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

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MARYLAND WATER RESOURCES ADMINISTRATION

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BY
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TIDEWATER ADMINISTRATION

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FOREWORD

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

Torrey C. Brown
Secretary
Department of Natural
Resources

ACKNOWLEDGMENTS

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

EXECUTIVE SUMMARY

The Hart-Miller Island Containment Facility was designed to receive material from channel dredging projects in Baltimore Harbor and its approaches. The disposal site is located northeast of the Baltimore Harbor in the Chesapeake Bay. This report contains the results of the eighth year of monitoring to assess the impacts on the biological and sedimentary environments exterior to the dike. As in previous years, samples of sediments and the benthic population were taken at a number of sites in the vicinity of Hart and Miller Islands during Fall 1988 and Spring 1989. A beach erosion study, initiated in the spring of 1984, was continued. Data collected from the previous seven years of monitoring indicated that there had been no significant impacts to the environment.

An increase in the zinc enrichment factor for sediments was detected during this monitoring period and probably indicated an impact related to the discharge of effluent from the facility. The monitoring program for the NPDES Discharge Permit (permit # 86-DP-2294) did not show any quantities of zinc in violation of the discharge permit. No significant impacts were detected on the benthic environment related to this increase in zinc concentration. During this monitoring year, none of the benthic stations were located in the area of zinc enrichment. Stations were added during the ninth year of monitoring to determine if the zinc enrichment impacted the benthic species. The monitoring program was modified to further assess this potential source of impact to the environment.

Sedimentary Environment

During the eighth monitoring year, Zn levels increased significantly in bottom sediments near spillway #1. (No associated changes were detected in the physical properties of the sediments.) The probable source of Zn enrichment 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 this year. Theoretically, the stations showing Zn enrichment should only be affected by low flows (< 5 mgd) from the dike; at higher discharge rates, the effluent bypasses the stations in the established sampling scheme. Not till after November 1988 did discharge rates consistently fall below 5 mgd. Zn enrichment was first observed following the April 1989 cruise. Several factors influence the distribution of anthropogenic Zn in bottom sediments around Hart-Miller Island:

1. the nature of the material being released,
2. the flow and dissipation of water discharged from the dike,
3. biological activity.

Beach Erosion Study

Wind-induced waves, in combination with high tides, were responsible for most of the erosion to the foreshore and nearshore of the recreational beach. Waves assaulting the beach created erosional escarpments. Sheetwash erosion, though greatly reduced from past years by upper dike stabilization, occurred in certain areas due to the increase in the slope of the reconstructed beach. Gullies formed below the snow fence almost immediately after reconstruction, also as a result of the increase in slope.

The volume of eroded sediment was much less than in previous years due to stabilization of the beach. Between June 1984 and June 1988, approximately 11,000 yd^3 (8410 m^3) of sediment were removed from the beach above the 0 ft contour. Approximately 600 yd^3 (459 m^3) of sediment above 0 ft MLW and 900 yd^3 (688 m^3) below 0 ft MLW were eroded during the period September 1988 to May 1989. Erosion in the foreshore decreased on all profiles except 30+00 and 32+00. Gully erosion was slight compared to past monitoring periods.

Benthic Study

The results of the eighth year benthic study are quite similar to those presented in the reports of the last three years (5th, 6th, and 7th). A total of 31 species (compared with 35, 30 and 26 for the 7th, 6th and 5th years, respectively) were collected in the quantitative grab samples. Again six species remain numerically dominant on soft bottoms: the annelids, *Scolipedies viridis*, *H. filiformis*, and *Tubificoides*; the crustaceans, *Leptocheirus plumulosus* and *Cyathura polita*; and the clam, *Rangia cuneata*. On oyster shell substrates, the barnacle *Balanus improvisus*, the worm *Neris succinea*, and the crab *Rithranopeus harrisi*, were the most common inhabitants. Some of the five most abundant soft bottom species were occasionally dominant on this substrate as well. Salinity variations on yearly and seasonal time scales appear to determine the position of dominance of the major species.

The average number of individuals per square meter was comparable for the nearfield and reference stations over the three sampling periods. Pfitzenmeyer and Tenore (1987) reported a somewhat greater number of individuals at the nearfield then the reference stations for the fifth monitoring year, which they attributed to an abundance of finer sediments close to the dike. However, the total numbers observed during the eighth year were similar to those observed during sixth and seventh year monitoring.

The highest average species diversity values this year were found in December rather than in August as had been the rule the previous two years. The lowest diversity values were in April 1989. This sample period was the same time the Zn enrichment levels were first observed to increase. They were substantially lower than we had observed in previous years which may account for the persistent low values in August 1989.

Length frequencies and cohort sizes of the clam, *R. cuneata*, and the other two common bivalves, *M. balthica* and *M. mitchelli* living close to the containment facility were comparable to populations at the reference stations. This year, there appeared to be a set and grow up of these three bivalves over the present sampling study, however, there still appears to be a general overall decline in population size of all three species from the high values reported in August 1987. The decline appeared at both the nearfield and reference stations and may be a result of less favorable salinities in the region.

Cluster analysis grouped stations of similar faunal composition in response to sediment type and general location within the Hart-Miller Island study area. Epifaunal species were similarly in terms of distributed at the nearfield and reference stations for all three sampling periods. At present, there appear to be no any discernible differences in the nearfield and reference populations resulting directly from operation of the containment facility itself. 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.

<u>Analytic Services (contaminant studies)</u>

Since 1981, metals and organic chemicals have been analyzed in sediments and biota as part of the Hart-Miller Island Containment Facility Environmental Assessment 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 (Year 8; November 1988-August 1989), 99 samples of sediment and biota were collected to determine the concentrations of 43 individual trace organic contaminant compounds in fish, benthos, and sediment. Biological samples (fish, benthos) were also analyzed for concentrations of six metals: chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), and zinc (Zn).

The only organic constituents that were found above detection limits in biota were chlordane, total polychlorinated biphenyls (PCBs), bis (2-ethylhexyl) phthalate (DEHP), and di-n-butyl phthalate. PCBs in one sample of Rangia were at the FDA action level of 2.0 mg/kg, which is used in this report as a guidance level for impact assessment. No fish samples contained PCBs at or above 2.0 mg/kg. None of the benthic species contained chlordane at or above the FDA action level of 0.3 mg/kg. Three samples of white perch contained chlordane at 0.3 mg/kg.

One sample of Rangia (HM22 from August 1989) contained unusually high levels of copper (940 mg/kg), iron (12,300 mg/kg), and nickel (1830 mg/kg). A sample of Macoma (S6 from August 1989) contained an extremely high level of zinc (1290 mg/kg). The causes for these extremely high measurements are unknown and sampling or laboratory contamination cannot be ruled out. No other samples contained abnormally high metal concentrations. Contaminant concentrations in benthos collected from reference and site stations were similar as were concentrations in fish collected adjacent to and removed from the facility.

Analysis of variance was performed on ranked values as a nonparametric test to determine if inter-station or inter-year differences were statistically significant. There were no significant differences in concentrations between stations in year 7 or year 8. Analysis of trends using pooled data from all stations, indicated that for some chemicals and species there were significant differences among years. In all cases where changes were monotonic, the apparent trend was of decreasing concentrations between years 1 and 2 (or if year 1 and 2 were not available, year 6) and years 7 and 8. No significant differences between years were observed for zinc with any species. PCB and chlordane concentrations in Macoma appear to have decreased during the monitoring program. Concentrations of PCBs, chromium, copper, and nickel in Cyathura and concentrations of chromium and copper in Rangia also appear to have decreased. Copper levels in white perch and copper and chromium levels in white perch and spot also appear to be decreasing but, since these are mobile species, they are more likely to be indicators of regional rather than local conditions.

The sediment samples collected during the eighth monitoring year only revealed one sample with any organic analyte (bis (2-ethylhexyl) phthalate) above the detection limits. The analysis of metals in sediment is contained in the Project II -- Sedimentary Environment Section of this report.

RECOMMENDATIONS

Sedimentary Environment

Expand the monitoring program to include the area affected by high flow conditions at spillway #1. Coordinate the selection of sites so that sediments, biota, and samples tested for organic contaminants are all collected from the same locations.

Run the 3-D hydrodynamic model. Model runs are needed to gain a better understanding of the fate of the material released from the dike. To ascertain which areas are likely to be affected by discharging from each of the active spillways, several runs, varying volume of effluent released and Susquehanna flow, are needed. If necessary, further adjustments in the sampling scheme should be made in accordance with that information.

Authorize MES to analyze the effluent for Zn on a weekly rather than quarterly basis, so that mass balances can be performed and the 3-D influence of the releases can be estimated.

Consider including sediment bioassay work in the scope of exterior monitoring. To date it is impossible to relate sediment loadings to effects in the biota at sub-lethal levels. MGS data are providing 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.

Beach Erosion

Although the upper dike face has been stabilized, the strip of beach below the snow fence is still subject to erosion, particularly by wave attack. Vegetating the area immediately downslope of the snow fence would reduce sheetwash erosion. With a reduction in the erosion of sediment from the upper and lower dike face, material lost from the foreshore and nearshore will not be replenished, and shoreline erosion will accelerate. To alleviate this situation, sand replenishment and/or the installation of an offshore breakwater may be necessary. Yearly renourishment of the foreshore and immediate nearshore would also reduce the beach slope, thereby deterring sheetwash erosion and creating an aesthetically-pleasing beach.

Benthic Studies

It is strongly recommended that the infaunal and epifaunal populations continue to be sampled at the established locations during this continued critical period of maximal operation to ascertain any possible future effects from the operation of the facility. Station locations and sampling techniques should be maintained as close as possible to the last few years to eliminate sampling variation and permit rapid recognition of effects resulting from the operation and existence of the containment facility. It is also recommended that additional stations be established and to assess the effects of effluent discharge. Effluent appears to travel beyond the area currently being monitored.

Analytic Services

The following recommendations are suggested as possible ways to improve the program:

- Identify possible problems with organic detection limits and determine if adequate sample sizes are being provided.

- Reevaluate the sampling locations. Since statistical analysis of years 7 and 8, indicated no significant differences between stations, it may be useful to sample a fewer number of stations more intensively. Establishment of additional benthic stations farther removed from the facility should be considered in order to guarantee that at least one reference station is well-removed from possible influences of the facility.

- Reevaluate the metals chosen for tissue analysis. It may be useful to replace iron and manganese with cadmium, lead, and mercury, which are included on the Chesapeake Bay Program's list of toxics of concern (Alliance for the Chesapeake Bay 1991).

- Consider selecting a smaller number of species as targets for analysis. Analyzing a single mud crab every few years will provide little useful information. Analytical funds would be better spent on sampling fewer species more intensively.

- Reevaluate the purpose of the fish monitoring data. If a non-mobile species (e.g., mummichog) cannot be collected, then it may be more useful to terminate the fish monitoring program and spend the resources on further benthic analyses. If the fish monitoring is continued, it would be useful to coordinate procedures with the MDE Fish Tissue Network to make data comparable.

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DEFINITION OF TERMS

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

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

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

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

Biometrics - The statistical study of biological data.

Biota - The animal and plant life of a region.

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

Brackish - Salty, though less saline than sea water.

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

Diversity index - A statistical measure that incorporates information on the number of species present in a habitat with the abundance of each species. A low diversity index suggests that the habitat has been stressed or disturbed.

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

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

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

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

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

Flocculate - An agglomeration of particles bound by electrostatic forces.

Flocculent - Having a fluffy or wooly appearance.

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

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

Infauna - Benthic animals living in bottom material.

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

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

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

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

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

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

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

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

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

Spillway - A channel for an overflow of water.

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

Supernatant - The clear fluid over a sediment or precipitate.

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

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

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

INTRODUCTION

The Hart-Miller Island Containment Facility monitoring program was established to determine the effects of the facility on the surrounding environment. The program was launched in 1981 so that environmental data for pre-construction and pre-operational conditions could be compared with the data collected during operation of the facility. The *Eighth Annual Interpretive Report* presents the results of the environmental monitoring of the Hart-Miller Island Containment Facility from August 1988 through August 1989.

DESCRIPTION OF THE CONTAINMENT FACILITY

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

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

DREDGED MATERIAL DISPOSAL

The breakdown of dredged material received is listed by project in Table 1. The material dredged in 1983 and 1984 was composed of mostly 42' channel maintenance (3.9 mcy) and facility maintenance (188,000 ft^3). One additional project was deposited in the facility in 1984, Dundalk Marine Terminal (500,000).

Material dredged in 1985 totaling of 3.7 mcy was deposited into the North Cell. Of the 7.5 mcy of dredged material disposed in 1986, 3.7 mcy was deposited into the North Cell and 3.8 mcy was deposited into the South Cell. The disposed volumes shown in the table for 1985 represent the entire 1985 and

TABLE 1

DISPOSAL 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' Channel Maintenance and Brewerton Eastern Extension	3,908,000
	TOTAL 1984	4,596,000
1985	42' Channel Maintenance	3,145,000
1985	Bethlehem Steel	596,000
	TOTAL 1985	3,741,000

TABLE 1 (cont.)

1986	42' Channel Maintenance	7,000,000
1986	Eastern Avenue Bridge	18,000
1986	Canton-Seagirt	500,000
1986	South Locust Point	185,000
1986	Hess Oil	7,200
1986	Bethlehem Steel Ore Pier	5,250
1986	Rukert Terminal	166,632
	TOTAL 1986	7,731,082
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	125,000
	Brewerton, Swann Point	
	Total 1988	8,342,724
1989	50' 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
	Grand Total* (cubic yards)	44,144,200

* through December 31, 1989

1986 dredging seasons (April 1985 through September 1985 and June 1986 through January 1987, respectively).

The major 1986 dredging task was to remove material from the main shipping channel to maintain a working depth of 42'. The other projects listed for that year were mainly to remove dredged material allowing shipping companies to make better use of the 42' deep channel. Since the beginning of the project to deepen the channel to 50', shipping companies have been dredging their access channels deeper to make better use of the 50' channel depth. The 50' contract #1 represents the first of two contracts to increase the Maryland shipping channel to a depth of 50'. The addition of the dredged material from these projects produced sufficient quantity of supernatant to 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 disposal 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 ft^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' channel project. The first contract of the 50' channel project totaled 9.9 mcy and 54,000 ft^3 of material that was used to relocate utilities related to the 50' channel.

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

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

SUMMARY OF MONITORING PROGRAMS

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

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

PROJECT I: SCIENTIFIC COORDINATION AND DATA MANAGEMENT

The Tidewater Administration, Power Plant and Environmental Review Division (PPER) is responsible for maintaining a database on the exterior monitoring program. Data stored include fish, benthos, water quality, climate, sediments and hydrography. It is also responsible for conducting applied scientific investigations necessary for developing information for management purposes. The compilation, data input, and long-term storage of all data related to the exterior monitoring effort are included in these responsibilities.

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

The Tidewater Administration provides overall scientific planning, review and coordination of the exterior monitoring activities for the Hart-Miller Island Facility, as well as compiling and distributing the annual Interpretive and Data Reports. This also includes the 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 has been involved in monitoring the physical and chemical behavior of the sediments around the Hart-Miller Containment Facility since 1981. This work has been conducted in two parts: sedimentary environment study and beach erosion study.

