUST 1990			
SPECIES OF FISH	F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
ANCHOVY	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC SILVERSIDES	0	0	0	0	0	0	0	0	0	4	0	0
CATFISH												
BROWN	5	0	0	0	83	1	0	0	1	0	0	1
WHITE	0	0	0	0	7	0	1	0				
CHANNEL	0	0	0	0	0	0	0	0	2	4	2	0
EEL	0	0	0	0	0	1	0	0	2	0	0	0
HOGCHOKER	0	2	1	4	1	3	0	0	79	69	57	21
MENHADEN	0	0	0	0	0	0	0	1	0	0	0	0
PUMPKINSEED	1	0	0	0	2	1	0	0	0	0	0	0
ROCKFISH	0	0	0	0	0	4	0	21	0	0	0	1
SHAD	0	1	0	0	0	0	0	0	0	0	0	0
SPOT	0	0	0	0	0	0	0	0	157	140	34	31
SUMMER FLOUNDER	0	0	0	0	0	0	0	0	0	1	2	0
WHITE PERCH	1	2	0	6	11	77	13	23	72	44	3	1
YELLOW PERCH	3	1	2	4	4	5	1	3	0	0	0	0
TOTAL # FISH	10	6	3	14	108	92	15	48	313	262	98	55

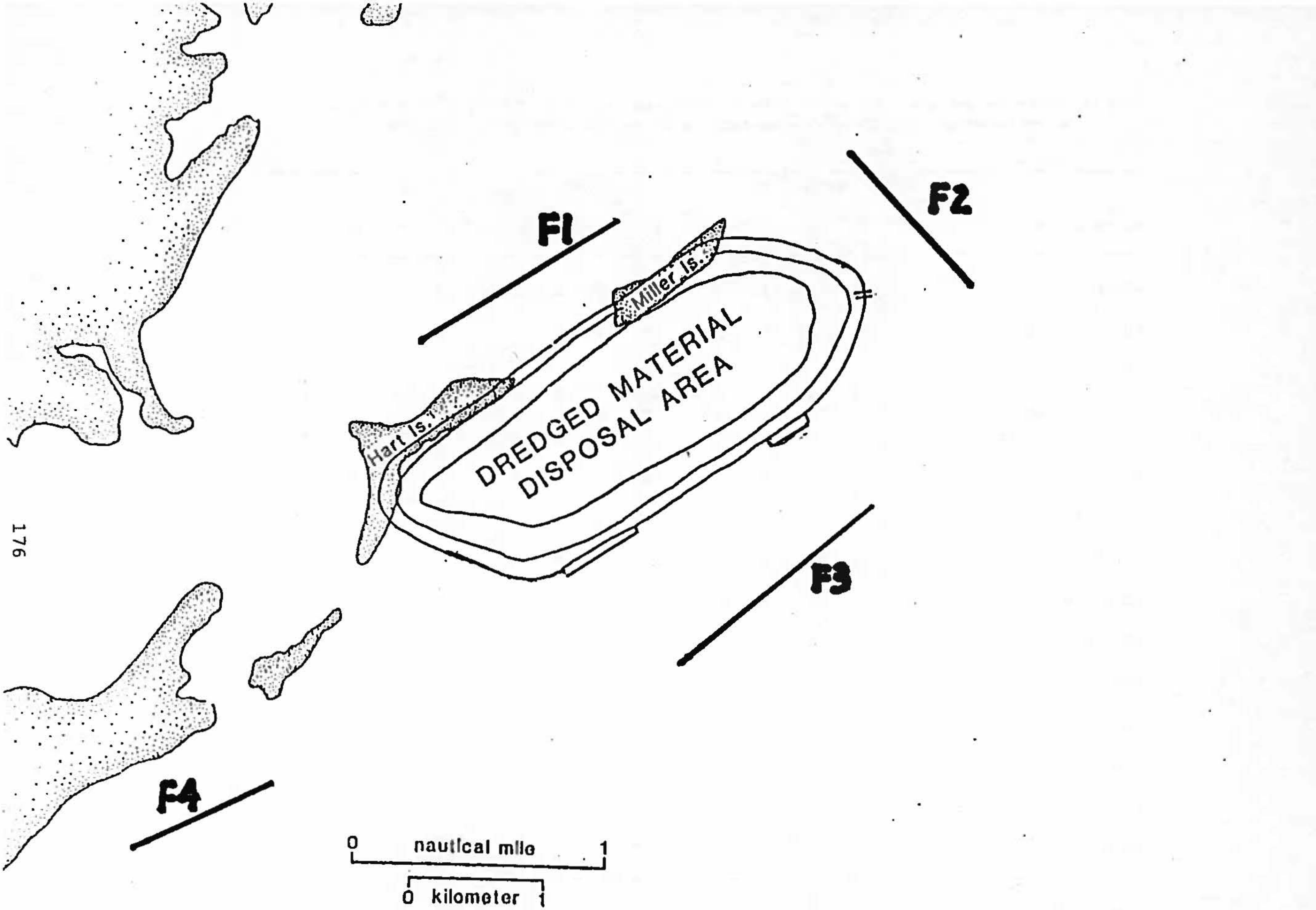


FIGURE 8. TRAWLING STATIONS FOR FISH SAMPLING DURING THE 9TH YEAR OF MONITORING STUDIES AT THE HART MILLER ISLANDS CONTAINMENT FACILITY.

CONCLUSIONS AND RECOMMENDATIONS

For the ninth year of sampling and monitoring, the benthic populations of organisms in and around the Hart and Miller Islands containment facility, the sampling locations, sampling techniques and analysis of the data were again maintained as close as possible to these for the previous years to eliminate as much variation as possible. Maintenance of sampling locations, techniques and analysis should render differences due to effects of the containment facility more readily apparent. We have continued to use the special piling scraping device developed in the seventh year program for our qualitative epifaunal samples. We added four infaunal sampling stations over the course of the year in response to the findings of the sedimentary group, from Maryland Geological Survey, of an observable enrichment of Zn in the sediments of certain regions surrounding the containment facility.

The results presented in this report are quite similar to those presented in the reports of the last four years (5th year through 8th year of monitoring). A total of 34 species (compared with 31, 35, 30 and 26 for the 8th, 7th, 6th and 5th years, respectively) were collected in the quantitative grab samples. Again, six species remain numerically dominant on soft bottoms. These six dominants are the worms, *S. viridis*, *S. benedicti*, and *Tubificoides*, the crustaceans, *L. plumulosus* and *C. polita*, and the clam, *R. cuneata*. The oyster shell substrates had very similar dominants to the soft bottom regions. The barnacle *Balanus improvisus* and the crab *R. harrisi* were also common and at times the dominant inhabitants of the shell regions. Salinity variations on yearly and seasonal time scales appear to determine the position of dominance of the major species in this oligohaline region of the Bay.

The average number of individuals per square meter (m^2) was comparable for the nearfield and the reference stations over the three sampling periods. Pfitzenmeyer and Tenore (1987) had reported a greater number of individuals at the nearfield versus the reference stations for the fifth monitoring year, which they attributed to an abundance of finer sediments close to the containment facility dike. However, the similarity we observed in total numbers this year was the same trend which we had previously observed during the sixth through eighth years and which seems to be the recent trend.

The highest average species diversity values this year were found in December rather than in August, which had been the rule the previous two years. The lowest diversity values were again in April. Two Zn enriched stations had both the highest (at G25) and lowest (at G84) diversity values recorded for this year's study.

Length frequencies and cohort sizes of the clam *R. cuneata* living close to the containment facility were comparable to populations at the reference stations, as was the case for the other two common bivalves, *M. balthica* and *M. mitchelli*. This year there appeared to be a set and grow up of these three ivalve clams over the present sampling study. All three clams were present at some of the Zn enriched stations, and the populations appeared comparable to those observed at the reference and nearfield stations.

The cluster analysis grouped stations of similar faunal composition in response to sediment type and general location within the study area, as has been the case in previous years. 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 sand station, S1, or 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. Friedman's non-parametric test indicated some differences in the reference stations in December and August but no differences in the nearfield or Zn enriched stations either on their own or when combined with the reference stations.

The epifaunal species were quite similar in terms of distribution at the nearfield and reference stations at all three sampling periods. Since sampling this year was again confined to the region below winter ice scour and low tide dehydration, no absence of species from the pilings was recorded. The amphipod, *Corophium,* was again one of the most abundant organisms as was the hydroid, *Cordylophora*, and the bryozoan, *Victorella*.

At present, there do not appear to be any discernible differences in the nearfield, reference and Zn enriched populations resulting directly from the containment facility. The barge activity does appear to churn up and scour the area but the opportunistic species inhabiting this oligohaline region of the Bay appear to be readily capable of repopulating these disturbed areas.

The Hart-Miller Island Containment Facility will continue to operate at least until the year 2000. It is strongly recommended that the infaunal and epifaunal populations continue to be sampled at the established locations along with the newly added Zn enriched areas during this continued period of active operation of the containment facility to ascertain any possible future effects. Station locations and sampling techniques should be maintained as close as possible to the last few years to eliminate sampling variations and permit rapid recognition of effects resulting from the operation and existence of the containment facility. It may also be advisable at this time to add some laboratory bioassay studies to test for any potential effects of the metal (Zn) enriched sediments on the activities, survivability and reproduction of selected organisms.

ACKNOWLEDGEMENTS

I would like to acknowledge my appreciation for assisting in this year's Hart Miller Island benthic monitoring program to: Mr. Hayes T. Pfitzenmeyer for helping with the field collections and expertise in identification of the organisms; to Tom Hass and Douglas Capone for assistance on the cruises and to Ms. Cindy Shoemaker and Ms. Veronica Miller for assistance on the cruises and the processing of the preserved samples. We also acknowledge the outstanding assistance of the Captains and Mates of the RV ORION and RV AQUARIUS of the UMCEES Research Fleet.

REFERENCES

Beukema, J. J. 1988. An evaluation of the ABC-method (abundance/ biomass comparison) as applied to macrozoobenthic communities living on tidal flats in the Dutch Wadden Sea. Mar. Biol., 99:425-433

Cain, T. D. 1975. Reproduction and recruitment of *Rangia cuneata* in the James River, Va. Fish. Bull. 73(2):412-413.

Dean, D., and H. H. Haskins. 1964. Benthic repopulation of the Raritan River estuary following pollution abatement. Limnol. Oceanogr. 9(4):551-563.

Dixon, W. J., and M. B. Brown. 1977. BMDP-77 biomedical computer programs P-series. University of California Press Berkeley, Ca.