Monitoring and documentation of the sedimentary environment are necessary to detect any changes which may occur as a result of the operation of the containment facility. Currently, highly organic, fine-grained sediments from the approach channels to Baltimore Harbor are being placed inside the dike. Improper handling or leakage of these dredged materials from the dike may produce changes in sand to mud ratios and the physical appearance of the surrounding sediments, as well as increase the levels of trace metals and organic contaminants. In seven years of monitoring, no major changes were detected within the sedimentary environment as a result of construction or operation of the facility. However, monitoring did reveal a fluid mud layer that was deposited during dike construction. This fluid mud layer was described in earlier exterior monitoring reports. Current monitoring has revealed an increase in the concentration of zinc in sediment exterior to the facility. The collected data for the NPDES Discharge Permit did not show any concentrations of zinc in violation of the State Permit (# 86-DP-2294). This increase in the concentration of zinc in the sediment can possibly be related to the operation of the facility, although no adverse impacts were detected on the benthic environment. The benthic stations during this monitoring year were not located in the area of zinc enrichment, this sampling pattern was modified in the ninth monitoring year.

Sediment samples are collected not only at various sites around the containment facility, but also at several reference sites outside the immediate area of the facility. These samples are put through a rigorous series of tests including organic contaminants (testing done under Project IV), trace metal, textural and radiographic analyses. Textural and trace metal data from the 1988-89 monitoring year indicate that no major changes occurred again this year, other than the increase in zinc enrichment.

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 disposal facility.

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

Since the beginning of the project in 1981, the dominant benthic species have remained relatively stable. Epifaunal populations on pilings have followed the same yearly pattern. During the winter, the populations living at the upper ends of the pilings are removed by ice scour and/or desiccation at low tide. In the spring, the populations are re-established by larval settlement and/or recolonization by mobile species. This year's results clearly indicate that the containment facility produces only localized and temporary effects on the benthos. These effects, primarily limited to the area near the rehandling pier and 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 then returned to the MES staff at Hart-Miller Island for transfer to Martel. Martel performed the chemical analysis.

This process reduced the time required for data analysis to as little as three months. Project III - Benthic Studies currently collects finfish and benthic material for organic and metals analysis. Project II - Sedimentary Environment provides sediment samples for organic analyses; the metals analysis is performed as a part of the sedimentary monitoring. The data analysis of the laboratory data revealed no significant impacts on the benthos.

PROJECT I

SCIENTIFIC COORDINATION AND DATA MANAGEMENT

EIGHTH YEAR INTERPRETIVE REPORT

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

Scientific planning, review and coordination of the monitoring activity is provided by Tidewater Administration. Sampling procedures, data analysis, and future directions of the program are discussed with the principal investigators at quarterly meetings of the Scientific Coordination Committee. Descriptions of any changes in sampling methods are included in the individual project reports that follow. Compilation, editing, technical review, and printing of the Interpretive and

Data Reports are the responsibilities of the Tidewater Administration. During the first seven years of the environmental assessment program, data collected by the Department of Natural Resources and research institutions were stored in the Tidewater Administration's "Resource Monitoring Data Storage System." The IBM-OS File/SAS Data Base is used for computer storage and analysis of data. The data are also stored on a VAX 8600 computer in a SAS file format. The Tidewater Administration staff assumes responsibility for the long-term storage of data related to the exterior monitoring program. Permanent storage of the data in a readily accessible form provides a continuous, documented record of baselines and trends in biota, sediments and contaminant levels. Data from the 1988-1989 monitoring year are included in the Eighth Year Data Report, which is compiled and printed separately from the Interpretive Report. The data is standardized using Resource Monitoring Data Storage (RMDSS) formats. The codes are documented in the manual to the Resource Monitoring System produced by the Tidewater Administration, Chesapeake Bay Research and Monitoring Division (Tidewater Admin., 1989).

The Scientific Coordination Committee meets quarterly with the principal investigators, Water Resources Administration (WRA), and Maryland Port Administration (MPA) to discuss issues related to the exterior monitoring program. Once a year the Scientific Coordination Committee meets in conjunction with the

Technical Review Committee to provide that committee with detailed information about the exterior monitoring program.

Conclusion and Recommendations

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

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

Project II

SEDIMENTARY ENVIRONMENT
EIGHTH YEAR INTERPRETIVE REPORT
(November 1988 - October 1989)

by
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ABSTRACT

Since 1981, the Coastal and Estuarine Geology Program of the Maryland Geological Survey (MGS) has participated in the State's environmental assessment of the Hart-Miller Island Dredged Material Containment Facility. The Program's staff monitors (1) the physical and chemical behavior of near-surface bottom sediments around the facility and (2) the erosional and depositional changes along the recreational beach between Hart and Miller Islands. The results of these two studies during the eighth year of monitoring are presented in this report.

For the first time since the facility began operating, a major change in the exterior sedimentary environment was detected. Zinc levels in samples collected near spillway #1 rose from the regional average enrichment factor of 3.2 to 5.5. Effluent released during normal operation of the dike was the probable source of zinc accumulating in the sediments. A flow net developed from preliminary results of a 3-D hydrodynamic model (Johnson, 1989) shows that the enriched area should only be affected by low flows from spillway #1 (<5 million gallons/day). Daily discharge records supplied by the Maryland Environmental Service (MES) indicate that, prior to the eighth monitoring year, 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 southeast of the spillway.

The recreational beach lost material again this year, despite stabilization of the upper dike face in August 1988 by recontouring and seeding. Erosion continued along the narrow, unvegetated strip of beach at the water's edge and immediately offshore. A total of 1514 yd^3 (1158 m^3) of material were lost from the lower dike face, foreshore, and nearshore between September 1988 and May 1989. Above 0 ft MLW, 600 yd^3 (459 m^3) were lost, in contrast to over 3000 yd^3 (2295 m^3) last year. Below 0 ft MLW, the volume lost increased slightly: 914 yd^3 (699 m^3) this year versus 773 yd^3 (591 m^3) last year.

Although reconstruction of the beach has slowed erosion, it has not stopped it. The lower dike face and foreshore are still subject to wave attack. Furthermore, stabilization of the upper dike face has reduced the influx of sediment to the lower dike face, foreshore, and nearshore. Additional erosion-control measures, particularly beach nourishment, are needed.

PART 1: SEDIMENTARY ENVIRONMENT

INTRODUCTION

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

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

PREVIOUS WORK

Changes in the sedimentary environment around the Hart-Miller Island Dredged Material Containment Facility were documented during the first seven years of the State's monitoring effort and are detailed in several reports (Kerhin et al., 1982a; Wells et al., 1984, 1985, 1986, 1987; Hennessee et al., 1989, in press). Knowledge of the physical characteristics and areal distribution of sediment types prior to the construction of the facility was based on data collected by the Maryland Geological Survey (MGS) in 1978 (Cuthbertson, 1987). The sediments graded from nearshore sand to sand-silt-clay to silty clay just northeast of the islands. On the Hawk Cove and southern sides of the complex, the sediment graded from nearshore sand to silty clay. The latter were described as dark gray mud with high water content. Live bivalves, *Rangia cuneata* and *Macoma balthica*, were common (Kerhin et al., 1982b).

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

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

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

The dike was completed in the spring of 1983. Until this year, monitoring revealed little additional change in sediment properties. The layer of fluid mud introduced during dike construction is still evident, although the upper 10 cm of the sediment column have been biogenically reworked. The color of the bioturbated sediment has reverted to the darker shades of gray typical of modern Bay mud. Enrichment factors have remained lower for the fluid mud accumulation, though they are gradually returning to the regional average. In areas beyond the blanket of fluid mud, enrichment factors for Zn remained consistent with pre-construction values, until April 1989.

OBJECTIVES

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

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

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

METHODOLOGY

FIELD METHODS

Surficial sediment (grab) samples were collected twice during the eighth monitoring year, on November 15, 1988, and on April 3, 1989. Thirty-five stations were occupied during the fall cruise (fig. 1-1). A new station (29) was added to monitor the effects of discharging from newly constructed spillway no. 5. Grab samples were also retrieved at all of the box core (BC) locations. In the spring, grab samples were collected at thirty stations.

Sampling sites, shown in Figure 1-1, were located in the field by means of the LORAN-C navigational system. (LORAN-C coordinates, latitude, and longitude of each station may be found in the *Eighth Year Data Report.*) The repeatability of LORAN-C navigation, that is, the ability to return to a location at which a navigation fix has previously been obtained, is affected primarily by seasonal and weather-related changes along the signal transmission path. Data recorded in 1982 from the U.S. Coast Guard Harbor Monitor at Yorktown, Virginia, provide an approximate range of repeatable error. That year, variations in the X-lines amounted to 0.256 units and, in the Y-lines, 0.521 units. In the central Chesapeake Bay, one X-TD unit equals approximately 285 m (312 yd) and one Y-TD unit, 156 m (171 yd). Thus, when a vessel reoccupies an established station in the Bay region, it should be within about 100 m (109 yd) of its original location (Halka, 1987).

Undisturbed samples of the upper 8-10 cm of the sediments were retrieved with a dip-galvanized Peterson sampler. At least one grab sample was collected at each station and subsampled for textural and trace metal analyses. At eight stations (3, 19, 21B, 23, 24, 28, BC-3, and BC-6), a second grab sample was taken for organic contaminant analysis. Triplicate grab samples were collected at three stations (11, 12, and 24) in November 1988 and at two stations (11 and 24) in April 1989.

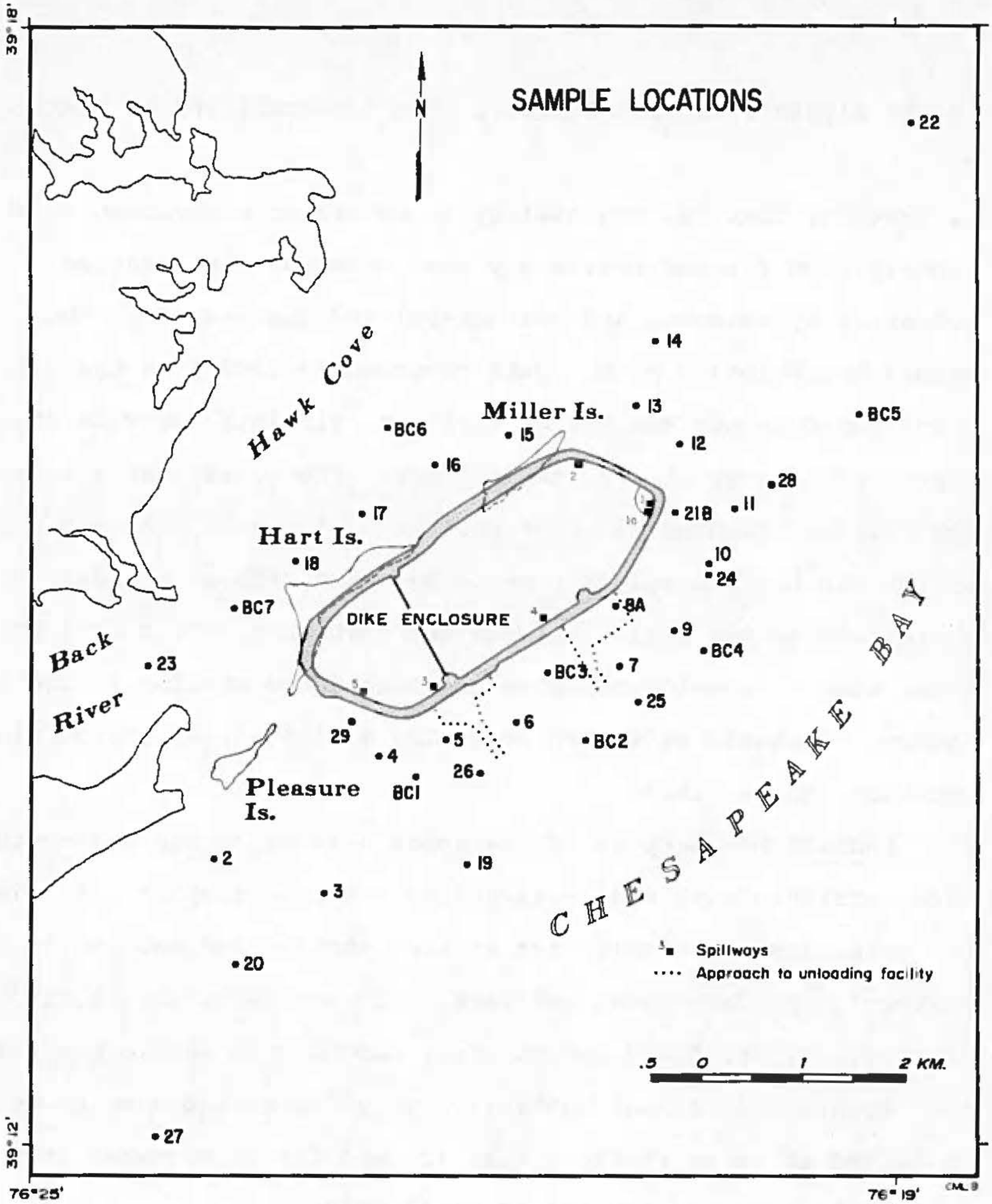


Figure 1-1: The Hart-Miller Island Dredged Material Containment Facility and vicinity, with locations of the surficial sediment and core stations sampled during the eighth year of exterior monitoring.

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

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

During the April cruise, 12 gravity cores were collected with a Benthos gravity corer (Model #2171) fitted with clean cellulose acetate butyrate liners, 6.7 cm in diameter. One core was collected at each of the seven box core (BC) stations and at station 12. Four additional cores were taken within 34 to 77 m (37 to 84 yd) of station 12 in order to assess the spatial and temporal variability in grain size composition around that site. A gravity core is usually taken at station 21B. This year, however, several attempts at retrieving a core there were unsuccessful - the sandy bottom was impenetrable. 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 mA, 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. Lower density objects (e.g., burrows, gas bubbles) permit easier penetration of x-rays and, therefore, appear as darker features. Reproductions of the xeroradiographs appear in Appendix A.

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

Textural Analysis

In the laboratory, subsamples from both the surficial grabs and gravity cores were analyzed for 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:

$$Wc = \frac{Ww}{Wt} \times 100, \qquad (1)$$

where Wc = water content (%),
Ww = weight of water (g), and
Wt = weight of wet sediment (g).