Duguay, L. E., K. R. Tenore, and H. T. Pfitzenmeyer. 1989. In, Assessment of the Environmental Impacts of the Hart/Miller Island Containment Facility, Sixth Annual Interpretive Report Aug. 86-Aug.87, Project III - Benthic Studies. pp. 97-149.

Duguay, L. E. 1989. In, Assessment of the Environmental Impacts of the Hart/Miller Island Containment Facility, Seventh Annual Interpretive Report Aug. 87-Aug.88, Project III - Benthic Studies. 29 pp.

Duguay, L. E. 1990. In, Assessment of the Environmental Impacts of the Hart and Miller Island Containment Facility. Eighth Annual Interpretive Report, Aug. 1988-Aug. 1989. Project III: Benthic Studies. pp 145-198.

Elliott, J. M. 1977. Some methods for the statistical analysis of samples of benthic invertebrates. Freshwater Biol. Assoc. Sci. Publ. 25, 160 pp.

Fager, W. W. 1957. Determination and analysis of recurrent groups. Ecology 38:586-595.

Holland, A. F. 1985. Long-term variation of macrobenthos in a mesohaline region of Chesapeake Bay. Estuaries 8(2a):93-113.

Holland, A. F. 1987. Long-term variation in mesohaline Chesapeake Bay macrobenthos: spatial and temporal patterns. Estuaries 10(3):227-245.

Nie, et al. 1961. Statistical package for the social sciences. McGraw-Hill 2nd Edition.

Pfitzenmeyer, H. T. 1981. The effect of shallow-water channel dredging on the community of benthic animals. Proc. Dredging and Related Problems in the Mid-Atlantic Region. NAEP and WEDA, Baltimore, Md. p. 60-89.Inc. 2nd Edition.

Pfitzenmeyer, H. T. 1985. Project II, Benthos. In: Assessment of the environmental impacts of construction and operation of the Hart and Miller Islands Containment Facility. Third Annual Interpretive Report, Aug.'83-Aug.'84. Md. Dept. Nat. Res., Tidewater Admin. p. 28-54.

Pfitzenmeyer, H. T. 1986. Benthic Studies. In, The assessment of the Environmental Impacts of the Hart and Miller Islands Containment Facility, Fourth Annual Interpretive Reprot, Aug. '84-Aug. 85.

Pfitzenmeyer, H. T., M. J. Johnston, and H. S. Millsaps. 1982. In: Assessment of the environmental impacts of construction and operation of the Hart and Miller Islands Containment Facility. First annual interpretative report, Aug. '81-Aug. '82. Md. Dept. Nat. Res. Tidewater Admin. pp. 100-132.

Pfitzenmeyer, H. T. and H. S. Millsaps. 1984. Chapter 5, Benthos. In: Assessment of the environmental impacts of construction and operation of the Hart and Miller Islands Containment Facility. Chapter 5, Benthos, Second Annual Interpretive Report, Aug.'82-Aug.'83. Chesapeake Research Consortium, pp. 151-184.

Pfitzenmeyer, H.T., and K. R. Tenore, 1987. In: Assessment of the environmental impacts of the Hart and Miller Islands Containment Facility. Fifth Annual Interpretive Report, Aug. '85-'86. Project III: Biota, Part 1. Benthic Studies, pp 132-171.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. J. Theor. Biol. 13:131-144.

Wells, D. V., R. T. Kerhin, E. Reinharz, J. Hill, and R. Cuthbertson. 1984. Sedimentary environment of Hart and Miller Islands, In: E. Cronin [ed.], Integration and coordination of the State assessment of the environmental impacts of construction and operation of the Hart and Miller Islands Containment Facility,. Second Year Interpretive Report, Aug. '82-Aug. '83 p. 64-150.

Wells, H. W. 1961. The fauna of oyster beds, with special reference to the salinity factor. Ecol. Monogr. 31:239-266.

ANALYTICAL SERVICES
NINTH YEAR INTERPRETIVE REPORT

Analyses Performed by

Martel Laboratory Services, Inc.
1025 Cromwell Bridge Road
Baltimore, MD 21204

Interpreted by

Dr. Jay W. Gooch

University of Maryland System
Center for Environmental and Estuarine Studies
Chesapeake Biological Laboratory
P.O. Box 38
Solomons, MD 20688-0038

February 1992

SUMMARY

Since 1981, sediments and biota have been analyzed for trace metal and organic contaminants as part of the Hart-Miller Island Containment Facility Environmental Assessment Monitoring Program. Yearly seasonal sampling has been conducted near the facility for monitoring the status and trends of contaminants in biota which might result from the operational release of contaminants. The data from the present monitoring year (Year 9) are from samples taken in December 1989, April 1990 and August 1990. Sixty five samples of biota (benthos and fish) were submitted to Martel laboratories for examination of 43 organic contaminants and six metals; chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni) and Zinc (Zn).

Concentrations of trace metals in benthos samples were highly variable and did not show any distinct differences based on station type (nearfield, reference and Zn enriched). One sample of *Rangia* from nearfield station S6 had high concentrations of Fe and Mn. Cr concentrations were highest in *Macoma* and generally higher than other bivalve populations in the Chesapeake and the Coastal U.S.. Cu and Zn concentrations were highest in *Cyathura*. Concentrations of Cu in *Rangia* and *Macoma* were similar to levels found previously in soft shell clams from around the Chesapeake and were also similar to the highest levels found in a nationwide survey of the blue mussel, *Mytilus edulis*. There were no distinct differences in Zn concentrations in samples from the Zn enriched stations in comparison to the other station types. Ni concentrations were highest in *Rangia* and were two to ten times higher than the nationwide survey of blue mussels. Trace metal concentrations in white perch and yellow perch samples were not unusually high and were similar among transects.

As in past years, the frequency of detection of organic contaminants was quite low. However, caution should be noted since the detection limits for many of the analytes in these samples were extraordinarily high. In several cases the detection limits were well above FDA action levels and Practical Quantitation Limits (PQLs) given in EPA procedures. While sample size data are not provided under this contract, it appears as though these high detection limits are partially the result of inadequate sample sizes. In addition, organismal size data are not standardized or provided and it is difficult to determine the influence this may have had on the detection of contaminants.

In the ninth year, one *Macoma* sample from the December 1989 sampling of HM16 contained 320 ppb (wet weight) of Bis (2-ethylhexyl) phthalate. This was the only positive for all *Macoma* samples. Three *Rangia* samples from the April 1990 sampling

contained detectable levels of total PCBs. These were three out of seven *Rangia* samples submitted in April 1990 and were from stations S1 (122 ppb), HM9 (60 ppb) and HM22 (24 ppb). PCBs were not detected in any other *Rangia* sampled for the ninth year. All samples of *Cyathura*, a benthic isopod, were negative for organic contaminants (at very high detection limits). Two samples of *Rithanopropreus* were also negative.

White perch and yellow perch from the April 1990 sampling contained substantial quantities of several organochlorine contaminants. Individual white perch samples from each of the four transects (F1-F4) contained detectable levels of chlordane (509 ppb F1; 156 ppb F2; 254 ppb F3; 243 ppb F4). The FDA action level for chlordane is 300 ppb, thus one sample is above, and two are quite close to, the FDA action level. Again, since size information is not provided, it is difficult to comment further on these data. These same white perch contained varying low ppb levels of the P,P' DDT,DDE, DDD complex. In addition, white perch samples from F1 and F4 contained total PCBs at 134 ppb and 772 ppb, respectively. The FDA action level for PCBs is 2 ppm. In contrast to white perch, yellow perch from the same sampling did not contain high chlordane levels. One sample from F2 contained 48 ppb. Yellow perch from F3 and F4 contained 10 and 23 ppb, respectively of p,p' DDE. Yellow perch from stations F2, F3 and F4 also contained PCBs (107 ppb, 103 ppb and 304 ppb).

1. INTRODUCTION

A long-term monitoring program has been conducted since 1981 in order to examine the possible impacts of the construction and operation of the Hart-Miller Island Containment Facility. Biological studies have monitored the populations and abundance of fish and benthos, while physical studies have characterized the nature of currents and sediments. Chemical studies have measured levels of nutrients in the water column as well as levels of selected trace metal and organic contaminants in sediments and biota. The Coastal and Estuarine Geology Program of the Maryland Geological Survey is responsible for the collection and characterization of sediment samples, while the Benthos Project is directed by the Chesapeake Biological Laboratory and is responsible for the collection and characterization of the fish and benthic biota samples. This interpretive report deals solely with contaminant levels in biological samples. Data on contaminant levels in sediments can be found under the Project II report on the sedimentary environment.

Analyses have been performed since the inception of the program, with the first three years (pre-operation 1981-1983) used as a baseline with which to compare subsequent operational years (though no chemical analyses were performed from August 1983 - August 1984). The sampling program since 1984 has evolved from modest in 1984-1987 to more intensive sampling in years 1987 and 1988 and back to less intensive sampling in the most recent surveys. The sampling year typically includes three sampling dates (e.g. December 1989, April 1990 and August 1990 for this Ninth Year Report).

2. METHODS

A. Sampling and Chemical Analyses

Nine benthic stations and four fish stations were sampled for chemical analysis of biota (Figures 1 and 2). These represent a subset of the overall sampling stations for the benthos project. Benthos stations fall into three categories. Stations G5, G25, G84 and HM12 are stations which have been added in order to examine the Zn enrichment issue described under the sedimentary environment report (i.e. Zn is enriched in the sediments at these stations relative to the baseline years). Stations HM9, HM16 and HM22, designated as reference stations, are not immediately adjacent to the facility. Station S1, S4 and S6 are designated as nearfield stations and are immediately adjacent to the facility. It should be noted, however, that the flow descriptions described under the sedimentary project suggest that these designations may not *a priori* indicate where contaminant burdens should be differentiable based on operation of the facility.

a priori - based on hypothesis or theory rather than experiment or experience.