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

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

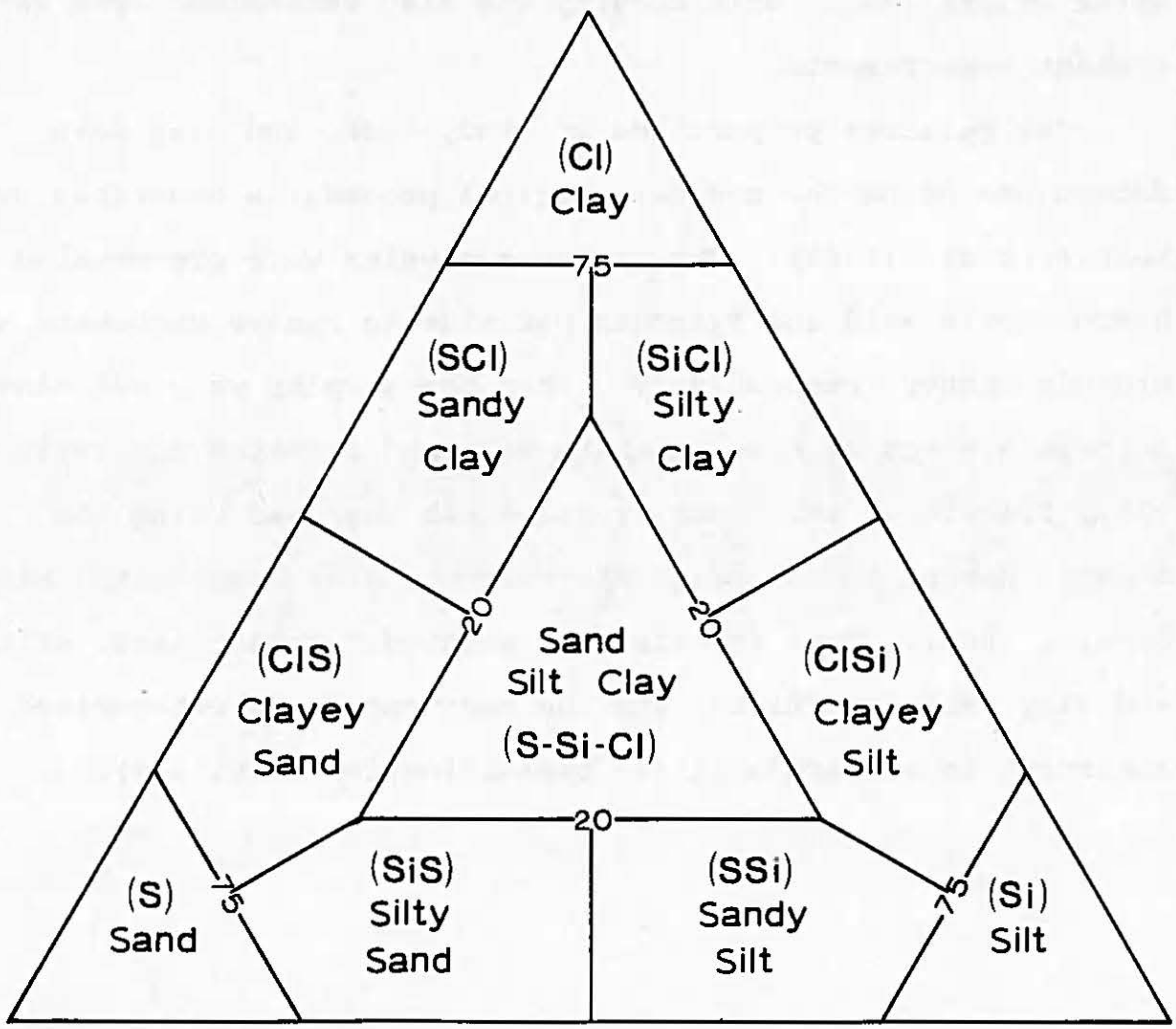


Figure 1-2: Shepard's (1954) classification of sediment type.

Organic plus carbonate content was approximated by the percent weight loss due to sample preparation (i.e., pre-treatment with acid and peroxide).

Trace Metal Analysis

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

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

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

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

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

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

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

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

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

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

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

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

Results of the analysis of NBS-SRM #1646 are compared to NBS certified values in Table 1-1. There is excellent agreement between the NBS certified concentrations and MGS's analytical results for Cr, Cu, Mn, and Ni; all of these elements fall within

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

Element analyzed	NBS certified concentrations*	MGS results November 1988 surficials	April 1989 surficials	April 1989 cores
Cr	76±3	78±3	79±1	79±1
Cu	18±3	20±1	17±1	17±1
Fe	3.35±0.10%	3.33±0.03%	3.16±0.02%	3.16±0.02%
Mn	375±20	377±6	368±5	368±5
Ni	32±3	28±1	33±1	33±1
Zn	138±6	115±4	116±2	116±2

* concentrations in $\mu g/g$ dry weight unless otherwise noted

the range of the determined standard deviation. Values for Zn, consistent for all three sets of samples, fall within the range of analytical uncertainty. The slight discrepancy between the analytical and certified Zn values is thought to be due to loss during the fusion process.

RESULTS AND DISCUSSION

SEDIMENT DISTRIBUTION

Surficial Sediments

November 1988

Sediment samples collected during the fall cruise were very similar texturally to those collected previously. A ternary diagram showing sediment type in November 1988 resembles the plot depicting samples collected in June 1983, immediately following completion of the dike (Fig. 1-3). Grain size composition ranges from very sandy (>95% sand) to very muddy (<1% sand). Sample points are scattered about a solid line drawn from the "sand" apex to the opposite side of the triangle. Such lines represent constant clay:mud ratios (Pejrup, 1988), in this case, the mean clay:mud ratio for all samples collected during the cruise. The mean clay:mud ratio for the June 1983 cruise is 0.51 and for the November 1988 cruise, 0.49 - on the average, half of the muddy fraction of the sediment consisted of clay. (In contrast, the mean pre-construction clay:mud ratio is 0.67 (Fig. 1-3 A).)

Each of the ternary diagrams presented in Figure 1-3 summarizes the sand-silt-clay composition of sampled bottom sediments at a particular point in time. The diagrams are especially useful in revealing widespread and radical changes in sedimentary environment, such as those that occurred during dike construction. Comparisons between these diagrams, however, should be made with caution. Because the stations themselves are

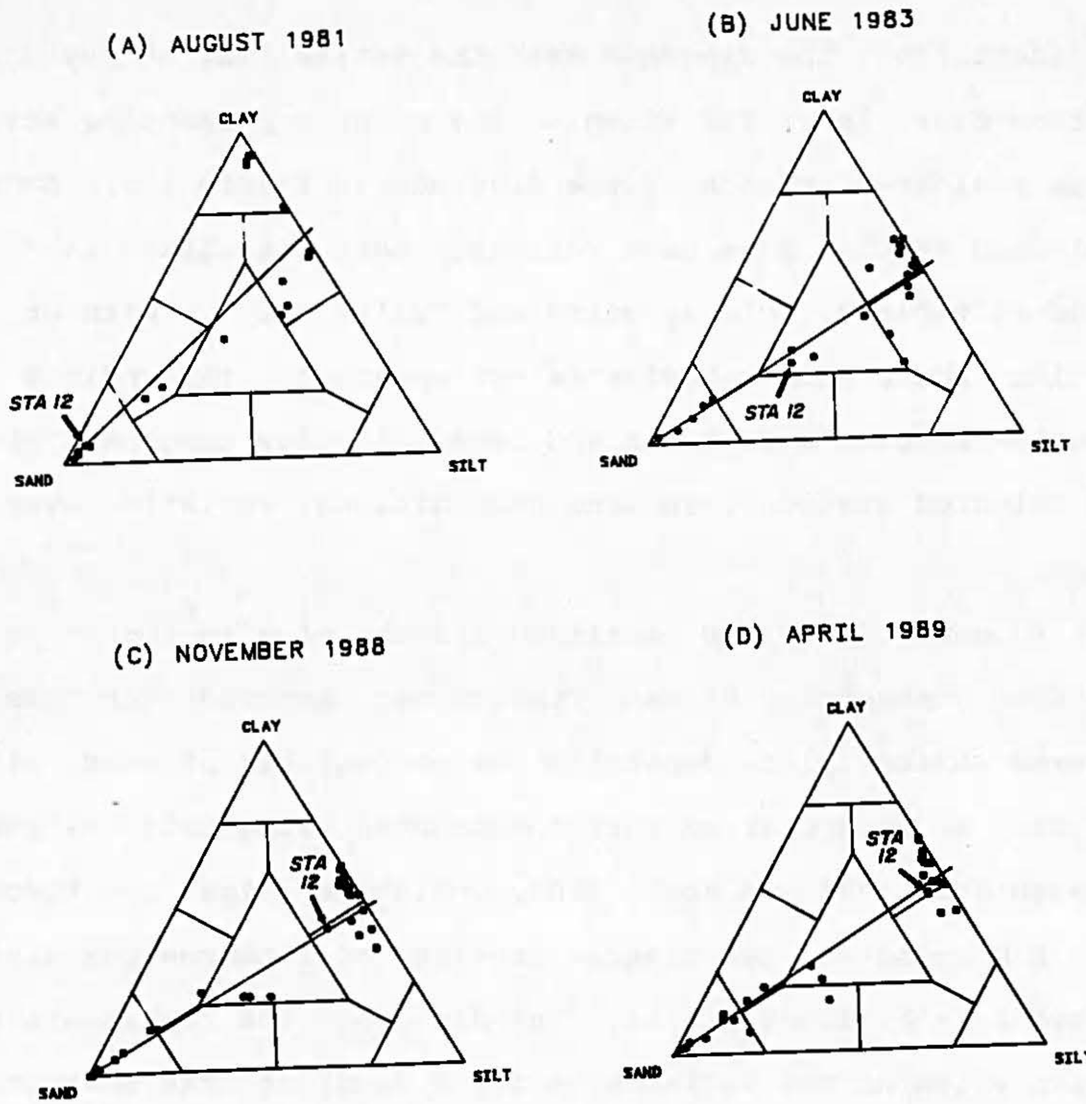


Figure 1-3: Sediment type of samples collected in (A) August 1981, prior to the onset of dike construction, (B) June 1983, immediately following completion of the dike, (C) November 1988, and (D) April 1989.

not identified, the diagrams mask the variability at any one station over time. For example, the point representing station 12 is indicated on each of the diagrams in Figure 1-3. Sediments collected at this site have variously been classified as "sand", "sand-silt-clay", "clayey silt" and "silty clay". Without station labels this behavior is not apparent. (Appendix B contains Shepard's diagrams and sand-silt-clay component plots for selected stations, showing compositional variation over time.)

To detect possible localized effects of dike operation, the sediment composition at each station was examined over time. Box-and-whisker plots depicting the percentages of sand, silt, and clay at each station were constructed using data collected between June 1983 and April 1989, inclusive (Figs. 1-4 through 1-6). 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 25^{th} and 75^{th} quartiles. "Whiskers" extend from the ends of the box to the nearest value lying beyond the box boundary. Extreme values, beyond 1.5 x the interquartile range, are plotted as separate points and identified by the date of collection (Tukey, 1977). None of the outliers is associated with the November 1988 cruise.

The areal distribution of sediment types in November 1988 is shown in Figure 1-7. Compared to the preceding cruise (April

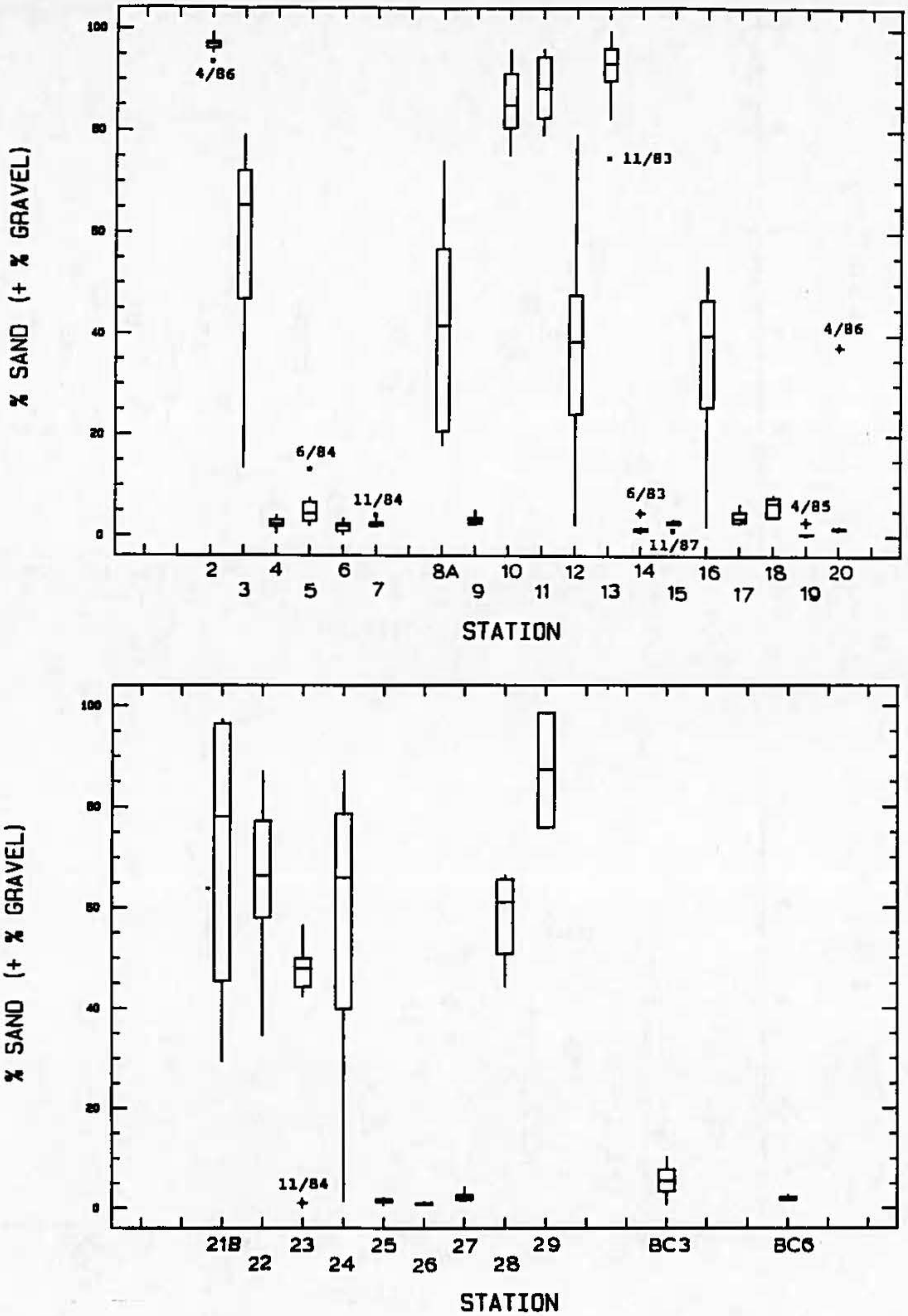


Figure 1-4: Box-and-whisker plots of percent sand for all stations, based on data collected between June 1983 and April 1989. Outliers are identified by date of collection.

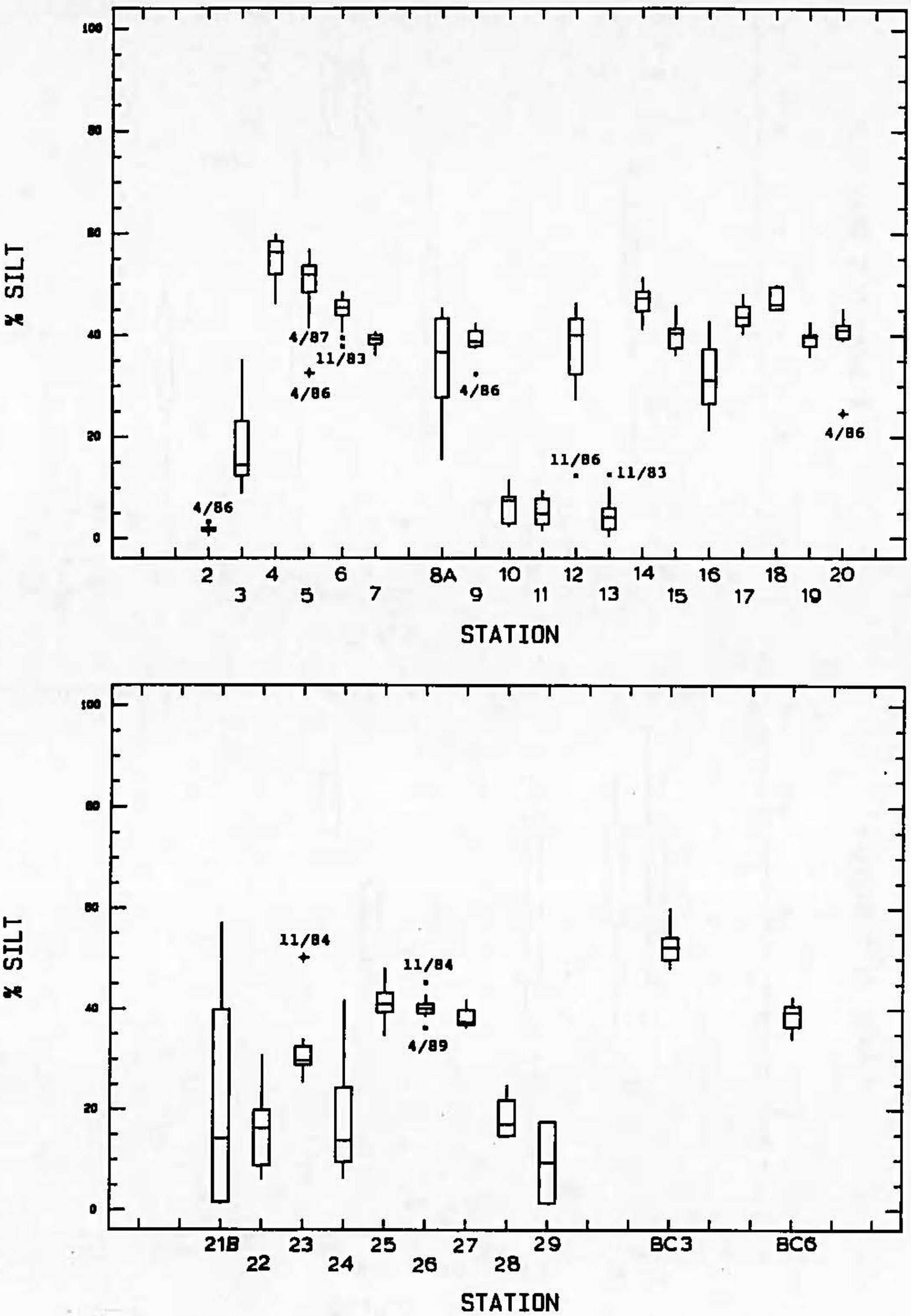


Figure 1-5: Box-and-whisker plots of percent silt for all stations, based on data collected between June 1983 and April 1989. Outliers are identified by date of collection.

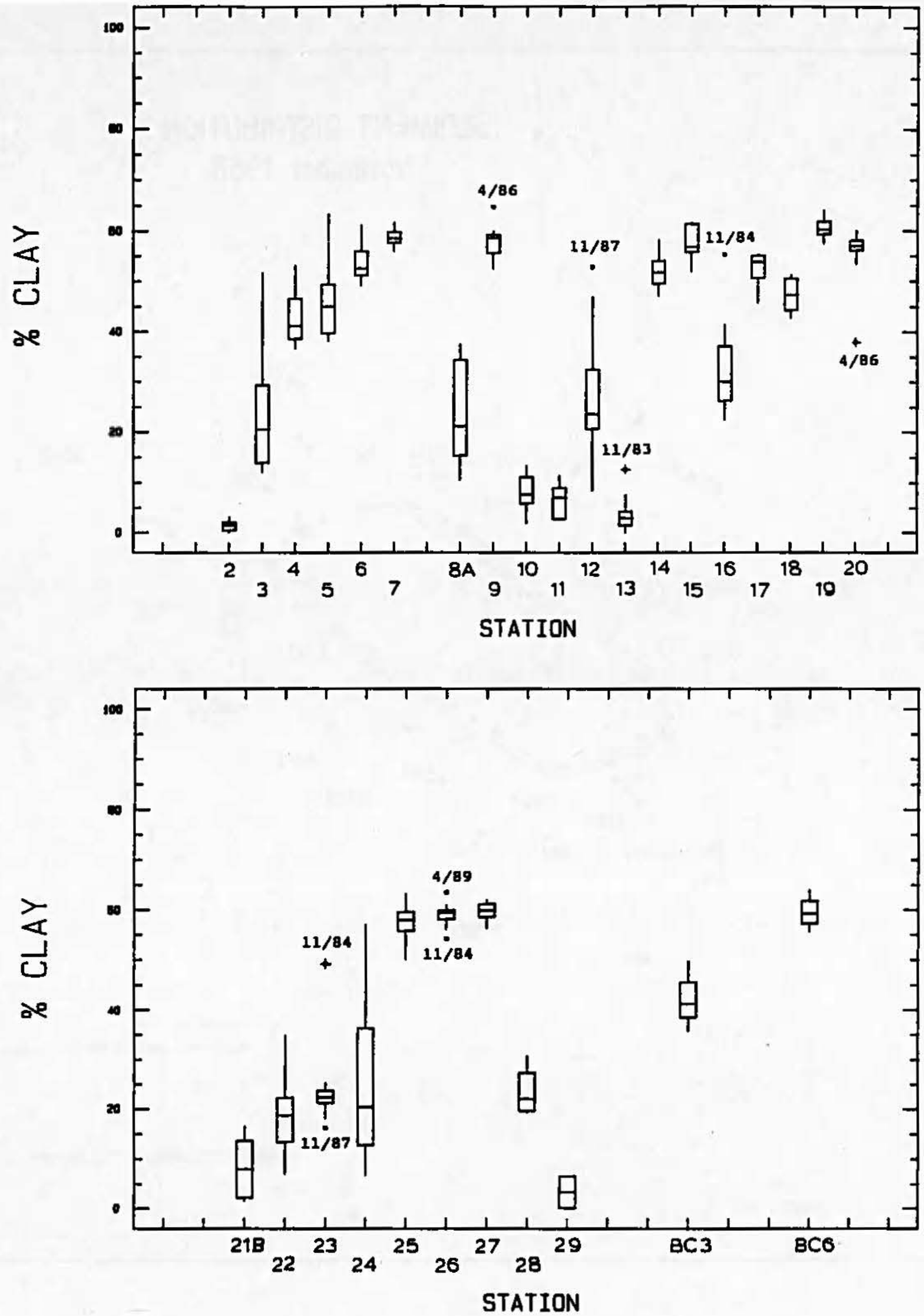


Figure 1-6: Box-and-whisker plots of percent clay for all stations, based on data collected between June 1983 and April 1989. Outliers are identified by date of collection.

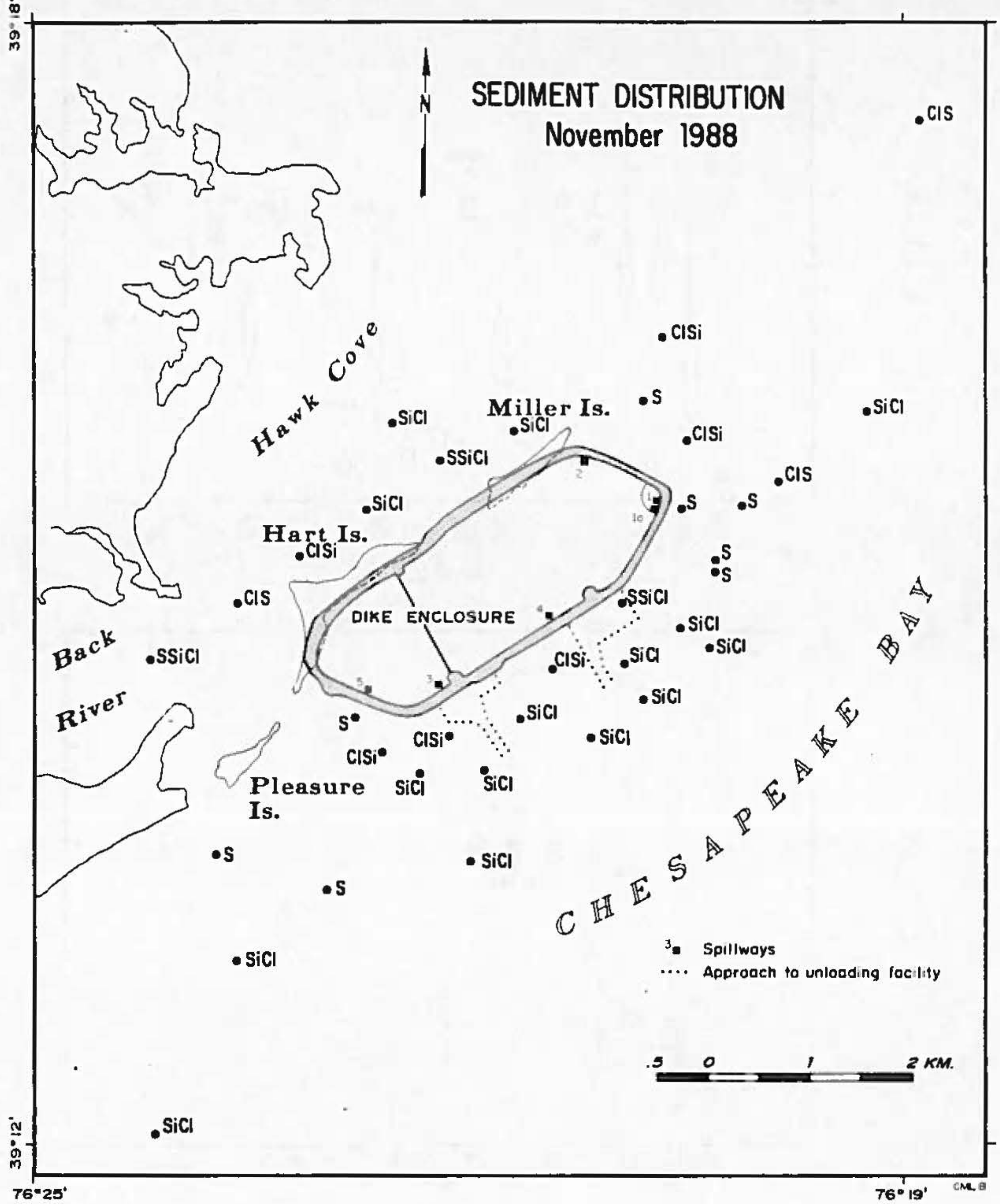


Figure 1-7: **Sediment type of surficial samples collected on November 15, 1988.**

1988), sediment type changed at six stations (3, 12, 14, 18, 21B, and 22). At station 3, bottom sediments were classified as "clayey sand" in April 1988, and as "sand" in November 1988 (Fig. B-1). Since completion of the dike, sediment type at this station has typically changed from one cruise to the next. Initially, that variability was pronounced - between June 1983 and November 1986, sand content ranged from a minimum of 13% to a maximum of 79%. Since 1986, however, variability in grain size composition has diminished (65% < sand < 77%). Rather than reflecting major differences in grain size composition, the recent changes in sediment type at station 3 are an artifact of the arbitrary subdivisions of Shepard's diagram. Samples collected in April 1988 and November 1988 both fell near the "clayey sand"-"sand" boundary, but on opposite sides of that line. In fact, sand-silt-clay percentages at station 3 have been relatively stable in recent years. They are also almost identical to their pre-construction values.

At station 12, the reverse trend is evident, with a recent increase in grain size variability (Fig. B-3). Between June 1983 and April 1986, bottom sediments were characteristically a mixture of nearly equal parts of sand, silt, and clay. Beginning in November 1986, however, grain size composition began fluctuating wildly. Sand content reached a high of 79% in November 1986, recovered, dropped to 2% in November 1987, recovered, then dropped again in November 1988. Triplicate grab samples collected at station 12 in November 1988 were all very muddy (3-14% sand), as was the sample collected in April 1989 (7% sand).

One possible explanation of the recent swings in grain size composition is extreme spatial (horizontal) or temporal (vertical) variability in sediment type. In order to evaluate that possibility, five gravity cores were collected in the vicinity of station 12 in April 1989. Findings are presented in the subsection entitled "Gravity Cores".

At stations 14 and 18, sediment type changed from "silty clay" to "clayey silt" between April and November 1988 (Figs. B-4 and B-5). Again, the actual differences in grain size composition are minor; the changes in sediment type are imposed by Shepard's classification.

Sediment type at station 21B changed from "silty sand" (45% sand) in April 1988 to "sand" (97% sand) in November 1988 (Fig. B-6). Similar transitions have occurred in the past. Bottom sediments at this site tend to be sandy, although sand content has varied over a wide range (24% to 97%). Much of the variation is due to abrupt changes in sediment type over short distances. In an extreme case, triplicate grab samples, collected within minutes of each other in April 1986, ranged in sand content from 39% to 96%.

At station 22, "sand" was collected in April 1988, and "clayey sand" in November 1988 (Fig. B-7). Sediment type has alternated between these two categories since November 1986. Unlike stations 3, 14, and 18, though, the differences in grain size composition are real, not just a consequence of using Shepard's classification. Furthermore, there has been a trend at this site toward increasingly sandy bottom sediments. The reason for this trend is not known. Preliminary work suggests that it is unrelated to discharge from the Susquehanna River.

April 1989

The physical features of bottom sediments outside the dike changed very little between the fall and spring cruises. Shepard's diagram of the sand-silt-clay composition of samples collected in April 1989 resembles both its June 1983 and November 1988 counterparts (Fig. 1-3). The average clay:mud ratio for the April 1989 samples is 0.53, compared with 0.49 for the November 1988 cruise.

Box-and-whisker plots reveal only one anomaly in April 1989. Silt content was comparatively low at station 26 (Fig. 1-5). Nonetheless, the sample falls within the "silty clay" category, along with all the other samples collected at that station since dike completion (Fig. B-9).