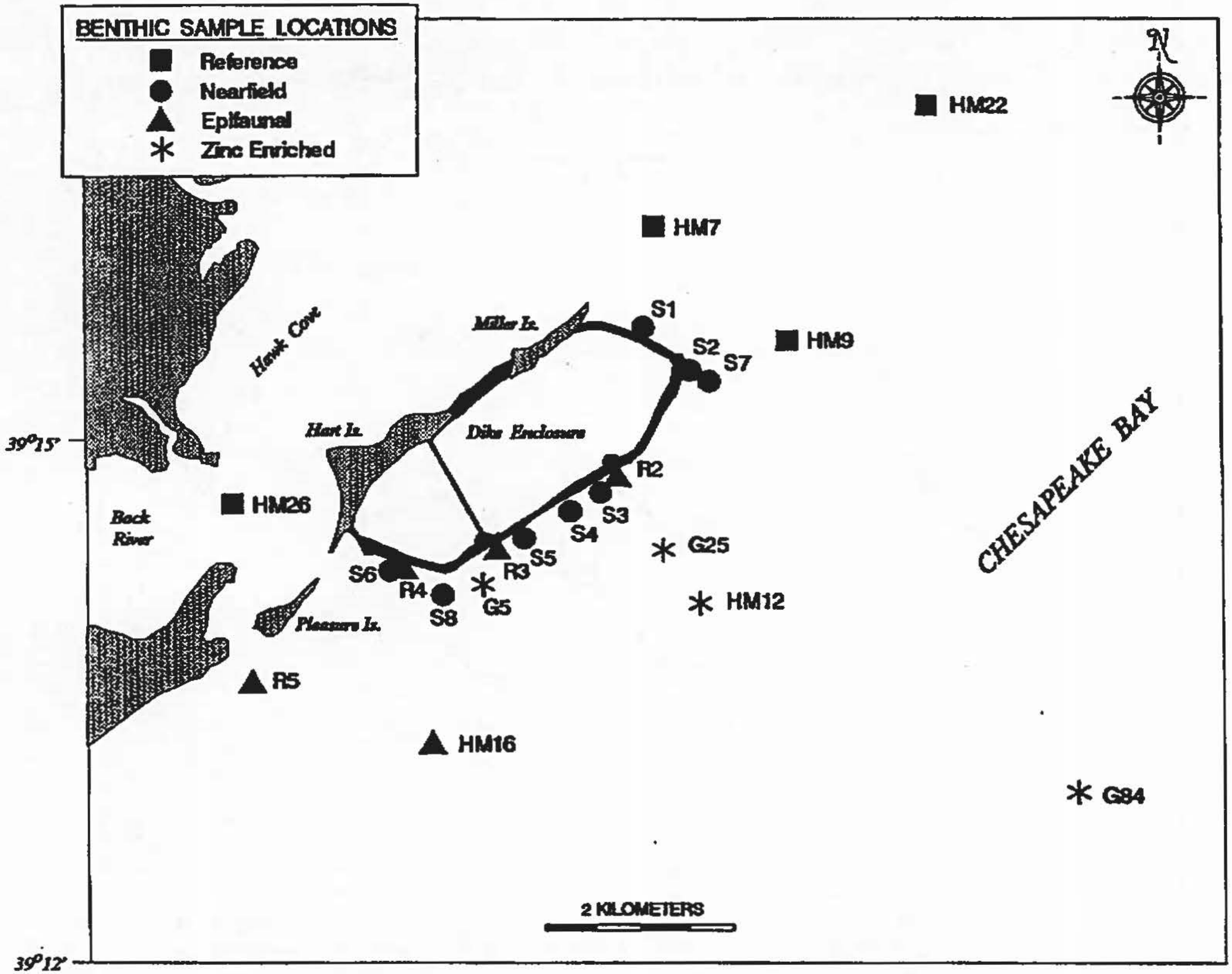


FIGURE 1. BENTHIC INFAUNAL AND EPIFAUNAL SAMPLING STATION LOCATIONS FOR THE 9TH YEAR OF BENTHIC MONITORING AT HART MILLER ISLANDS CONTAINMENT FACILITY. UNIVERSITY OF MARYLAND, CHESAPEAKE BIOLOGICAL LAB DESIGNATIONS.

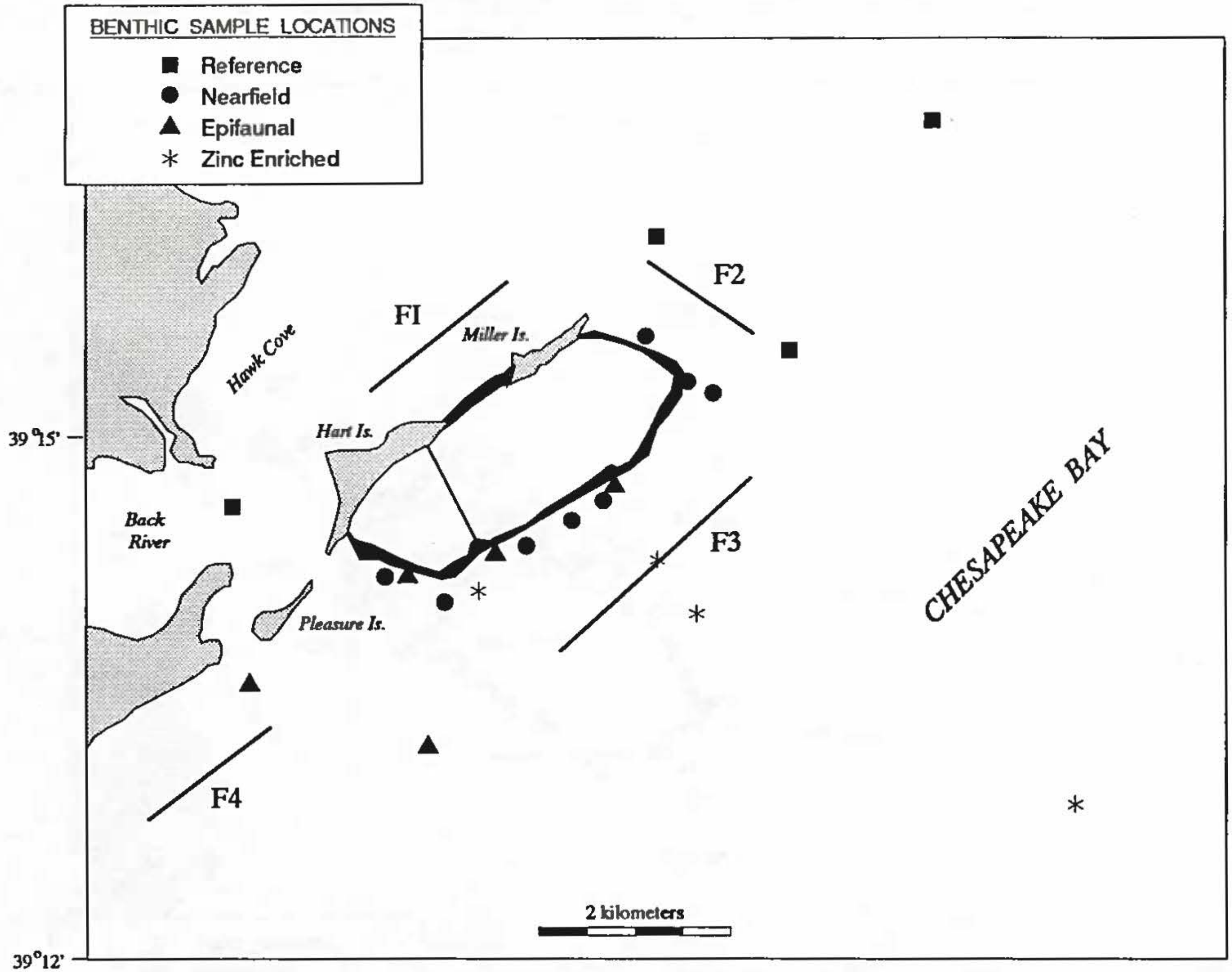


Figure 2. Fish sampling transects for Year Nine HMI sampling.

Benthos and fish samples were collected by the Chesapeake Biological Laboratory in December 1989, April 1990 and August 1990. A 0.05 m^2 Ponar grab was used for benthos, while fish were collected with a 16 ft otter trawl with a 1 1/2" mesh, which was towed for five minutes. Benthos and fish samples were identified as to genus or species prior to submission for metal and organic analyses. Fish were filleted so that only muscle tissue was analyzed. Benthos samples were not necessarily standardized for size across sampling dates.

In year nine, two benthic bivalves were collected, *Macoma sp.* and *Rangia cuneata*. The benthic isopod, *Cyathura polita* and the mud crab, *Rhithropanapreus harrisi*, were also collected. Two fish species were collected in the ninth year, the white perch, *Morone americana* and the yellow perch, *Perca flavescens*.

Biota samples were collected and frozen in pre-cleaned glass containers until extraction and analyses were performed by Martel Laboratories, Inc. Biota were analyzed for Cr, Cu, Fe, Mn, Ni, Zn, selected chlorinated pesticides, total PCBs, phthalate esters and selected polycyclic aromatic hydrocarbons (PAHs). The analytical methods used are listed in Table 1. Individual organic analytes are also listed in the summary tables.

Table 1. Analytical methods used to determine concentrations of metals and organic contaminants in sediments and biota.

Parameter	Media	EPA Method Number/Reference	
Chromium (Cr)	Tissues	(EPA 218.1)	(EPA 1983)
Manganese (Mn)	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/PCBs	Tissues	(EPA 8080)	(EPA 1986)
Phthalate esters and Polycyclic Aromatic Hydrocarbons	Tissues	(EPA 8270)	(EPA 1986)

B. Data Analysis

Data were entered into the Statview II® statistical analysis package and summary statistics tabulated. An exhaustive statistical analysis of this data was not performed for several reasons. In general, appropriate statistical tests are not available for this type of data. The data set is characterized by very small sample sizes (frequently only one sample at a station for all three sampling dates) and a substantial number of non-detects with varying detection limits.

With small data sets and censored data (non-detects), it is impossible to estimate and partition variance so that appropriate among station contrasts can be performed. In essence, there is insufficient data to estimate both among-sample and within-sample variability. The among-sample variance is the true variability in contaminant burdens at a station while the within-sample variance can be viewed as the "analytical error" variance. Most sampling programs designed to determine contaminant differences among stations and/or sampling years incorporate a standardization protocol (e.g. size, age, lipid content) in order to reduce unwanted variance (Popham and D'Auria 1983). Since many contaminant burdens are correlated with these variables, standardization can often reduce variance and allow true station differences to be resolved. Alternately, multivariate techniques can be used if sufficient additional biological variables related to contaminant burdens are collected and used in the analysis (e.g. age, length, weight, lipid concentration, etc.; see for example Misra and Uthe 1987). These kinds of issues can not be addressed using the current sampling protocol.

Finally, the interpretive report supplied for the sedimentary environment project suggests that contaminant distributions resulting from effluent flow (particularly spillway #1) may vary substantially depending on the flow in any given year. This suggests that the contaminant burdens seen in sediments and biota may not, and probably should not, be a simple function of distance from the facility. Clearly, a major controlling mechanism for the dispersion of pollutants exiting from the facility will be associated with the distribution of water and particles around the facility. It is clear that this is not a simple process in space or time. Therefore, the data presentation used here is to simply summarize the analytical results in tabular format and to highlight unusual or atypical results where noted. The data summaries are grouped into the station types discussed above (nearfield, reference and Zn enriched sediments) using bold lines to separate the groups. Tabulated summaries as well as individual sample data have been included.