The areal distribution of sediment types is shown in Figure 1-8. Compared to the preceding cruise, sediment type changed at six stations (3, 8A, 14, 18, 22, and BC3). At all of these sites, the observed sediment type had occurred before (Appendix B). In fact, the April 1988 sediment types recurred at stations

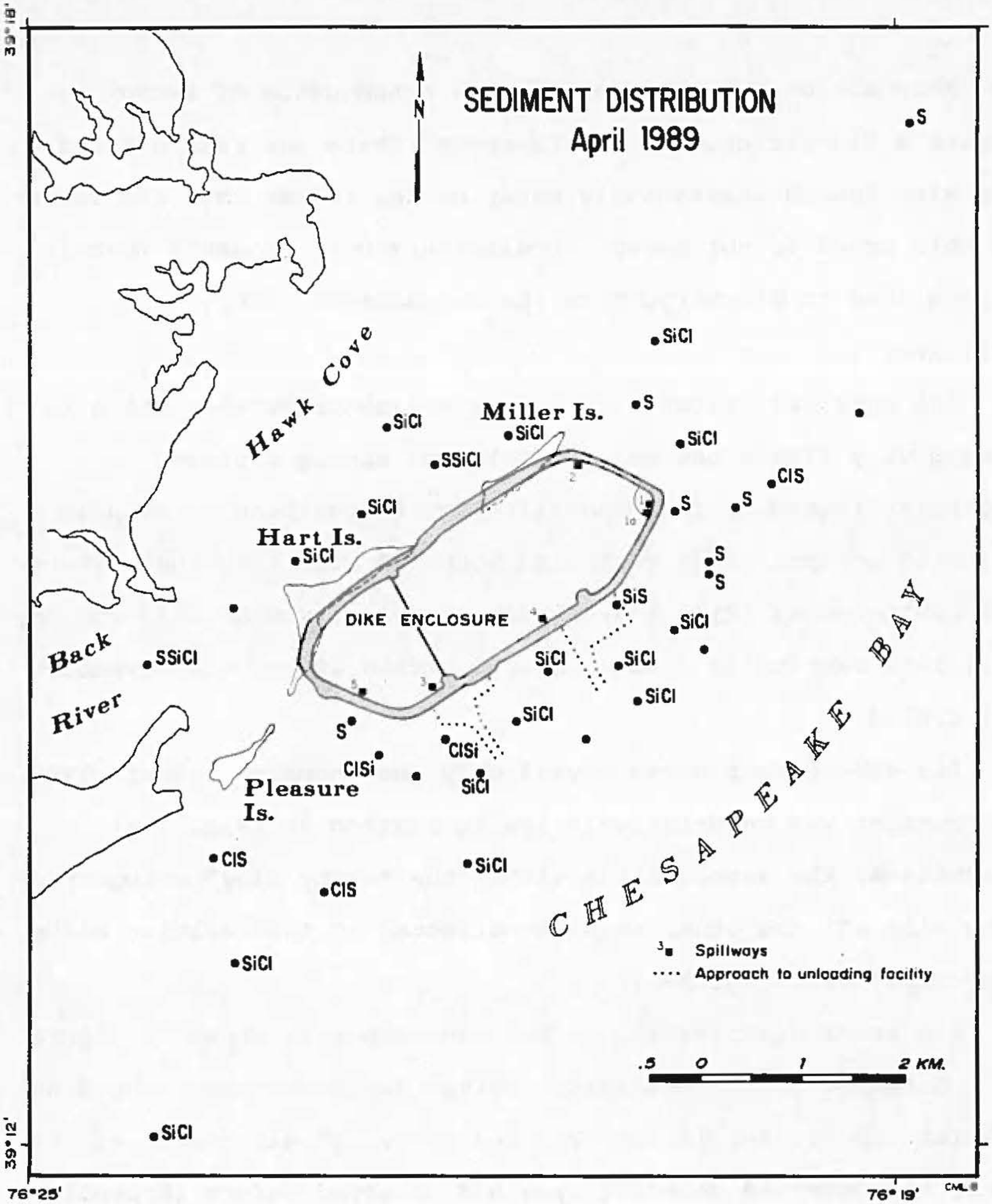


Figure 1-8: Sediment type of surficial samples collected on April 3, 1989.

3, 14, 18, and 22. At these stations, as well as station BC3, differences in sediment type were artifacts of the classification scheme - instances of two samples falling on either side of a boundary between classes.

Gravity Cores

In April 1989, gravity cores were collected at the seven box core (BC) stations and at station 12. Based on a comparison of xeroradiographs, cores BC-2 through BC-7 were very similar to those collected the previous spring, indicating that no major changes occurred at those locations during the past year. Cores collected at stations BC-2, BC-4, BC-5, and BC-6 consisted of dark grayish silty clays and contained surface shell layers (Figs. A-2, A-4, A-5, and A-6). The core collected at station BC-7 consisted of a layer of dark grayish clayey silt overlying silty clay and contained only isolated shells (Fig. A-7). Highly reticulated networks of burrows and tubes, indicative of high bioturbation levels, were present in all of these cores.

At stations BC-1 and BC-3, cores penetrated the fluid mud layer. BC-3 consisted of an upper layer, approximately 26 cm thick, of finely laminated, pale reddish brown to gray, smooth clayey silt overlying firmer, more darkly-colored silty clay (Fig. A-3). The top 6-10 cm were disrupted or mixed by biogenic activity. BC-1 resembled BC-3 except that all of the subsamples analyzed from core BC-1 were categorized as silty clays. Also, the fluid mud layer was only 12 cm thick in BC-1, about 8 cm thinner than it was in the core collected from that site last year (Fig. A-1).

As was mentioned earlier, five gravity cores (Figs. A-8 through A-12) were collected in the vicinity of station 12 to determine if recent swings in grain size composition might be due to extreme spatial (horizontal) or temporal (vertical) variability in sediment type. Figure 1-9 depicts the sand-silt-clay percentages of the top 50 cm of each core. (The top of each core is located at depth = 0 cm.) The average sand content of the top 10 cm, the approximate interval collected by a grab sampler, ranges from 5.8% (12C) to 83.8% (12A). So, sediment type does change abruptly over short distances around station 12. Slight changes in boat position from one cruise to the next may account for the compositional variability at station 12.

The other noteworthy feature, seen in all the cores depicted in Figure 1-9, is the consistent decrease in sand content over time (from bottom to top of the core). Sand content at station 12 in August 1981, preceding dike construction, was 90.8%. Subsamples from all of the cores reach that pre-construction high at varying depths. Presumably, the overlying, finer-grained blanket of sediment was deposited during dike construction and/or operation. The precise origins of this sediment are obscure - construction material settling beyond the dike boundary; particles discharged from the dike, settling from suspension in the vicinity of station 12; suspended sediment from elsewhere in the Bay, deposited at the site because of different hydrodynamic

conditions created by the physical structure itself; and/or sediments deposited biogenically by the large *Rangia cuneata* population.

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. In lieu of actual elemental concentrations, enrichment factors are used to facilitate the interpretation of changes from one sampling period to the next. An enrichment factor is defined as follows:

$$EF(X)\ ref = \frac{(X/Y)sample}{(X/Y)ref} \tag{2}$$

where X = the element of interest;
Y = an immobile element, such as Al or Fe, that is not affected by anthropogenic inputs;
(X/Y)sample = the analytically determined ratio of the concentration of X to Y in the sample; and
(X/Y)ref = the ratio of the concentration of X to Y in a reference material, such as an average rock type (Turekian and Wedepohl, 1961).

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

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

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

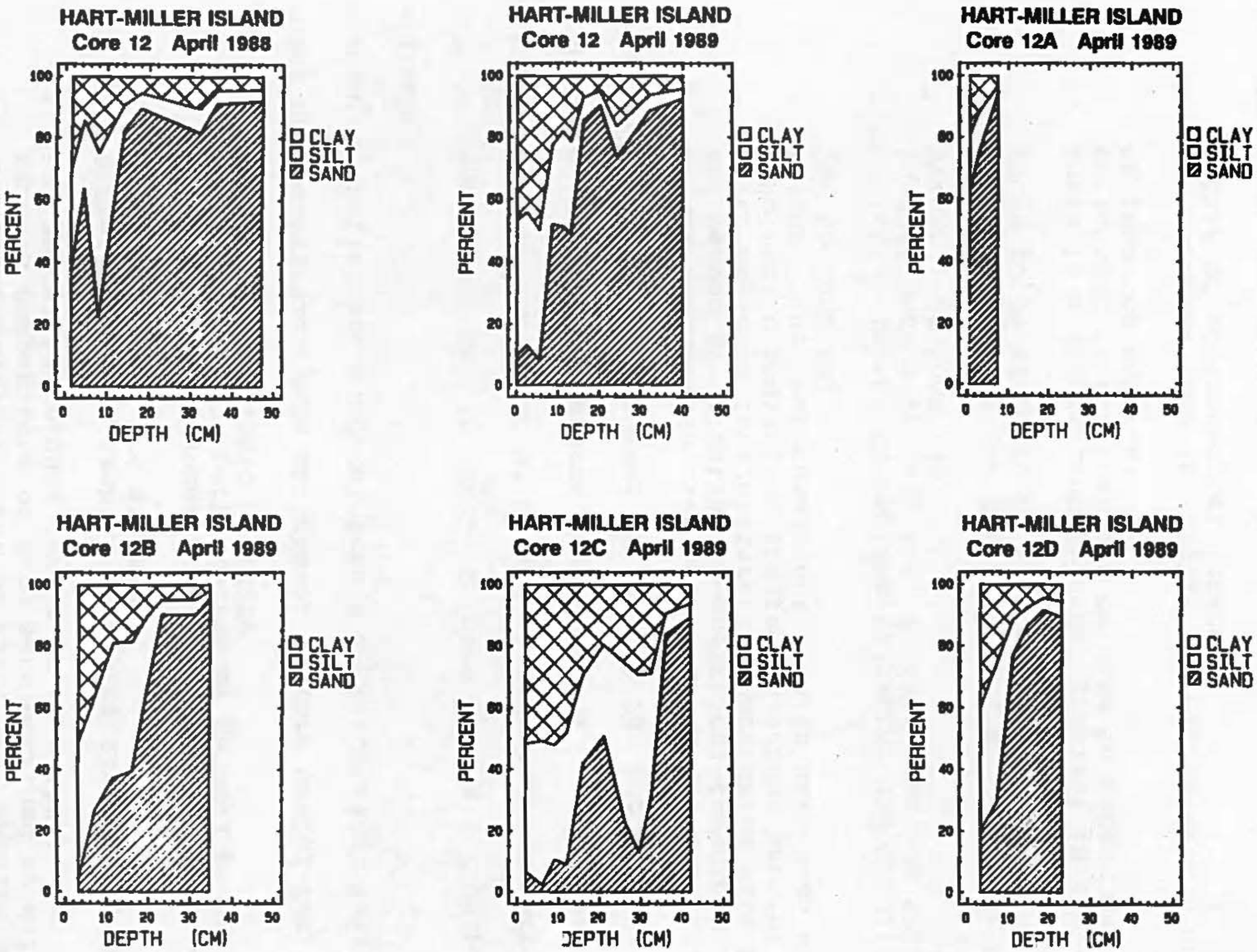


Figure 1-9: Grain size composition of the top 50 cm of cores collected at or near station 12 in April 1988 and April 1989.

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

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

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

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

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

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

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

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

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

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

Contour maps of the Zn enrichment factor show that, between April and November 1988, the sedimentary environment remained stable (Fig. 1-10). Contours are broad and gentle, similar to pre-construction conditions. In April 1989, however, two areas, around stations 25 and 27, showed elevated levels of Zn. Enrichment factors at those sites approximated 5.5, greatly exceeding the regional average of 3.2. Station 25 is of primary concern because of its proximity to spillway #1. Also, in contrast to station 27, trace metal levels at station 25 are probably not influenced by the flow from Back River.

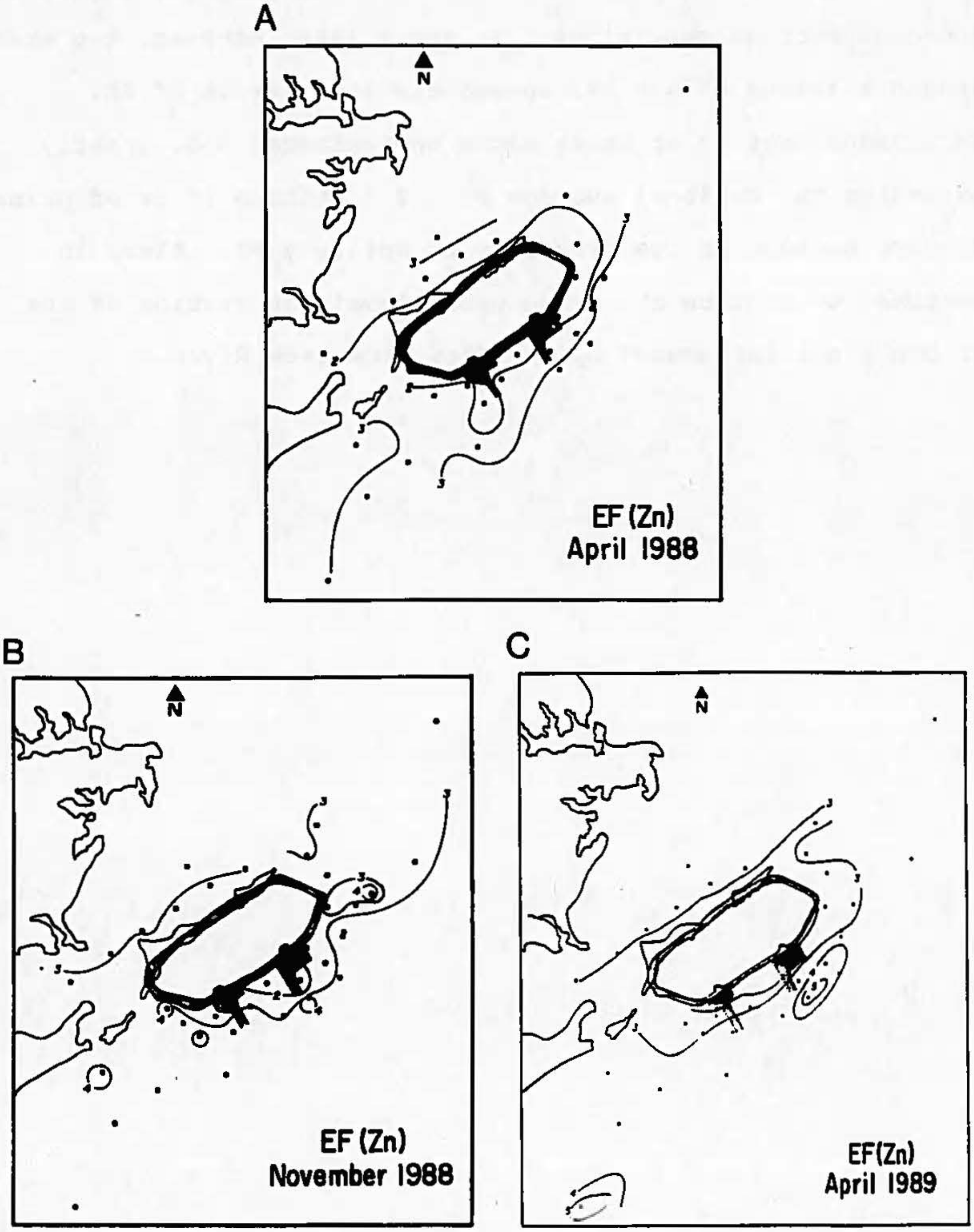


Figure 1-10: **Spatial distribution of the enrichment factor for Zn, based on surficial sediments collected in (A) April 1988, (B) November 1988, and (C) April 1989.**

Figure 1-11 shows that the Zn enrichment factor at station 25 has been increasing systematically through time. This variation is independent of sediment composition. Sediment type has remained unchanged since sampling began at the site in November 1983; station 25 samples have consistently been classified as "silty clays" (Fig. B-8). Increasing Zn levels, coupled with a relatively uniform sediment composition, indicate a metals loading unrelated to normal sedimentary processes operating in the area.

In order to assess the problem, the changes must be referenced to a regional norm. This can be accomplished by correlating trace metal levels with grain size composition. Data collected over the past six years were fitted to the following equation:

$$X = a(SAND) + b(SILT) + c(CLAY) \qquad (3)$$

where X = the element of interest,
a, b, and c = the determined coefficients, and
SAND, SILT, and CLAY = the grain size fractions of the samples.