In this report, all chemical concentrations are reported as wet weight values. Trace metal concentrations are listed as ug/g (ppm) while organic contaminants are listed as ng/g (ppb). Since many bivalve sampling programs report dry weight values (e.g. NOAA's Mussel Watch), approximate comparisons can be made by increasing wet weight values by 8-fold (i.e. biological tissues are typically 80-90% water).

3. RESULTS AND DISCUSSION

Trace Metals

Summary statistics for individual trace metal concentrations in benthic biota, including the frequency of detection, detection limits for non-detects, maximum and individual values by station, and species summaries (min, max and range) are provided in Tables 2a-f. Individual sample summaries are provided in Appendix A.

Two tables have been provided as reference information from which to compare selected trace metal concentrations in Hart-Miller benthos samples. Table 3 is a compilation of information from the NOAA benthic surveillance program, a nationwide survey of contaminants in the blue mussel, *Mytilus edulis* (NOAA 1987). Table 3 contains information from the highest and lowest stations encountered nationwide. The data were converted from the original dry weight data by using a conversion factor of 8 (i.e. dry weight data were *decreased* by 8-fold to account for an approximate 80% water content of biological tissue). Table 4 is a summary of selected trace metal concentrations found in a survey of Chesapeake Bay soft shell clams, *Mya arenaria* (Murphy 1990). These data are the original reported wet weight data. The data compilations are for selected trace metals, since neither of the surveys analyzed the same complement of trace metals as that of HMI. In addition, in each section, contaminant concentrations have been compared to year eight results.

Table 2-a.				CHROMIUM			
			%	MIN/MAX	ug/g	ug/g	
Species	**Station**	**N**	**Detects**	**Det. Limits**	**Maximum**	**Values**	**Min/Max/Range**
Rangia	G25	3	33	1 / 1	0.8	0.8	
Rangia	G84	1	0	1	ND	ND	
Rangia	HM12	2	0	0.4 / 1	ND	ND	
Rangia	HM16	2	50	0.5	3	3	
Rangia	HM22	3	0	0.5 / 1	ND	ND	
Rangia	HM9	1	0	1	ND	ND	
Rangia	S1	3	33	0.5 / 1	1.7	1.7	
Rangia	S4	1	100		2.9	2.9	
Rangia	S6	2	50	1	19	19	
Rangia	All Stations	18	28	0.4 / 1	19		0.8 / 19 / 18.2
Macoma	G5	2	100		22	22, 0.8	
Macoma	G25	1	0	6	ND	ND	
Macoma	G84	2	50	3	2.5	2.5	
Macoma	HM12	1	0	2	ND	ND	
Macoma	HM16	3	66	2	45	45, 4.2	
Macoma	S4	2	50	4	32	32	
Macoma	S6	3	100		29	29, 9.1, 3.4	
Macoma	All Stations	14	64	2 / 6	45		0.8, 45, 44.2
Cyathura	G5	1	100		8.9	8.9	
Cyathura	G25	1	0	8	ND	ND	
Cyathura	G84	2	0	1 / 8	ND	ND	
Cyathura	HM16	2	0	2 / 4	ND	ND	
Cyathura	S4	3	33	4 / 8	7.5	7.5	
Cyathura	S6	3	66	6	10	10, 4.5	
Cyathura	All Stations	12	33	2 / 8	10		4.5, 10, 5.5
Rithanopropreus	S2	2	50	5	3.6	3.6	

Table 2-b.			IRON				
Species	Station	N	% Detects	MIN/MAX Det. Limits	ug/g Maximum	ug/g Values	Min/Max/Range
Rangia	G25	3	100		140	140, 43, 27	
Rangia	G84	1	100		240	240	
Rangia	HM12	2	100		60	60, 52	
Rangia	HM16	2	100		258	258, 150	
Rangia	HM22	3	100		310	310, 200, 42	
Rangia	HM9	1	100		32	32	
Rangia	S1	3	100		180	180, 39, 28	
Rangia	S4	1	100		35	35	
Rangia	S6	2	100		11800	11800. 230	
Rangia	All Stations	18	100		11800		27. 11800. 11773
Macoma	G5	2	100		280	280 140	
Macoma	G25	1	100		1080	1080	
Macoma	G84	2	100		1300	1300. 95	
Macoma	HM12	1	100		1300	1300	
Macoma	HM16	3	100		1900	1900, 620, 260	
Macoma	S4	2	100		689	689, 170	
Macoma	S6	3	100		670	670, 540, 360	
Macoma	All Stations	14	100		1900		95, 1900, 1805
Cyathura	G5	1	100		160	160	
Cyathura	G25	1	100		350	350	
Cyathura	G84	2	100		570	570, 320	
Cyathura	HM16	2	100		200	200, 160	
Cyathura	S4	3	100		412	412, 320, 150	
Cyathura	S6	3	100		830	830, 550, 270	
Cyathura	All Stations	12	100		830		150, 830, 680
Rithanopropreus	S2	2	100		640	640, 270	

Table 2-c.			Manganese				
Species	Station	N	% Detects	MIN/MAX Det. Limits	ug/g Maximum	ug/g Values	Min/Max/Range
Rangia	G25	3	100		35	35, 4.3, 4	
Rangia	G84	1	100		49	49	
Rangia	HM12	2	100		13	13, 5.9	
Rangia	HM16	2	100		40	40, 38	
Rangia	HM22	3	100		55	55, 28, 9.7	
Rangia	HM9	1	100		3.4	3.4	
Rangia	S1	3	100		27	27, 5.4, 2.5	
Rangia	S4	1	0	3	ND		
Rangia	S6	2	100		670	670, 33	
Rangia	All Stations	18	94		670		2.5, 670, 667.5
Macoma	G5	2	100		200	200, 35	
Macoma	G25	1	100		130	130	
Macoma	G84	2	100		140	140, 130	
Macoma	HM12	1	100		130	130	
Macoma	HM16	3	100		200	200, 170, 81	
Macoma	S4	2	100		250	250, 190	
Macoma	S6	3	100		3000	3000, 180, 150	
Macoma	All Stations	14	100		3000		35, 3000, 2965
Cyathura	G5	1	100		190	190	
Cyathura	G25	1	100		180	180	
Cyathura	G84	2	100		410	410, 51	
Cyathura	HM16	2	100		190	190, 150	
Cyathura	S4	3	100		300	300, 290, 190	
Cyathura	S6	3	100		1200	1200, 660, 140	
Cyathura	All Stations	12	100		830		51, 1200, 1149
Rithanopropreus	S2	2	100		1100	1100, 614	

Table 2-d.			Copper				
Species	Station	N	% Detects	MIN/MAX Det. Limits	ug/g Maximum	ug/g Values	Min/Max/Range
Rangia	G25	3	66	1	2.4	2.4, 2	
Rangia	G84	1	0	1	ND	ND	
Rangia	HM12	2	0	0.5 / 1	ND	ND	
Rangia	HM16	2	100		2.9	2.9, 2	
Rangia	HM22	3	66	1	2	2, 1.8	
Rangia	HM9	1	0	1	ND	ND	
Rangia	S1	3	66	1	3	3, 2.5	
Rangia	S4	1	0	3	ND	ND	
Rangia	S6	2	50	1	14	14	
Rangia	All Stations	18	50		14		1.8, 14, 12.2
Macoma	G5	2	100		14	14, 2.4	
Macoma	G25	1	100		11	11	
Macoma	G84	2	100		21	21, 3	
Macoma	HM12	1	100		7	7	
Macoma	HM16	3	100		14	14, 10, 6	
Macoma	S4	2	100		11	11, 8.7	
Macoma	S6	3	100		22	22, 20, 14	
Macoma	All Stations	14	100		22		2.4, 22, 19.6
Cyathura	G5	1	100		43	43	
Cyathura	G25	1	100		11	11	
Cyathura	G84	2	100		41	41, 2.6	
Cyathura	HM16	2	100		33	33, 14	
Cyathura	S4	3	100		35	35, 28, 24	
Cyathura	S6	3	100		66	66, 45, 39	
Cyathura	All Stations	12	100		66		2.6, 66, 63.4
Rithanopro.	S2	2	100		29	29, 26	

Table 2-e.			Nickel				
			%	MIN/MAX	ug/g	ug/g	
Species	Station	N	Detects	Det. Limits	Maximum	Values	Min/Max/Range
Rangia	G25	3	66	4	13	13, 6	
Rangia	G84	1	100	1	4	4	
Rangia	HM12	2	0	0.4 /4	ND	ND	
Rangia	HM16	2	100		8	8, 5	
Rangia	HM22	3	100		9.7	9.7, 6.8, 6	
Rangia	HM9	1	0	6	ND	ND	
Rangia	S1	3	100		8	8, 4.2, 3.8	
Rangia	S4	1	100		2.9	2.9	
Rangia	S6	2	100		19	19, 6	
Rangia	All Stations	18	78	4 / 6	19		2.9, 19, 16.1
Macoma	G5	2	50	0.4	13	13	
Macoma	G25	1	0	11	ND	ND	
Macoma	G84	2	50	8	1	1	
Macoma	HM12	1	0	8	ND	ND	
Macoma	HM16	3	33	4 / 8	1.1	1.1	
Macoma	S4	2	50	7	0.8	0.8	
Macoma	S6	3	33	3 / 9	2.4	2.4	
Macoma	All Stations	14	36	0.4 / 11	13		0.8, 13, 12.2
Cyathura	G5	1	100		2	2	
Cyathura	G25	1	0	40	ND	ND	
Cyathura	G84	2	50	40	8.2	8.2	
Cyathura	HM16	2	0	2 / 7	ND	ND	
Cyathura	S4	3	0	2 / 40	ND	ND	
Cyathura	S6	3	0	3 / 28	ND	ND	
Cyathura	All Stations	12	17	2 / 40	8.2		2, 8.2, 6.2
Rithanopro.	S2	2	0	4 / 25	ND		ND

Table 2-f.			ZINC				
Species	Station	N	% Detects	MIN/MAX Det. Limits	ug/g Maximum	ug/g Values	Min/Max/Range
Rangia	G25	3	100		468	468, 28, 15	
Rangia	G84	1	100		22	22	
Rangia	HM12	2	100		17	17, 3.4	
Rangia	HM16	2	100		23	23, 17	
Rangia	HM22	3	100		24	24, 22, 15	
Rangia	HM9	1	100		17	17	
Rangia	S1	3	100		25	25, 21, 18	
Rangia	S4	1	100		28	28	
Rangia	S6	2	100		78	78, 45	
Rangia	All Stations	18	100		468		3.4, 468, 464.6
Macoma	G5	2	100		28	28, 16	
Macoma	G25	1	100		83	83	
Macoma	G84	2	100		87	87, 34	
Macoma	HM12	1	100		170	170	
Macoma	HM16	3	100		110	110, 92, 14	
Macoma	S4	2	100		46	46, 9.8	
Macoma	S6	3	100		48	48, 36, 24	
Macoma	All Stations	14	100		170		9.8, 170, 160.2
Cyathura	G5	1	100		160	160	
Cyathura	G25	1	100		350	350	
Cyathura	G84	2	100		570	570, 320	
Cyathura	HM16	2	100		200	200, 160	
Cyathura	S4	3	100		412	412, 320, 150	
Cyathura	S6	3	100		830	830, 550, 270	
Cyathura	All Stations	12	100		830		150, 830, 680
Rithanopropr	S2	2	100		640	640, 270	

Table 3. Trace metal concentrations in bivalve mussels from the National Status and Trends Program 1984, 1985, 1986. (NOAA 1987). Estimated ug/g wet weight concentrations from original dry weight data (8X conversion).