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 1-2. 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,

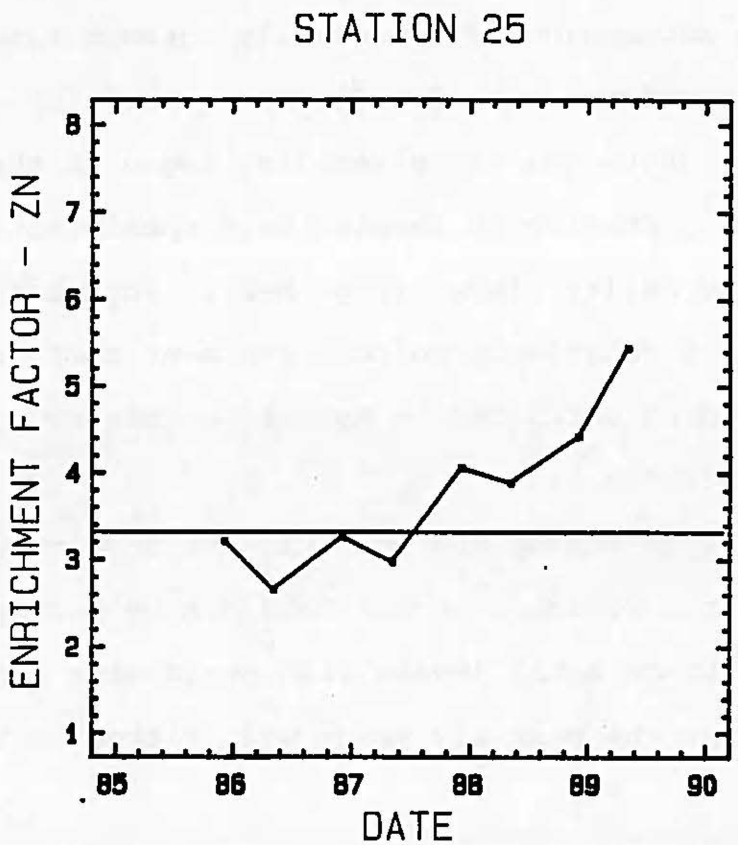


Figure 1-11: The enrichment factor for Zn at station 25, over time. The horizontal line represents the regional average enrichment factor for Zn.

Table 1-2: Least squares coefficients of the trace metal data.

Size fraction	Metal Fe	Zn	Cr	Ni	Mn	Cu
SAND	0.05533	44.43	25.27	15.30	668.60	12.26
SILT	1.16947	-0.01	71.92	0.02	248.91	13.99
CLAY	7.57373	472.53	160.80	136.00	4123.60	76.54
R^2	0.915	0.766	0.733	0.819	0.356	0.596

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.

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 distribution is known. This can be done by substituting the least squares coefficients from Table 1-2 for the determined coefficients in equation 3. 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.

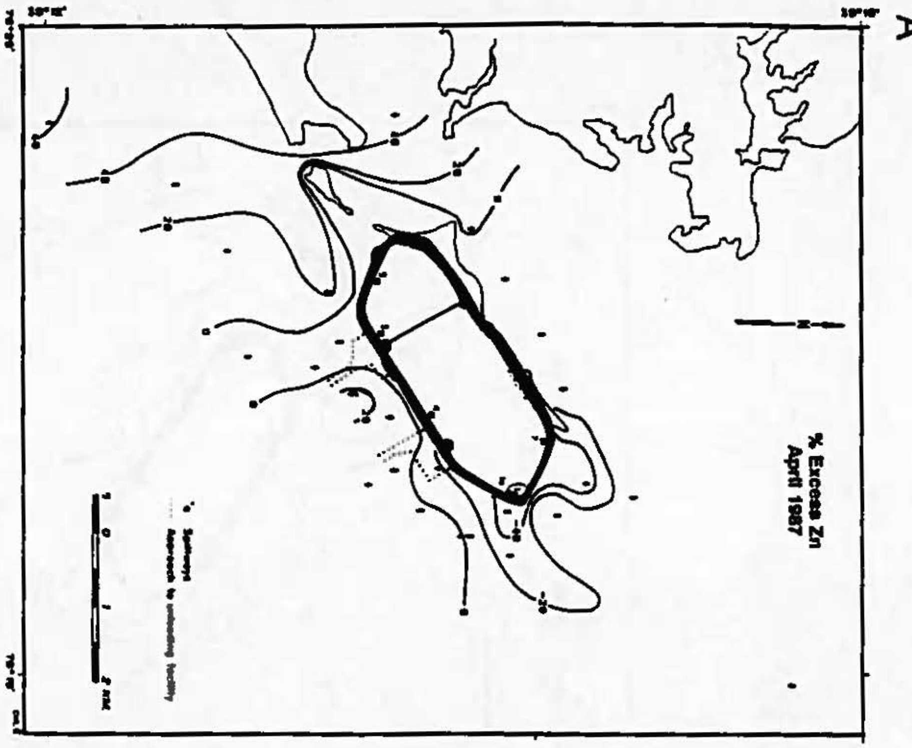
The following equation was used to examine the variation from the norm around the containment facility:

$$\% \text{ excess Zn} = \frac{(\text{measured Zn} - \text{predicted Zn})}{\text{predicted Zn}} * 100 \qquad (4)$$

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

The results of this exercise are shown in Figure 1-12 for four sampling periods. The April 1987 sampling period is typical of the area prior to April 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 and continuing through April 1989, an area of enrichment, incorporating station 25, appears southeast of the facility in the vicinity of spillway #1. The eastward extent of the affected area is presently unknown. Further study is necessary to determine the areal extent and the likely source of enrichment. In response to that need, MGS intensively sampled the area in January 1990, collecting 67 surficial samples.

The sampling plan for the January 1990 cruise (Fig. 1-13) 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



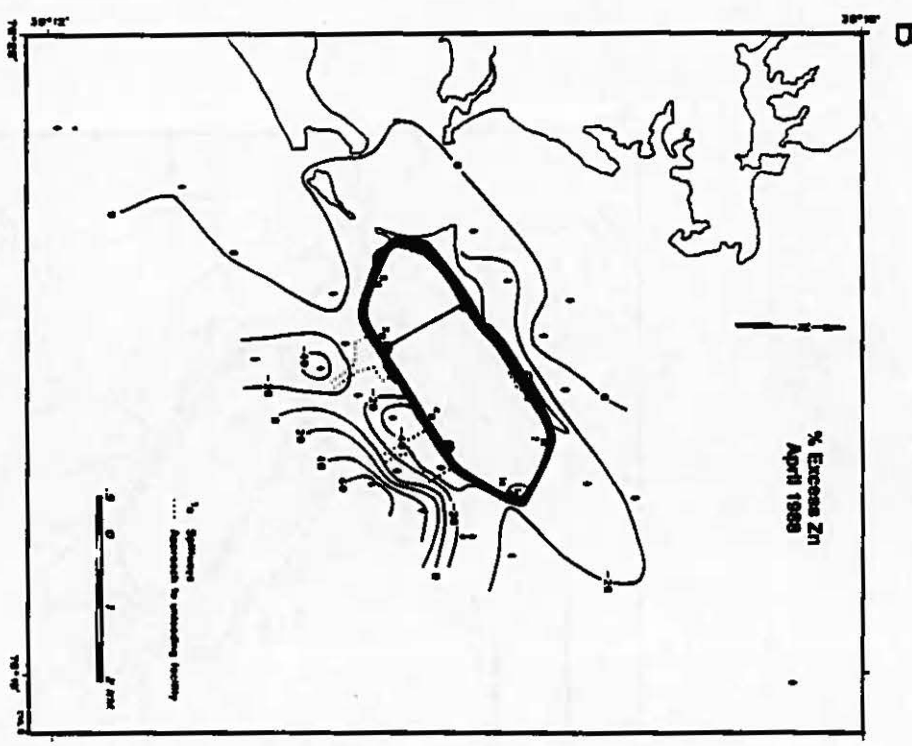
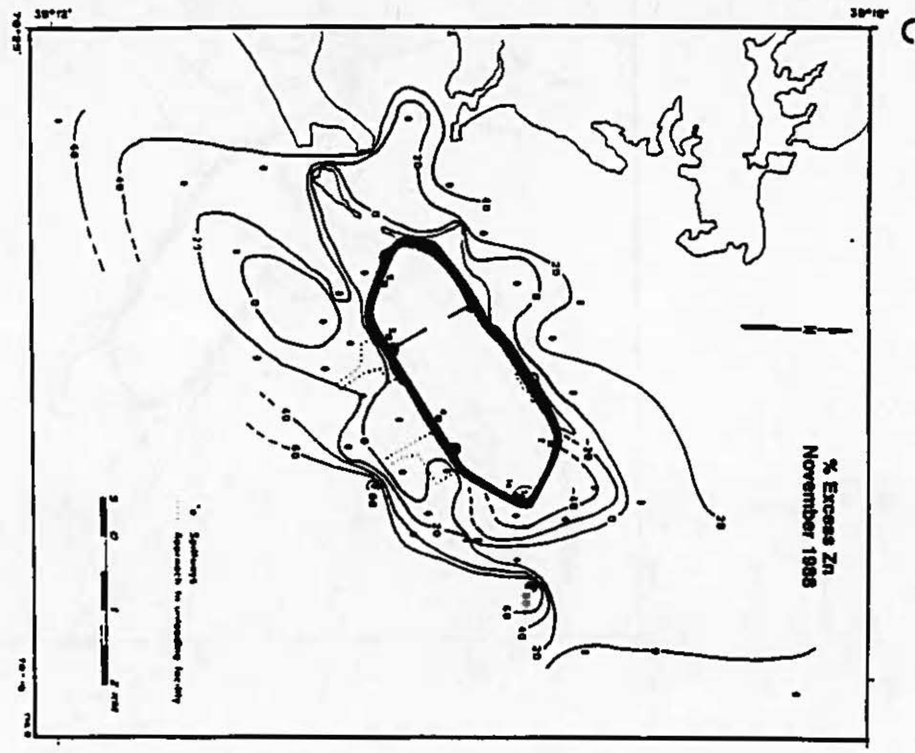


Figure 1-12 (p.1) Spatial distribution of % excess Zn, based on surficial sediments collected in (A) April 1987, (B) April 1988, (C) November 1988, and (D) April 1989.



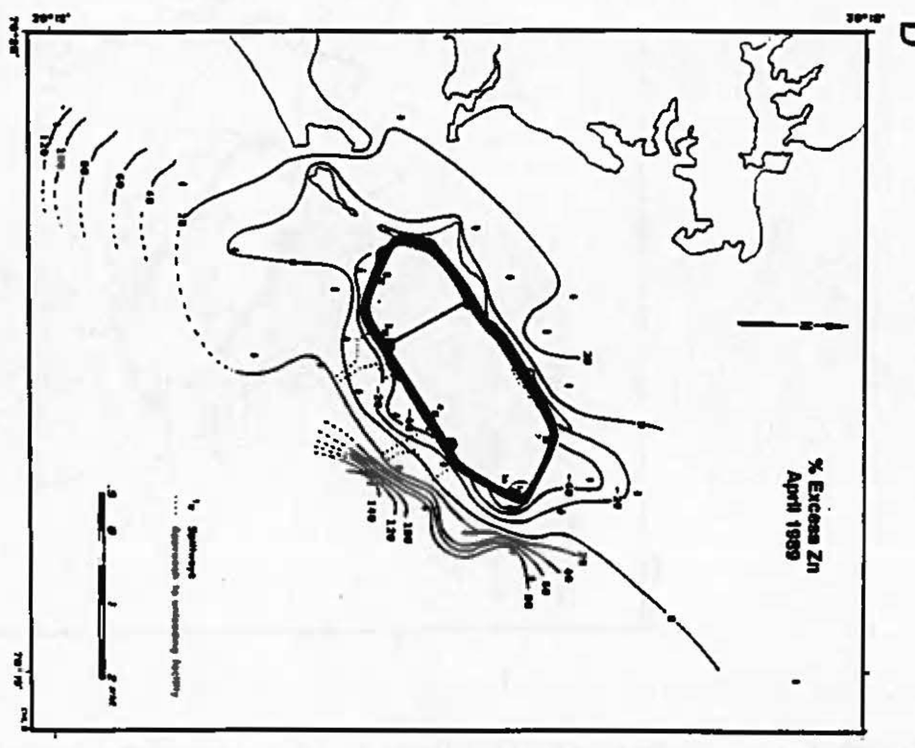


Figure 1-12
(p.2)

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. 1-13). The dashed lines in Figure 1-13 represent the distance the effluent travels along a calculated trajectory within a specified period of time (from 0.5 to 3 hours). (Time is an important factor in the sedimentation of material from the effluent.) Sampling stations are located at the grid nodes and at intermediate points along the grid lines.

Superimposing the flow net on a map of our established sampling locations shows that these sites should only be affected by low discharges from spillway #1 (<5 mgd). Daily discharge records supplied by MES indicate that prior to the November 1988 sampling period, comparatively high flow conditions prevailed at spillway #1 (Fig. 1-14). 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 from stations near the 1 mgd trajectory. This coincidence indicates that effluent being discharged from the dike is the likely source of the Zn found in the surrounding bottom sediments. It also indicates a shortcoming in the current exterior monitoring program. None of the sediment sampling stations is located in the area affected by high flow conditions at spillway #1. If discharge of effluent had an impact on the

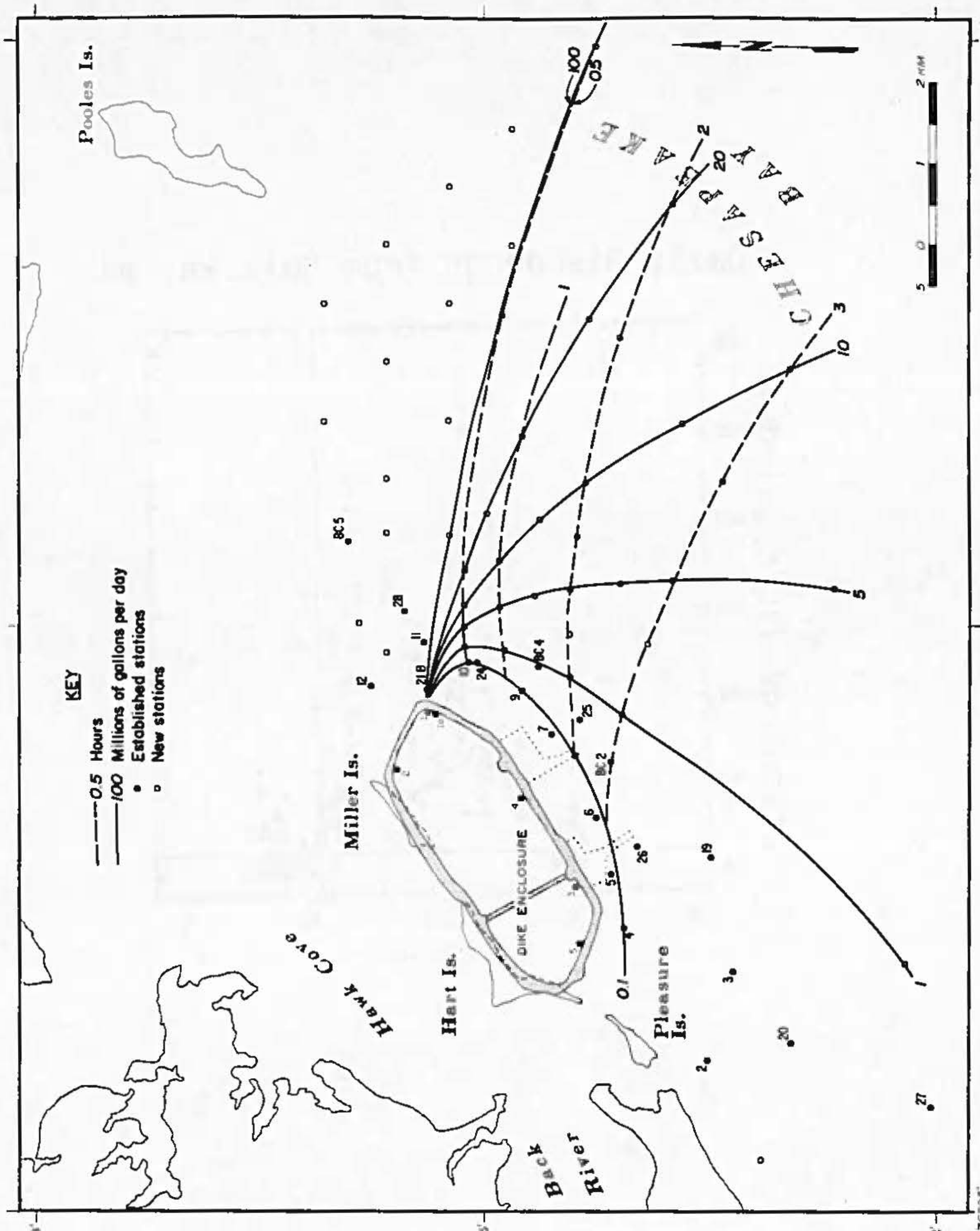


Figure 1-13: Expanded sampling plan and the flow net on which it was based.

Daily Discharge from Spillway #1

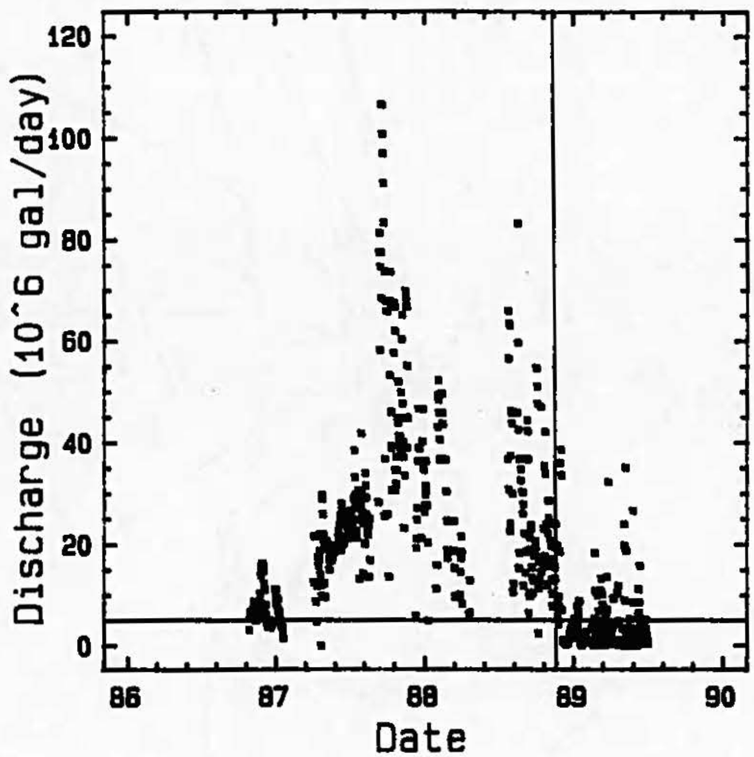


Figure 1-14: Daily discharge (million gallons/day) from spillway #1, from MES records.

sedimentary environment prior to November 1988, the established sampling scheme was incapable of detecting it.

CONCLUSIONS

During the eighth monitoring year, Zn levels increased significantly in bottom sediments near spillway #1. (No associated changes were detected in the physical properties of the sediments.) The probable source of Zn enrichment 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 this year. Theoretically, the stations showing Zn enrichment should only be affected by low flows (< 5 mgd) from the dike; at higher discharge rates, the effluent bypasses the stations in the established sampling scheme. Not till after November 1988 did discharge rates consistently fall below 5 mgd. Zn enrichment was first observed the following April.

Several factors influence the distribution of anthropogenic Zn in bottom sediments around Hart-Miller Island:

1. the nature of the material being released,

   Only if the Zn signature of the suspended solids discharged from the dike is higher or lower than the regional norm will a change in Zn content be detected in the bottom sediments. Constant Zn levels, however, do not mean that the material is not physically blanketing the bottom.

2. the flow and dissipation of water discharged from the dike,

   Flow and dissipation of water discharged from the dike will determine the most probable target for the material. Flow and dissipation are controlled by the flow of the

Susquehanna River as well as the volume of effluent released from the dike. High river stages will bend the trajectories closer to the dike. Accumulation of material adjacent to the dike, in the original study area, will be most pronounced when discharge from the dike is low and discharge from the Susquehanna is high.

3. biological activity.

Bioturbation mixes surficial material with deeper sediments. Generally, this will lower the apparent surficial loading of material. The effects of biological mixing are dependent on the time of year and temperature.

RECOMMENDATIONS

- o Expand the monitoring program to include the area affected by high flow conditions at spillway #1. Coordinate the selection of sites so that sediments, biota, and samples tested for organic contaminants are all collected from the same locations.

- o Run the 3-D hydrodynamic model. Model runs are needed to gain a better understanding of the fate of the material released from the dike. To ascertain which areas are likely to be affected by discharging from each of the active spillways, several runs, varying volume of effluent released and Susquehanna flow, are needed. If necessary, further adjustments in the sampling scheme should be made in accordance with that information.

- o Authorize MES to analyze the effluent for Zn on a weekly rather than quarterly basis, so that mass balances can be performed and the 3-D influence of the releases can be estimated.

- o Consider including bioassay work in the scope of exterior monitoring. To date it is impossible to relate sediment loadings to effects on the biota at sub-lethal levels. MGS data are providing 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.

ACKNOWLEDGMENTS

We would like to thank our colleagues at MGS for their assistance, given willingly, during all phases of the project: Captain Jerry Cox and first mate Rick Younger of the R/V Discovery, for their expert seamanship and spirit of cooperation; Bob Conkwright, Katy Koczot, Bill Panageotou, June Park, and Allen Slaughter, 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; Cindy Lang-Bachur, for drafting many of the figures; 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 provided us with much of the information related to site operation.

PART 2: BEACH EROSION STUDY

INTRODUCTION

Early in the construction of the containment facility, a recreational beach was created between Hart and Miller Islands (Fig. 2-1). Approximately 500,000 yd^3 (382,500 m^3) of sediment were pumped from the dike interior to create the outer dike face and recreational beach bordering Hawk Cove. The original engineering plans called for a wide, gently sloping beach (width = 250 ft; grade = 1:15 or 3.8°). The shoreline of the new beach parallelled the curvilinear outline of the dike itself - convex at the northern (Miller Island) end of the beach and concave at the southern (Hart Island) end.

Natural erosional and depositional processes began modifying the beach almost immediately after its construction. Waves breaking along the shoreline produced vertical escarpments of varying heights. Rain falling on the upper dike face led to sheetwash erosion and gully formation. Large volumes of sediment were removed from the recreational beach, and the original curvilinear outline of the shore was altered. The shoreline at the northern end of the beach receded quickly. The sediments eroded from that section of the beach were carried as littoral drift to the southern end of the beach. There, they were deposited, expanding the beach into Hawk Cove.

Study area

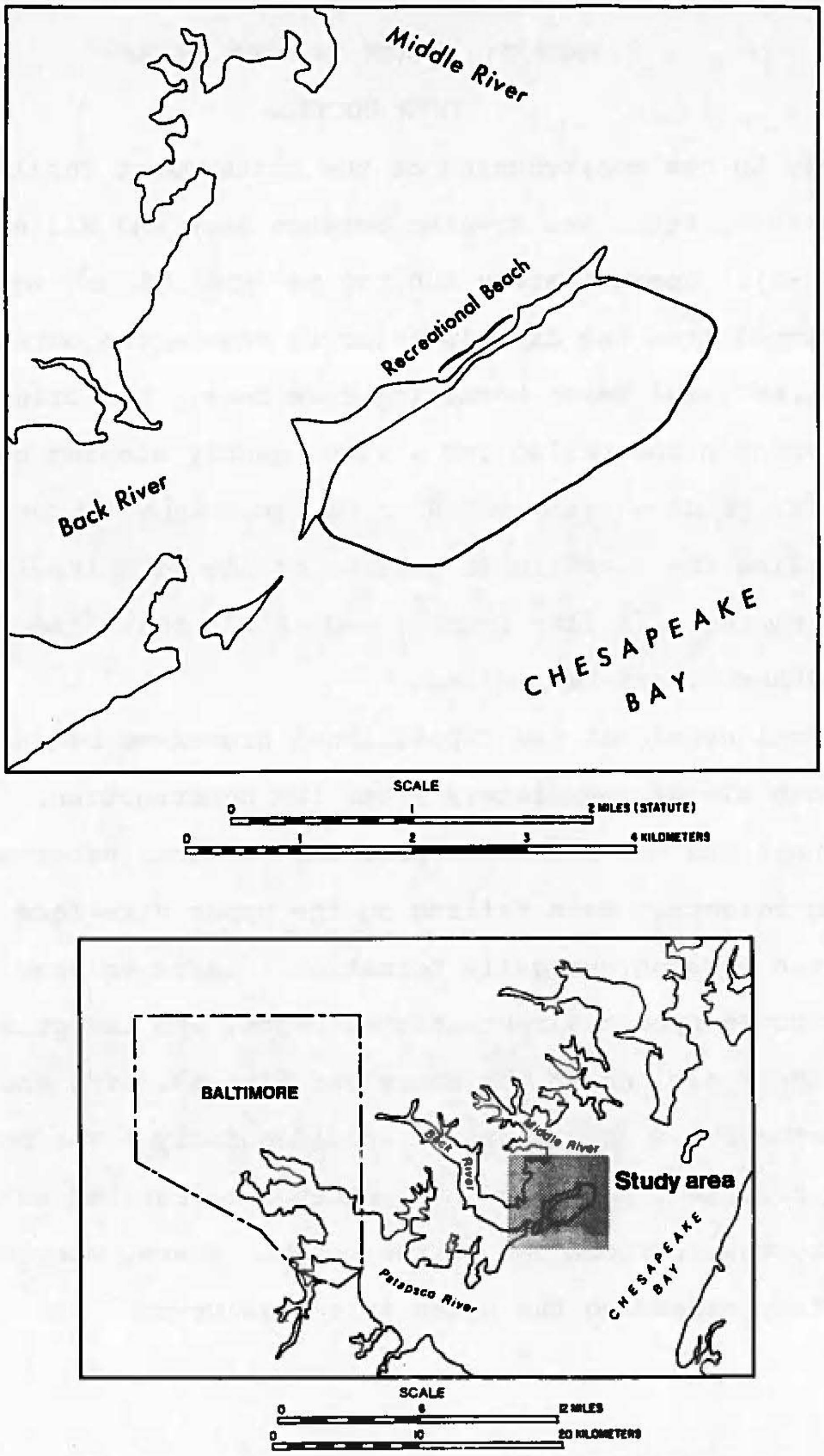


Figure 2-1: Location of the study area.

PREVIOUS WORK

Since May 1984, the Maryland Geological Survey (MGS) has monitored the erosional and depositional changes along the recreational beach. Results of investigations during the past five years of monitoring are reported in Wells et al. (1985, 1986, 1987) and Hennessee et al. (1989, in press). Based on the results of profile surveys, the beach was divided into three geomorphic regions affected by different natural and anthropomorphic processes (Fig. 2-2): (1) the outer dike face, extending from the chain link fence at the edge of the dike 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.

In previous monitoring years, the outer dike face was affected primarily by pluvial (rain-related) processes and secondarily, by aeolian (wind-related) ones. Gullies, excavated by rainfall and runoff, were common along most of the beach. Annual regrading of the outer dike face also contributed to beach erosion. Successive regrades steepened the slope of the dike face. Steeper slopes promoted gully formation and led to more severe erosion.

The foreshore was modified by wind-generated wave activity. Waves, in conjunction with high tides, eroded the shoreline, producing vertical escarpments. Smoothing the beach by

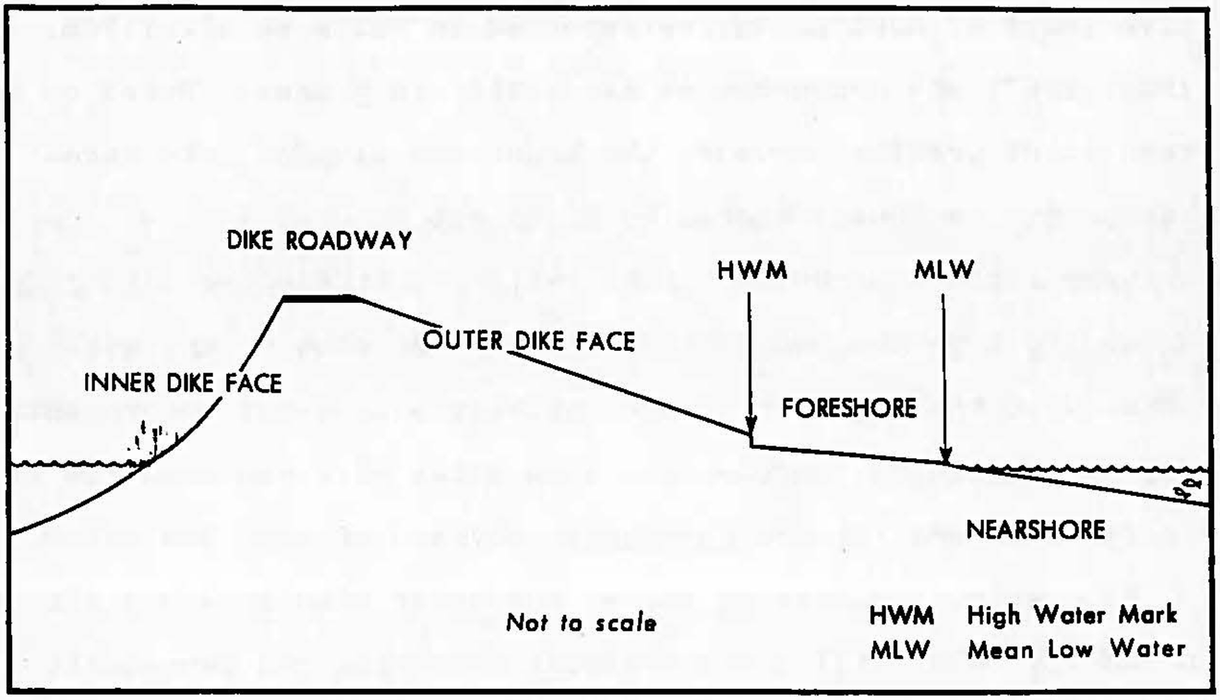


Figure 2-2: Pre-reconstruction (August 1988) schematic cross-section of the dike illustrating geomorphic regions of the beach.

bulldozing erased the wave-cut escarpments, but only temporarily. Usually within a few months of gradation, the escarpment was re-established.

The nearshore was modified by waves and longshore currents. Sediments eroded from the outer dike face and foreshore were redistributed in the nearshore. Longshore currents, running parallel to the beach, transported sediments southward.

From the inception of the beach erosion study in June 1984 to May 1988, approximately 11,244 yd3 (8,602 m3) of material were lost from the beach. This is a conservative estimate, excluding gully and nearshore erosion. Net sediment loss, computed for the four monitoring periods between regrades, is presented in Table 2-1.