Metal	Highest Samples (Range)	Lowest Samples (Range)
Copper	1.3 - 2.5	0.7 - 0.9
Nickel	0.4 - 1.6	0.07 - 0.1
Zinc	19 - 39	7 - 12

Table 4. Levels of Chromium Copper and Zinc in soft shell clams from the Chesapeake Ba and its tributaries: 1981-1985. From Murphy 1990. Data as ug/g wet weight.

Metal	Range	Mean	Median
Chromium	<0.1 - 1.4	0.3	<0.5
Copper	0.63 - 15.8	6.55	6.26
Zinc	8.04 - 451	29.1	19.8

Invertebrates

Rangia cuneata

Eighteen *Rangia* samples were analyzed in the ninth year, six samples each for reference, nearfield and Zn enriched stations.

Cr was detected in 28% of all samples with one of two samples from the nearfield station S6 yielding the highest concentration of 19 ug/g. Detection limits ranged from 0.4 to 1 ug/g. Zn enriched stations did not yield high levels of Cr relative to other stations. Detection frequencies were higher for nearfield stations than the others. With the exception of the one sample at S6, the range of concentrations of Cr detected in *Rangia* were similar to HMI sampling years seven and eight (See Eighth Year Report). The reported Cr concentrations exceed the values reported for the most recent Baywide survey of soft shell clams.

Fe and Mn were detected in all samples of *Rangia* except for one non-detect for Mn at station S4 (3 ppm detection limit). These values are characterized by high variability within and among station types. Station S6 yielded one sample with extremely high Fe and Mn (11800 ug/g and 670 ug/g respectively). Both of these elements can be considered required for normal physiological processes, though very few values are available for comparison with these data. Roesijadi and Crecelius (1984) measured the elemental composition of a representative near-shore sample of the blue mussel (*Mytilus edulis*) and found concentrations of 30 ug/g Fe and 1 ug/g Mn (estimated from dry weight data). Assuming similar needs for these elements among bivalves, these data serve as a useful comparison. Many of the values encountered in HMI *Rangia* samples are well above these values

The high variability in these data could hypothetically be due to varying amounts of Fe and Mn enriched sediments present in the guts of the animals at the time of sampling. Wright et al (1986) discussed this concern in their sampling of *Macoma* from a variety of Bay stations. In *Macoma* samples collected from Chalk Point and Clay Island, these investigators noted a substantial reduction in Fe and Mn concentrations in *Macoma* allowed to purge gut contents before analyses were conducted. Consequently, it is plausible that Fe and Mn values could be used as covariates to explain variance in the levels of other toxicologically important trace metals. To estimate this, a simple correlation analysis was done for several pairs of analytes, including the Fe/Mn pair. Correlation coefficients were generally low for all pairs (ca 0.1- 0.2) (data not shown) and therefore Fe and Mn values do not appear to hold promise as clear indicators of sediment burdens in the bivalves at the time of sampling. However, it is important to note that the bivalves are not purged of gut contents at the time of sampling, and, thus, all analytical results are presumed to reflect the combination of true tissue burdens as well as contamination from particles in the gut (Wright et al. 1986).

Cu was detected in 50% of all *Rangia* samples, with a high of 14 ug/g at the same nearfield S6 station as the highest Cr value. Among station differences were not notable and most values were in the 2-3 ug/g range. These values are similar to HMI year seven data and are in contrast to the wide range of concentrations found in year eight. Cu concentrations were in the same range as soft shell clams from the Chesapeake and were generally in the highest sample range of the nationwide NOAA survey of the blue mussel.

Ni was detected in 78% of the *Rangia* samples, with a high value of 19 ug/g in one sample at station S6. Values were variable among station types, with no major differences notable. In general, Ni concentrations at most stations were similar to the eighth year data. However, station HM22, which last year had a high range of concentrations, did not show this behavior in the ninth year. Detected Ni concentrations were generally 2-10 times higher than the highest sample concentrations in blue mussels nationwide

Zn was detected in all samples, with an extreme value of 468 ug/g in one sample from the G25 Zn enriched station. However, other samples at the Zn enriched stations were not notably higher than the nearfield or reference stations. Concentrations at all stations were similar to year eight. Zn concentrations were similar to concentrations found by Murphy (1990) in Chesapeake soft shell clams and similar to the high sample range found in blue mussels.

Macoma sp.

Fourteen samples of Macoma were sampled for the ninth year; six samples from four Zn enriched stations, three samples from one reference station and 5 samples from two nearfield stations.

Cr was detected in 64% of all samples with a high of 45 ug/g at reference station HM16. Detection limits were two to six-fold higher than for *Rangia*. Cr concentrations were generally greater in *Macoma* than in *Rangia* and exceeded the Baywide range of concentrations encountered in soft shell clams. Maximum Cr concentrations in *Macoma* were approximately 5-8 fold higher in year nine than in year eight. These values and the variability associated with them are not atypical of Cr in *Macoma* from the vicinity of Baltimore Harbor (Wright et al. 1986).

Fe and Mn were detected at relatively high levels in all samples of *Macoma*. Extreme values were 1900 ug/g Fe and 3000 ug/g Mn. As with *Rangia*, the values were characterized by high variability. There were no clear differences among station types.

The concentration of Fe and Mn were also quite high relative to the reference values cites above for blue mussels (Roesijadi and Crecelius 1984).

Cu was detectable in all samples of *Macoma* and were generally three to five-fold higher than levels found in *Rangia*. No clear differences in maximum or minimum values were found among station type and year nine values are similar to year eight. Cu concentrations were approximately four-fold higher than the high range samples of blue mussels in the NOAA survey and while generally in the same range of concentrations found in Chesapeake Bay soft shell clams, most values exceeded the mean soft shell clam concentration by about two-fold.

Ni concentrations in *Macoma* were measurable in approximately 36% of the samples and lower than those found in *Rangia*. Levels in *Macoma* in year nine were similar to year eight, though the frequency of detection was higher. The Ni concentrations were similar to the high range samples of blue mussels.

As with *Rangia*, Zn was detected in all samples of *Macoma*. Concentrations tended to be higher than in *Rangia* and similar to the survey of Chesapeake soft shell clams. The range of Zn concentrations found in year nine were similar to year eight and the extreme value found at station S6 in year eight was not found in year nine. Zn concentrations in *Macoma* were more than an order of magnitude higher than the high sample range found for blue mussels nationwide.

Cyathura polita

Twelve samples of *Cyathura* were collected for the ninth year; four from the Zn enriched stations, 2 from the reference stations and 6 from nearfield stations.

Concentrations of Cr were detected in 33% of the *Cyathura* samples with a high of 10 ug/g at nearfield station S6. As with year eight samples, Cr tends to be detected more frequently in *Cyathura* at the nearfield stations than the others. Cr concentrations were in the same range as found with other biological samples.

Fe and Mn were found in all samples and were at levels similar to *Rangia* and *Macoma*. Maximum values were 830 ug/g and 1200 ug/g for Fe and Mn respectively and are quite high relative to the proposed background concentrations of 30 ug/g and 1 ug/g.

Cu was detected in all samples of *Cyathura* and concentrations were typically higher than those found for *Rangia* and *Macoma* by about two to five-fold. Maximal values for Cu were highest at the nearfield stations and were much higher than either the blue mussel or soft shell clam reference values listed in

table 4

This Page is

Intentionally Page

Tables 3 and 4. Cu was detected more frequently in year nine than in year eight and maximum values were slightly higher.

Ni was detected in only 17% of the *Cyathura* samples, in contrast to the higher frequency of detection in *Rangia* and *Macoma*. However, the detection limits reported for many of the *Cyathura* samples are five to ten-fold higher than detection limits for the other biological samples. Ni was detected in *Cyathura* most frequently at the Zn enriched stations.

Zn was found in 100% of the *Cyathura* samples with a maximum value of 830 ug/g found at nearfield station S6. Zn concentrations in *Cyathura* were generally five to tenfold higher than in the bivalves and are high relative to other reference bivalve populations as well. This data suggests that *Cyathura* may have a greater tendency to bioaccumulate Zn relative to bivalves and also suggests that further research should be conducted to examine the relationship between Zn concentrations in sediments and Zn accumulation in *Cyathura*. Zn concentrations in *Cyathura* were generally much higher (3-4-fold) in year nine than in year eight.

Rhithropanapeus harrisi

Two samples of the mud crab, *Rhithropanapeus harrisi*, were collected from the nearfield station S2.

Trace metal concentrations for these samples are listed in the data tables. The limited sample size precludes further comment on these data.

Fish Species

White Perch (*Morone americana*)

Eleven white perch were sampled from four transects as shown in Figure 2. Transect F4 is somewhat removed from the facility, though fish are mobile and values may not necessarily reflect conditions at the designated transect. Summaries of trace metal concentrations in white perch and yellow perch are presented in Table 5 a-f. Individual samples and their reported values are given in Appendix A.

Cr was detected in 55% of all samples with a maximum value of 5 ug/g detected at station F2. Cr concentrations were within a narrow range of 1.5 to 5 ug/g for all samples, with individual concentrations similar among stations. Detection frequencies were higher in year nine (no Cr was detected in white perch in year eight) and approximately two-fold higher than the year eight detection limits.

Table 5-a.			CHROMIUM				
			%	MIN/MAX	ug/g	ug/g	
Species	Station	N	Detects	Det. Limits	Maximum	Values	Min/Max/Range
W. Perch	F1	3	33	1	3.9	3.9	
W. Perch	F2	3	66	1	5	5, 1.8	
W. Perch	F3	2	50	1	3.8	3.8	
W. Perch	F4	3	66	1	2.9	2.9, 1.5	
W. Perch	All Stations	11	55	1	5		1.5, 5, 3.5
Y. Perch	F1	2	50	1	3.4	3.4	
Y. Perch	F2	2	50	1	2.6	2.6	
Y. Perch	F3	2	50	1	4.3	4.3	
Y. Perch	F4	2	50	1	3.4	3.4	
Y. Perch	All Stations	8	50	1	4.3		2.6, 4.3, 1.7

Table 5-b. **IRON**

			%	MIN/MAX	ug/g	ug/g	
Species	**Station**	**N**	**Detects**	**Det. Limits**	**Maximum**	**Values**	**Min/Max/Range**
W. Perch	F1	3	100		17	17, 6.4, 5.5	
W. Perch	F2	3	100		8.3	8.3, 8.2, 7.3	
W. Perch	F3	2	100		9.3	9.3, 6.3	
W. Perch	F4	3	100		15	15, 7.1, 5.6	
W. Perch	All Stations	11	100		15		5.5, 15, 9.5
Y. Perch	F1	2	100		14	14, 4.9	
Y. Perch	F2	2	100		12	12, 3.6	
Y. Perch	F3	2	100		14	14, 12	
Y. Perch	F4	2	100		14	14, 6.9	
Y. Perch	All Stations	8	100		14		12, 14, 2

Table 5-c.			MANGANESE				
Species	Station	N	% Detects	MIN/MAX Det. Limits	ug/g Maximum	ug/g Values	Min/Max/Range
W. Perch	F1	3	66	1	26	26, 0.66	
W. Perch	F2	3	100		3.6	3.6, 1, 0.14	
W. Perch	F3	2	100		16	16, 0.12	
W. Perch	F4	3	100		14	14, 10, 1.6	
W. Perch	All Stations	11	91	1	26		0.12, 26, 25.88
Y. Perch	F1	2	100		17	17, 0.4	
Y. Perch	F2	2	100		32	32, 0.53	
Y. Perch	F3	2	100		49	49, 0.62	
Y. Perch	F4	2	100		25	25, 1.4	
Y. Perch	All Stations	8	100		49		0.4, 49, 48.6

Table 5-d.			COPPER				
Species	Station	N	% Detects	MIN/MAX Det. Limits	ug/g Maximum	ug/g Values	Min/Max/Range
W. Perch	F1	3	33	1	2	2	
W. Perch	F2	3	0	1	ND	ND	
W. Perch	F3	2	0	0.9 / 1	ND	ND	
W. Perch	F4	3	33	1	1.9	1.9	
W. Perch	All Stations	11	18	0.9 / 1	2		1.9, 2, 0.1
Y. Perch	F1	2	50	1	1.7	1.7	
Y. Perch	F2	2	50	1	1.3	1.3	
Y. Perch	F3	2	50	1	1.9	1.9	
Y. Perch	F4	2	0	1	ND	ND	
Y. Perch	All Stations	8	38	1	1.9		1.3, 1.9, 0.6

Table 5-e. NICKEL

Species	Station	N	% Detects	MIN/MAX Det. Limits	ug/g Maximum	ug/g Values	Min/Max/Range
W. Perch	F1	3	0	0.9 / 3	ND	ND	
W. Perch	F2	3	33	2 / 3	1.1	1.1	
W. Perch	F3	2	50	3	1.6	1.6	
W. Perch	F4	3	66	2 / 4	1.2	1.2	
W. Perch	All Stations	11	27	0.9 / 4	1.6		1.2, 1.6, 0.4
Y. Perch	F1	2	0	2 / 3	ND	ND	
Y. Perch	F2	2	0	1 / 3	ND	ND	
Y. Perch	F3	2	0	1 / 4	ND	ND	
Y. Perch	F4	2	0	2 / 4	ND	ND	
Y. Perch	All Stations	8	0	1 / 4	ND		

Table 5-f.			ZINC				
			%	MIN/MAX	ug/g	ug/g	
Species	**Station**	**N**	**Detects**	**Det. Limits**	**Maximum**	**Values**	**Min/Max/Range**
W. Perch	F1	3	100		40	40, 15, 7	
W. Perch	F2	3	100		19	19, 17, 13	
W. Perch	F3	2	100		18	18, 16	
W. Perch	F4	3	100		33	33, 22, 11	
W. Perch	All Stations	11	100		40		7, 40, 33
Y. Perch	F1	2	100		20	20, 14	
Y. Perch	F2	2	100		19	19, 11	
Y. Perch	F3	2	100		25	25, 15	
Y. Perch	F4	2	100		26	26, 11	
Y. Perch	All Stations	8	100		26		11, 26, 15

Fe and Mn were detected in all samples with the exception of one non-detect for Mn in a sample from station F1. Fe and Mn concentrations were generally an order of magnitude lower than concentrations found in the benthic species and were more variable for Mn than for Fe. Typical elemental compositions of fish fillets were not available for comparison.

Cu was detected in only 18% of the white perch samples and the two samples measurable were similar at 1.9 and 2 ug/g. These levels are not high for biological tissues, as is evident from comparison to the benthic bivalves, and are similar to year eight values.

Ni was measured in 27% of the samples, with all concentrations in a narrow range of 1.2 to 1.6 ug/g. Again, these values are not high in comparison to benthic species and are similar to year eight values.

Zn was detectable in all samples analyzed, with values ranging from 7 to 40 ug/g. There were no obvious differences in concentrations among the stations, and values were similar to those found in year eight.

Yellow Perch (*Perca flavescens*)

Eight yellow perch samples were analyzed, two from each of the four transects.

Cr was detectable in 50% of the samples, with concentrations measured over a narrow range of 2.6 to 4.3 ug/g. Concentrations of Cr in yellow perch were similar to those found in white perch. Cr was not detected in year eight yellow perch samples, and this difference was not caused by differing detection limits.

Fe and Mn were detected in 100% of all samples with concentrations similar to those found in white perch.

Cu was detected in 38% of the samples with concentrations nearly identical to those found in white perch. Cu was not detected in yellow perch samples from the F4 reference station. Concentrations of Cu in yellow perch were similar to those found in year eight.

Ni was not detected in any yellow perch samples at detection limits of 1 to 4 ug/g. These detection limits are similar to those for white perch, where Ni was detected at around 1 ug/g. Ni was also not detected in yellow perch from year eight.

Zn was detected in 100% of the samples with concentrations ranging from 11 to 26 ug/g. Concentrations for Zn were similar to those found in the white perch and are not unusually high for biological tissues. Concentrations of Zn in yellow perch were similar to year eight.

Organic Contaminants

Table 6 is a summary of the target analytes for the organic contaminant component of the HMI monitoring program. These target analytes are grouped into three broad categories: Pesticides and PCBs, Phthalate esters, and Polycyclic Aromatic Hydrocarbons (PAH). As in years past, most of the samples contain non-detectable quantities of most of these target analytes. However, great caution should be used in interpretation of these data since the detection limits for these samples range across several orders of magnitude and, in many cases, are too high for adequate interpretation. For example, detection limits as high as 40 ug/g for total PCBs for some *Cyathura* samples and 10 ug/g for some *Macoma* samples are well outside the range of any anticipated concentrations in any biological matrix from samples nationwide. Concentrations this high would occur only in the most severely contaminated environments.

Tables 7 a-e are compilations, by species, of the target analytes and the range of detection limits reported by Martel laboratories. As can be seen from these data, detection limits are highly variable and can be quite high. If the lowest values for detection limits could consistently be achieved, the data reported here would provide more convincing evidence of the degree of organic contamination of these samples. Detection limits are typically a function of the sample size and background and matrix interferences experienced using the chosen analytical method. Martel laboratories uses EPA standard methods and most frequently those of SW 846. Many of the detection limits reported are well above the practical quantitation limits given as guidance in SW 846. While it is not clear what the basis for some of these high detection limits are, discussions with Ms. CeCe Donovan of MES indicate that detection limit problems are frequently due to an insufficient sample size.

Table 8 is a summary of all organic contaminants detected in biological samples from the ninth year HMI sampling.

Rangia and Macoma

Organic contaminants were detectable in only one sample of *Macoma*. Bis (2-ethylhexyl) phthalate, a common plasticizer was detected at 320 ng/g in a sample from the reference station HM16. This contaminant is frequently difficult to quantitate accurately

Table 6. Target Organic Analytes

Analyte

Pesticides and PCBs

Aldrin
a-BHC
Atrazine
b-BHC
g-BHC
chlordane
4,4'-DDD
4,4'-DDE
4,4'-DDT
Diazinon
Dieldrin
Endrin
Ethyl Parathion
Heptachlor
Heptachlor Epoxide
Linuron
Malathion
Methyl Parathion
Toxaphene
Trifluraline
PCB's (Total)

Polycyclic Aromatic Hydrocarbons (PAH)

Benzo(b)fluoranthene
Acenaphthylene
Benzo(a)anthracene
Benzo(g,h,i)perylene
Chrysene
Fluoranthene
Indeno(1,2,3-cd)pyrene
Phenanthrene
Acenaphthene
Anthracene
Benzo(a)pyrene
Benzo(k)fluoranthene
Dibenzo(a,h)anthracene
Fluorene
Naphthalene
Pyrene

Phthalate Esters

Butyl Benzyl phthalate
Di-n-octyl phthalate
Bis (2-ethylhexyl) phthalate
Di-n-butylphthalate
Diethyl phthalate
Dimethyl phthalate

Table 7a. Organic Detection Limits for Rangia

Rangia cuneata

Analyte	Detection Limits Listed
Pesticides and PCBs	
Aldrin	0.1-0.5-1-2-10-15-20-25-30
a-BHC	0.1-0.5-1-2-10-15-20-25-30
Atrazine	0.2-1-2-4-20-30-40-50-60
b-BHC	0.1-0.5-1-2-10-15-20-25-30
g-BHC	0.1-0.5-1-2-10-15-20-25-30
Chlordane	1-5-10-20-100-150-200-250-300
4,4'-DDD	0.1-0.5-1-2-10-15-20-25-30
4,4'-DDE	0.1-0.5-1-2-10-15-20-25-30
4,4'-DDT	0.1-0.5-1-2-10-15-20-25-30
Diazinon	0.2-1-2-4-20-30-40-50-60
Dieldrin	0.1-0.5-1-2-10-15-20-25-30
Endrin	0.1-0.5-1-2-10-15-20-25-30
Ethyl Parathion	0.2-1-2-4-20-30-40-50-60
Heptachlor	0.1-0.2-0.5-1-2-4-20-30-40-50-60
Heptachlor Epoxide	0.1-0.5-1-2-10-15-20-25-30
Linuron	0.2-1-2-4-20-30-40-50-60
Malathion	0.2-1-2-4-20-30-40-50-60
Methyl Parathion	0.2-1-2-4-20-30-40-50-60
Toxaphene	1-5-10-20-100-150-200-250-300
Trifluraline	0.2-1-2-4-20-30-40-50-60
PCB's (Total)	10-50-100-1000-1500-2000-2500-3000
Phthalate Esters	
Butyl Benzyl phthalate	1-5-10-50-100-200-300-1000
Di-n-octyl phthalate	1-5-10-50-100-200-300-1000
Bis (2-ethylhexy) phthalate	10-50-100-1000-2000-3000
Di-n-butylphthalate	1-5-10-50-100-200-300-1000
Diethyl phthalate	1-5-10-50-100-200-300-1000
Dimethyl phthalate	1-5-10-50-100-200-300-1000
Polycyclic Aromatic Hydrocarbons (PAH)	
Benzo(b)fluoranthene	1-5-10-50-100-200-300-1000
Acenaphthylene	1-5-10-50-100-200-1000
Benzo(a)anthracene	1-5-10-50-100-200-1000
Benzo(g,h,i)perylene	2-10-20-50-200-400-1000
Chrysene	1-5-10-50-100-200-1000
Fluoranthene	1-5-10-50-100-200-1000
Indeno(1,2,3-cd)pyrene	2-10-20-50-200-400-1000
Phenanthrene	1-5-10-50-100-200-1000
Acenaphthene	1-5-10-50-100-200-1000
Anthracene	1-5-10-50-100-200-1000
Benzo(a)pyrene	1-5-10-50-100-200-1000
Benzo(k)fluoranthene	2-10-20-50-200-400-1000
Dibenzo(a,h)anthracene	2-10-20-50-200-400-1000
Fluorene	1-5-10-50-100-200-1000
Naphthalene	1-5-10-50-100-200-1000
Pyrene	1-5-10-50-100-200-1000

Table 7b. Organic Detection Limits for Macoma

Macoma baltica

Analyte	Detection Limits Listed
Pesticides and PCBs	
Aldrin	1-10-20-22-40-1000
a-BHC	1-10-20-22-40-1000
Atrazine	2-20-40-44-80-2000
b-BHC	1-10-20-22-40-1000
g-BHC	1-10-20-22-40-1000
Chlordane	10-100-200-220-400-10000
4,4'-DDD	1-10-20-22-40-1000
4,4'-DDE	1-10-20-22-40-1000
4,4'-DDT	1-10-20-22-40-1000
Diazinon	2-20-40-44-80-2000
Dieldrin	1-10-20-22-40-1000
Endrin	1-10-20-22-40-1000
Ethyl Parathion	2-20-40-44-80-2000
Heptachlor	1-10-40-44-80-2000
Heptachlor Epoxide	1-10-20-22-40-1000
Linuron	2-20-40-44-80-2000
Malathion	2-20-40-44-80-2000
Methyl Parathion	2-20-40-44-80-2000
Toxaphene	10-100-200-220-400-10000
Trifluraline	2-20-40-44-80-2000
PCB's (Total)	10-100-2000-2200-4000-10000
Phthalate Esters	
Butyl Benzyl phthalate	10-100-200-400-1000
Di-n-octyl phthalate	10-100-200-400-1000
Bis (2-ethylhexy) phthalate	10-100-800-1000-2000
Di-n-butylphthalate	10-100-200-400-1000
Diethyl phthalate	10-100-200-400-1000
Dimethyl phthalate	10-100-200-400-1000
Polycyclic Aromatic Hydrocarbons (PAH)	
Benzo(b)fluoranthene	10-100-200-400-1000
Acenaphthylene	10-100-200-400-1000
Benzo(a)anthracene	10-100-200-400-1000
Benzo(g,h,i)perylene	20-200-400-800-1000
Chrysene	10-100-200-400-1000
Fluoranthene	10-100-200-400-1000
Indeno(1,2,3-cd)pyrene	20-200-400-800-1000
Phenanthrene	10-100-200-400-1000
Acenaphthene	10-100-200-400-1000
Anthracene	10-100-200-400-1000
Benzo(a)pyrene	10-100-200-400-1000
Benzo(k)fluoranthene	20-200-400-800-1000
Dibenzo(a,h)anthracene	20-200-400-800-1000
Fluorene	10-100-200-400-1000
Naphthalene	10-100-200-400-1000
Pyrene	10-100-200-400-1000

Table 7c. Organic Detection Limits for Cyathura

Cyathura polita

Analyte	Detection Limits Listed
Pesticides and PCBs	
Aldrin	10-100-130-200-400-1000
a-BHC	10-100-130-200-400-1000
Atrazine	20-200-260-400-800-2000
b-BHC	10-100-130-200-400-1000
g-BHC	10-100-130-200-400-1000
Chlordane	100-1000-1300-2000-4000-10000
4,4'-DDD	10-100-130-200-400-1000
4,4'-DDE	10-100-130-200-400-1000
4,4'-DDT	10-100-130-200-400-1000
Diazinon	20-130-200-260-400-800-2000
Dieldrin	10-100-130-200-400-1000
Endrin	10-100-130-200-400-1000
Ethyl Parathion	20-200-260-400-800-1000
Heptachlor	10-200-260-400-800-2000
Heptachlor Epoxide	10-100-130-200-400-1000
Linuron	20-200-260-400-800-1000
Malathion	20-200-260-400-800-1000
Methyl Parathion	20-200-260-400-800-1000
Toxaphene	100-1000-1300-2000-4000-10000
Trifluraline	20-200-260-400-800-1000
PCB's (Total)	100-1000-5000-10000-13000-20000-40000
Phthalate Esters	
Butyl Benzyl phthalate	100-1000-2000-4000-5000
Di-n-octyl phthalate	100-1000-2000-4000-5000
Bis (2-ethylhexyl) phthalate	1000-5000-20000-40000
Di-n-butylphthalate	100-1000-2000-4000-5000
Diethyl phthalate	100-1000-2000-4000-5000
Dimethyl phthalate	100-1000-2000-4000-5000
Poly. Arom. Hydro. (PAH)	
Benzo(b)fluoranthene	100-1000-2000-4000-5000
Acenaphthylene	100-1000-2000-4000-5000
Benzo(a)anthracene	100-1000-2000-4000-5000
Benzo(g,h,i)perylene	200-1000-2000-4000-5000-8000
Chrysene	100-1000-2000-4000-5000
Fluoranthene	100-1000-2000-4000-5000
Indeno(1,2,3-cd)pyrene	200-1000-2000-4000-5000-8000
Phenanthrene	100-1000-2000-4000-5000
Acenaphthene	100-1000-2000-4000-5000
Anthracene	100-1000-2000-4000-5000
Benzo(a)pyrene	100-1000-2000-4000-5000
Benzo(k)fluoranthene	200-1000-2000-4000-5000
Dibenzo(a,h)anthracene	200-1000-2000-4000-5000-8000
Fluorene	100-1000-2000-4000-5000
Naphthalene	100-1000-2000-4000-5000
Pyrene	100-1000-2000-4000-5000

Table 7d. Organic Detection Limits for White Perch

White Perch

Analyte	Detection Limits Listed
Pesticides and PCBs	
Aldrin	0.2-1-10-12-15
a-BHC	0.2-1-10-12-15
Atrazine	0.4-2-20-24-30
b-BHC	0.2-1-10-12-15
g-BHC	0.2-1-10-12-15
chlordane	2-10-100-120-150
4,4'-DDD	0.2-1-10-12-15
4,4'-DDE	0.2-1-10-12-15
4,4'-DDT	0.2-1-10-12-15
Diazinon	0.4-2-20-24-30
Dieldrin	0.2-1-10-12-15
Endrin	0.2-1-10-12-15
Ethyl Parathion	0.4-2-20-24-30
Heptachlor	0.2-1-10-12-15
Heptachlor Epoxide	0.2-1-10-12-15
Linuron	0.4-2-20-24-30
Malathion	0.4-2-20-24-30
Methyl Parathion	0.4-2-20-24-30
Toxaphene	2-10-100-120-150
Trifluraline	0.4-2-20-24-30
PCB's (Total)	20-100-1000-1200-1500
Phthalate Esters	
Butyl Benzyl phthalate	1-2-100
Di-n-octyl phthalate	1-2-100
Bis (2-ethylhexyl) phthalate	10-20-1000
Di-n-butylphthalate	1-2-100
Diethyl phthalate	1-2-100
Dimethyl phthalate	1-2-100
Polycyclic Aromatic Hydrocarbons (PAH)	
Benzo(b)fluoranthene	1-2-100
Acenaphthylene	1-2-100
Benzo(a)anthracene	1-2-100
Benzo(g,h,i)perylene	2-4-200
Chrysene	1-2-100
Fluoranthene	1-2-100
Indeno(1,2,3-cd)pyrene	2-4-200
Phenanthrene	1-2-100
Acenaphthene	1-2-100
Anthracene	1-2-100
Benzo(a)pyrene	1-2-100
Benzo(k)fluoranthene	2-4-200
Dibenzo(a,h)anthracene	2-4-200
Fluorene	1-2-100
Naphthalene	1-2-100
Pyrene	1-2-100

Table 7e. Organic Detection Limits for Yellow Perch

Yellow Perch

Analyte	Detection Limits Listed
Pesticides and PCBs	
Aldrin	0.1-0.2-1
a-BHC	0.1-0.2-1
Atrazine	0.2-0.4-2
b-BHC	0.1-0.2-1
g-BHC	0.1-0.2-1
chlordane	1 2 10
4,4'-DDD	0.1-0.2-1
4,4'-DDE	0.1-0.2-1
4,4'-DDT	0.1-0.2-1
Diazinon	0.2-0.4-2
Dieldrin	0.1-0.2-1
Endrin	0.1-0.2-1
Ethyl Parathion	0.2-0.4-2
Heptachlor	0.1-0.2-1
Heptachlor Epoxide	0.1-0.2-1
Linuron	0.2-0.4-2
Malathion	0.2-0.4-2
Methyl Parathion	0.2-0.4-2
Toxaphene	1 2 10
Trifluraline	0.2-0.4-2
PCB's (Total)	10-20-100
Phthalate Esters	
Butyl Benzyl phthalate	1 - 2
Di-n-octyl phthalate	1 - 2
Bis (2-ethylhexyl) phthalate	10 - 20
Di-n-butylphthalate	1 - 2
Diethyl phthalate	1 - 2
Dimethyl phthalate	1 - 2
Polycyclic Aromatic Hydrocarbons (PAH)	
Benzo(b)fluoranthene	1 - 2
Acenaphthylene	1 - 2
Benzo(a)anthracene	1 - 2
Benzo(g,h,i)perylene	2 - 4
Chrysene	1 - 2
Fluoranthene	1 - 2
Indeno(1,2,3-cd)pyrene	2 - 4
Phenanthrene	1 - 2
Acenaphthene	1 - 2
Anthracene	1 - 2
Benzo(a)pyrene	1 - 2
Benzo(k)fluoranthene	2 - 4
Dibenzo(a,h)anthracene	2 - 4
Fluorene	1 - 2
Naphthalene	1 - 2
Pyrene	1 - 2

Table 8. Organic Contaminants in HMI Year Nine Biota Samples

Sample	Species	Station	Bis-2-E	Chlordane	4,4' DDT	4,4' DDE	4,4' DDD
890887	*Macoma*	HM 16-2	**320**	nd	nd	nd	nd
900181	*Rangia*	S 1-1	nd	nd	nd	nd	nd
900182	*Rangia*	HM 9-1	nd	nd	nd	nd	nd
900183	*Rangia*	HM 22-1	nd	nd	nd	nd	nd
900184	W. Perch	HMIT 1-1	nd	**509**	nd	**40**	**40**
900186	W. Perch	HMIT 2-1	nd	**156**	nd	**49**	nd
900188	W. Perch	HMIT 3-1	nd	**254**	nd	nd	nd
900190	W. Perch	HMIT 4-1	nd	**243**	**52**	**15**	**86**
900185	Y. Perch	HMIT 1-2	nd	nd	nd	nd	nd
900187	Y. Perch	HMIT 2-2	nd	**48**	nd	nd	nd
900189	Y. Perch	HMIT 3-2	nd	nd	nd	**10**	nd
900191	Y. Perch	HMIT 4-2	nd	nd	nd	**23**	nd

References

Chapman, P. M., Dexter, R. N., & Long, E. R. (1987). Synoptic measures of sediment contamination, toxicity and infaunal community composition (the Sediment Quality Triad) in San Francisco Bay. 37, 75-96.

Garreis, M. J., & Murphy, D. (1986). Intensive survey for chlordane contamination in finfish in Lake Roland, Back River and Patapsco River . State of Maryland, Water Management Administration, Department of Health and Mental Hygiene.

Maryland Department of Natural Resources. (1990). Assessment of the environmental impacts of the Hart-Miller Island Containment Facility. Eighth Annual Interpretive Report .

Misra, R. K., & Uthe, J. F. (1987). Methods of time trends analysis applied to contaminant levels in Canadian Atlantic cod (Gadus morhua). 44, 1987.

Murphy, D. L. (1990). Contaminant levels in oysters and clams from the Chesapeake Bay: 1981-1985 (102). Maryland Department of the Environment, Water Management Administration.

NOAA (1987). National Status and Trends Program for Marine Environmental Quality. Progress Report. A summary of selected data on chemical contaminants in tissues collected during 1984, 1985 and 1986. NOAA Technical Memorandum NOS OMA 38.

Popham, J. D., & D'Auria, J. M. (1983). Combined effect of body size, season, and location on trace element levels in mussels (Mytilus edulis). 12, 1-14.

Roesijadi, G., & Crecelius, E. A. (1984). Elemental composition of the hydrothermal vent clam Calyptogena magnifica from the East Pacific Rise. Marine Biology, 83, 155-161.

Schmitt, C. J., Zajicek, J. L., & Ribick, M. A. (1985). National pesticide monitoring program: Residues of organochlorine chemicals in freshwater fish, 1980-1981. Archives of Environmental Contamination and Toxicology, 14, 225-260.

Wright, D. A., Foster, G. D., & Whitlow, S. I. (1986). Chesapeake Bay-Water Quality Monitoring Program: Toxic Chemicals and Bioaccumulation Component (UMCEES[CBL] 86-135). University of Maryland Center for Environmental and Estuarine Studies Chesapeake Biological Laboratory.

APPENDIX A

QNS = Quantity NOT sufficient

Sample	Species	Station	Chromium	Iron	Manganese	Copper	Nickel	Zinc	Note
900172	*Rangia*	G 25-1	<1	43	4.3	<1	<4	15	
900741	*Rangia*	G 25-1	0.8	140	35	2.4	13	28	
890895	*Rangia*	G 25-1	<1	27	4	2	6	468	
900176	*Rangia*	G 84-1	<1	240	49	<1	4	22	
900732	*Rangia*	HM 12-1	<0.4	60	13	<0.5	<0.4	3.4	
900174	*Rangia*	HM 12-2-1	<1	52	5.9	<1	<4	17	
900182	*Rangia*	HM 9-1	<1	32	3.4	<1	<6	17	
890886	*Rangia*	HM 16-1		258	40	2	8	23	
900722	*Rangia*	HM 16-1	<0.5	150	38	2.9	5	17	
890903	*Rangia*	HM 22-1	<1	42	9.7	1.8	9.7	24	
900183	*Rangia*	HM 22-1	<1	310	55	<1	6	22	
900735	*Rangia*	HM 22-1	<0.5	200	28	2	6.8	15	
890902	*Rangia*	S 1-1	1.7	39	2.5	2.5	4.2	25	
900181	*Rangia*	S 1-1	<1	28	5.4	<1	8	21	
900736	*Rangia*	S 1-1	<0.5	180	27	3	3.8	18	
890892	*Rangia*	S 4-1	2.9	35	<3	<1	2.9	28	
890889	*Rangia*	S 6-1	19	11800	670	14	19	78	
900170	*Rangia*	S 6-1	<1	230	33	<1	6	45	
900728	*Macoma*	G 5-1	22	280	200	14	<0.4	16	
900751	*Macoma*	G 5-3	~~0.8~~	~~140~~	~~35~~	~~2.4~~	~~13~~	~~28~~	ERROR; QNS
890896	*Macoma*	G 25-2	<6	1080	130	11	<11	83	
900177	*Macoma*	G 84-2	<3	1300	130	3	<11	87	
900733	*Macoma*	G 84 A-1	2.5	95	140	21	1	34	
900175	*Macoma*	HM 12-2-2	<2	1300	130	7	<8	170	
900169	*Macoma*	HM 16-1	<2	620	81	6	<8	110	QNS
890887	*Macoma*	HM 16-2	4.2	1900	200	10	<4	92	
900723	*Macoma*	HM 16-2	45	260	170	14	1.1	14	
900730	*Macoma*	S 4-1	32	170	190	8.7	0.8	9.8	QNS
890893	*Macoma*	S 4-2	<4	689	250	11	<7	46	
900725	*Macoma*	S 6-1	3.4	670	3000	22	2.4	48	QNS
890890	*Macoma*	S 6-2	9.1	360	150	14	<9	36	
900727	*Macoma*	S 6-3	29	540	180	20	<3	24	QNS
900729	*Cyathura*	G 5-2	8.9	160	190	43	2	440	
900173	*Cyathura*	G 25-2	<8	350	180	11	<40	110	QNS
900178	*Cyathura*	G 84-3	<8	570	410	41	<40	120	
900734	*Cyathura*	G 84 A-2	<1	320	51	2.6	8.2	32	
890888	*Cyathura*	HM 16-3	<4	200	150	14	<7	57	
900724	*Cyathura*	HM 16-3	<2	160	190	33	<2	41	
900179	*Cyathura*	S 4-1	<8	320	290	24	<40	71	
900731	*Cyathura*	S 4-2	7.5	150	190	28	<2	29	
890894	*Cyathura*	S 4-3	<4	412	300	35	<8	88	
900171	*Cyathura*	S 6-2	<6	830	1200	39	<28	58	
900726	*Cyathura*	S 6-2	4.5	550	660	66	<3	70	
890891	*Cyathura*	S 6-3	10	270	140	45	<10	110	
890897	*Rithro.*	S 2-1	3.6	271	614	29	<4	23	
900180	*Rithro.*	S 2-1	<5	640	1100	26	<25	27	

2453

Sample	Species	Station	Chromium	Iron	Manganese	Copper	Nickel	Zinc
890898	W. Perch	HMIT 1-1 X1F5727	3.9	17	26	2	<2	40
900184	W. Perch	HMIT 1-1 X1F5727	<1	5.5	0.66	<1	<3	15
900737	W. Perch	HMIT 1-1 X1F5727	<1	6.4	<1	<1	<0.9	7
890900	W. Perch	HMIT 2-1 X165704	1.8	7.3	3.6	<1	<2	19
900186	W. Perch	HMIT 2-1	<1	8.2	0.14	<1	<3	13
900738	W. Perch	HMIT 2-1 X165704	5	8.3	1	<1	1.1	17
900188	W. Perch	HMIT 3-1 X1F2743	<1	6.3	0.12	<1	<3	18
900739	W. Perch	HMIT 3-1 X1F4516	3.8	9.3	16	<0.9	1.6	16
890905	W. Perch	HMIT 4-1 X1F2743	2.9	15	14	1.9	<2	33
900190	W. Perch	HMIT 4-1 X1F2743	<1	7.1	1.6	<1	<4	22
900740	W. Perch	HMIT 4-1 X1F2743	1.5	5.6	10	<1	1.2	11
890899	Y. Perch	HMIT 1-2 X1F5727	3.4	14	17	1.7	<2	20
900185	Y. Perch	HMIT 1-2 X1F5727	<1	4.9	0.4	<1	<3	14
890901	Y. Perch	HMIT 2-2	2.6	12	32	1.3	<1	19
900187	Y. Perch	HMIT 2-2	<1	3.6	0.53	<1	<3	11
890904	Y. Perch	HMIT 3-1	4.3	12	49	1.9	<1	25
900189	Y. Perch	HMIT 3-2	<1	14	0.62	<1	<4	15
890906	Y. Perch	HMIT 4-2	3.4	14	25	<1	<2	26
900191	Y. Perch	HMIT 4-2	<1	6.9	1.4	<1	<4	11

98 records

Yellow Perch – P. flavescens

NOTE 900751 Macoma G5-3 does not match with data report page 372, Electronic file is the same as data report page 372

2004 – 2009 } Cut 1709

The facilities and services of the Department of Natural Resources are available to all without regard to race, color, religion, sex, age, national origin, physical or mental disability.

recycled paper