Table 2-1: Volume of sediment eroded between regrades, since the inception of the beach erosion study in June 1984 to May 1988.

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

* based on ISRP (Birkemeier, 1986)

OBJECTIVES

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

1. analyze the beach configuration;
2. reassess the erosional and deposition processes altering the beach; and
3. calculate the volume of eroded sediment.

Most of the data included in this report were collected between May 27, 1988 and May 18, 1989. Offshore comparisons are based, in part, on a profile survey in September 1989.

In August 1988, three months after the start of this monitoring year, the beach was re-contoured and seeded (Fig. 2-

3). These erosion control measures, some of which were recommended in previous reports, stabilized the upper beach. Continued monitoring of the outer dike face above the snow fence was no longer necessary or, in some places, even feasible. Rather, this year's investigation was largely confined to the narrow strip of beach below the snow fence.

METHODOLOGY

FIELD METHODS

In May 1984, MGS established ten profile lines along the recreational beach (Fig. 2-4). These lines roughly coincided with those established by the Waterway Improvement Division of the Tidewater Administration during a hydrographic survey in the summer of 1983. Profile line 22+00 was relocated to 21+75 in June 1988, following the construction of comfort stations at the southern end of the beach. The ten lines were surveyed four times during this year's beach study (Table 2-2). Profile lines 21+75, 30+00, 40+00, and 49+00 were extended approximately 300 ft bayward of the water line in order to detect erosional/depositional changes in the nearshore. The extended profile lines were surveyed twice during the study year.

Profile elevations were transferred indirectly from Maryland Port Administration (MPA) bench mark number 281614 (elevation = 14.57 ft MLW), located approximately 22 ft east of the center

Table 2-2: Beach profile survey dates.

Profile	1	2	3	4	Extended survey
21+75	6/ 7/88*	9/14/88	12/14/88	5/17/89	9/15/89
24+00	6/ 7/88	9/14/88	12/14/88	5/17/89	
28+00	6/ 7/88	9/14/88	12/14/88	5/17/89	
30+00	6/ 7/88*	9/14/88	12/14/88	5/17/89	9/15/89
32+00	6/10/88	9/14/88	12/14/88	5/17/89	
36+00	6/10/88	9/14/88	12/14/88	5/18/89	
40+00	6/10/88*	9/15/88	12/15/88	5/18/89	9/14/89
44+00	6/10/88	9/15/88	12/15/88	5/18/89	
48+00	6/10/88	9/15/88	12/15/88	5/18/89	
49+00	6/10/88*	9/15/88	12/15/88	5/18/89	9/14/89

* Also an extended survey

line of the dike roadway at station 30+00. Additional bench marks were later established along the chain link fence by the Great Lakes Dredging Company. These bench marks are 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
31+50	18.38	stake
34+91.04	18.00	cemented pipe
39+73.7	18.21	stake
44+90	21.75	on fence crosspipe
47+00	19.49	stake
49+50	21.91	on fence crosspipe

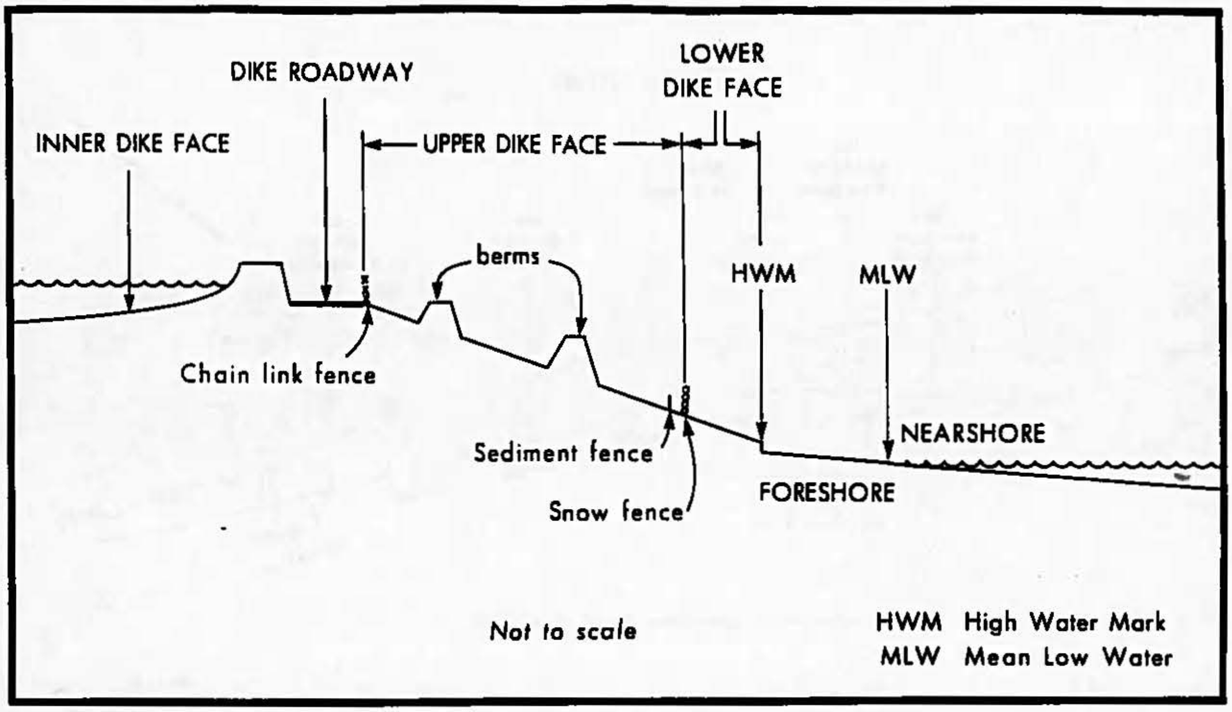


Figure 2-3: **Post-reconstruction (August 1988) schematic cross-section of the dike illustrating geomorphic regions of the beach.**

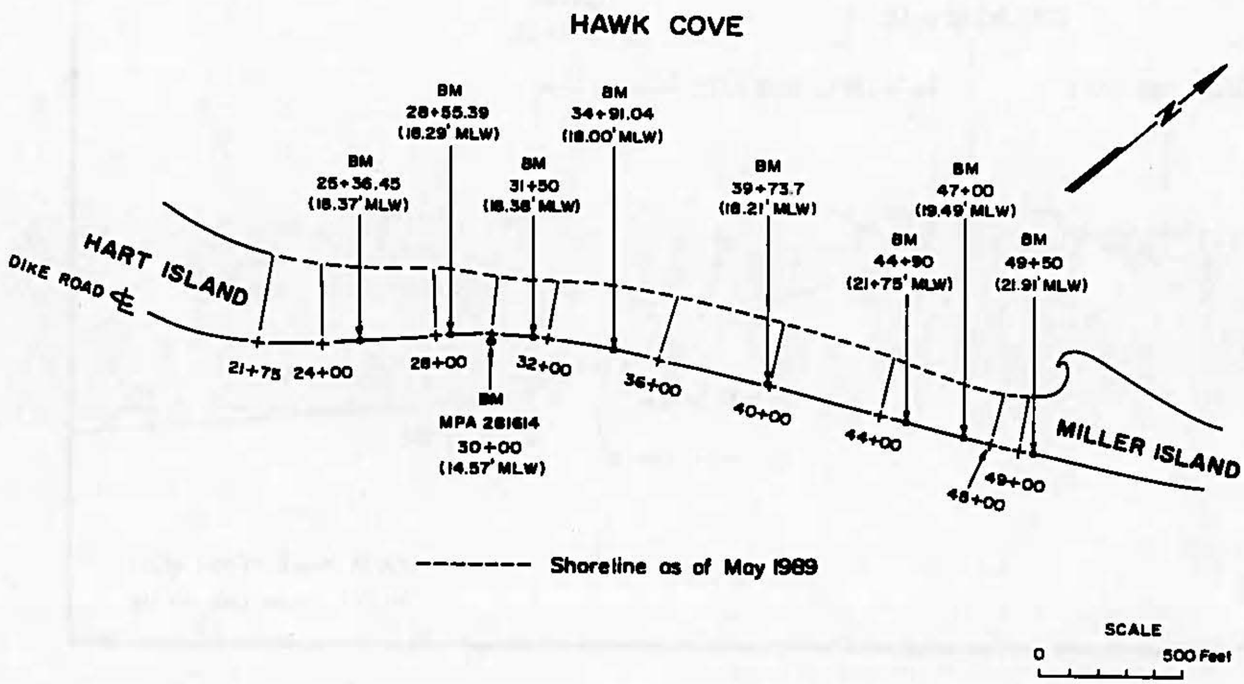


Figure 2-4: Locations of profile lines and bench marks along the recreational beach between Hart and Miller Islands.

Initially, the location of each profile station along the center line of the dike roadway was established as described in Hennessee et al. (1989). During subsequent surveys, the center line of the roadway was located by measuring 13 ft east of the chain link fence with a fiberglass tape. Correct azimuths were maintained by lining up the self-leveling level with an orange mark painted on the chain link fence.

Standard techniques were followed in surveying the profiles. Through May 1989, profiles were measured from the center line of the dike roadway downslope in 50 ft increments and at obvious changes in elevation. The water line and elevations below mean low water were also recorded. By September 1989, however, the heavily vegetated area between the chain link fence and the snow fence was no longer accessible to survey crews. The beach and nearshore were surveyed from the center line of the dike roadway, but no measurements were recorded for the area between the fences. (Distance and elevation data from the five profile surveys are tabulated in the *Eighth Year Data Report*.)

Photographs were taken to document the erosional and depositional features observed on the beach. Photographs were shot at each profile, facing upslope, from approximately 50 ft offshore. They were also taken at selected sites along the beach, facing north and south. Aerial photographs were taken after each profiling period to record overall changes in shoreline configuration, escarpment and gully development, and vegetation patterns.

DATA REDUCTION

For each profile, a computer program, Interactive Survey Reduction Program (ISRP), was used to calculate sediment gains and losses above and below datum (0 ft MLW) (Birkemeier, 1986). The average sediment gain or loss for two adjacent profiles was multiplied by the distance between them. Those products were summed, giving the net volume change along the entire beach.

RESULTS AND DISCUSSION

To assess changes in beach configuration, four contour maps were constructed from survey data obtained during the monitoring year (Appendix C). The overall shape of the beach, delineated by the 0 ft contour, was curvilinear throughout the study period - convex at profile 36+00 and concave on either side, at profiles 30+00 and 48+00 (Figs. C-1 through C-4). Erosion and deposition along the foreshore was inferred from the apparent migration of the 0 ft contour.

Between June and September 1988, the 0 ft contour migrated shoreward at all profiles except 30+00, 40+00, and 49+00, where it remained stationary. The migration was slight, usually less than 15 ft. During this period, the beach above elevation ≈ 7 ft was stabilized - totally reconstructed and seeded. Two berms were created parallel to the shoreline, and drainage ditches were installed. A sediment barrier and a snow fence separate the resculpted dike face above from an unaltered strip of beach below (Fig. 2-3). Shoreward migration of the 0 ft contour was probably related to the refacing of the beach. Less sediment was delivered to the nearshore, and the shoreline adjusted accordingly.

Between September and December 1988, the 0 ft contour migrated offshore along the entire shoreline, with two exceptions. The shoreline remained stationary at 30+00 and migrated slightly shoreward at 40+00. If the apparent offshore migration was real, then it probably resulted from an influx of sediment eroded from the lower dike face. However, the profiling method may have introduced an error. ISRP determines the intersection of a profile with the 0 ft contour by interpolating between the two points that bracket it. If distance and elevation are not measured near the 0 ft contour, there is a range across which the 0 ft contour can be drawn. Thus, the location of the 0 ft contour is only approximate. To eliminate this source of error in the future, surveys will include the actual 0 ft contour as delimited by leveling methods.

During the period between December 1988 and May 1989, the 0 ft contour moved shoreward on all profiles except 40+00, where it remained fixed. Erosion of the foreshore by wave attack during winter storms was responsible for the observed movement.

A comparison of contour maps for the first and last surveys of the study period (June 1988 and May 1989) shows a net shoreward migration of the 0 ft contour along the entire beach. Stabilization of the upper dike face reduced erosion; less sediment was washed down onto the foreshore and into the nearshore. Consequently, the shoreline receded.

To visualize the changing beach slope, four sets of cross-sectional profiles were constructed (Appendix D). The first set of profiles (Figs. D-1 through D-10) compares the first beach survey (June 1984) with the June 1988 survey, which immediately preceded major reconstruction of the beach. A pattern emerges of deposition at the southern end of the beach, grading into erosion at the northern end. Sediments accumulated along the lower dike face, foreshore, and immediate nearshore between profiles 21+75 and 24+00 (Figs. D-1 and D-2). The source of the deposited sediments was material eroded from the northern end of the beach and carried southward by longshore currents. The beach between profiles 28+00 and 30+00 was a transitional zone (Figs. D-3 and D-4). Erosion occurred along the lower dike face, while sediments were deposited in the foreshore and nearshore areas. In contrast to the southern profiles, the steeper slope of the dike face contributed to beach erosion by sheetwash and gully formation. Like the southern profiles, longshore currents deposited reworked sediments from the northern beach in foreshore and nearshore areas. All profiles north of 30+00 show erosion of the lower dike face and foreshore (Figs. D-5 through D-10). Beach slope was steepest along this stretch, and, consequently, sediment losses were greatest. Material eroded from the northern dike face and foreshore, in effect, nourished the beach south of profile 30+00.

Between June 1984, and June 1988, erosion of the recreational beach greatly exceeded deposition. Approximately 1000 yd^3 (765 m^3) of material accumulated in the area from profile 21+75 north to about 25+00. However, the rest of the beach lost approximately 10,800 yd^3 (8262 m^3) of sediment, yielding a net loss of 9800 yd^3 (7497 m^3).

The second set of cross-sectional profiles (Figs. D-11 through D-20), based on surveys in June and September 1988, depicts the beach immediately before and after its reconstruction and stabilization. Above 0 ft MLW, there was a calculated net gain of approximately 5800 yd^3 (4437 m^3) of sediment. Part of that increase was due to the construction of comfort stations between profiles 22+00 and 24+00. Excavated sediments were piled along profile 21+75, adding approximately 1850 yd^3 (1415 m^3) to the beach between profiles 21+75 and 24+00. This estimate is high, however, determined by averaging the net volumes gained at profiles 21+75 and 24+00, then applying that mean value across the interval between profiles. The pile of sediment at 21+75 skewed the results, which indicate a larger gain than actually occurred. It is reasonable to subtract most of the 1850 yd^3 (1415 m^3), revising the net sediment gain above 0 ft MLW to about 4000 yd^3 (3068 m^3). Part (80%) of the 4000 yd^3 increase can be accounted for by the approximately 3200 yd^3 (2448 m^3) of composted sewage sludge added to the beach as fertilizer for the newly planted vegetation.

During the same time period, erosion occurred along the foreshore and nearshore of every profile. In the immediate nearshore, approximately 620 yd^3 (474 m^3) were lost. During reconstruction of the beach, nearshore sediments may have been pushed up onto the dike face. If so, then the 620 yd^3 loss below 0 ft MLW accounts for an additional 15% of the 4000 yd^3 gain in sediment volume above 0 ft MLW. Alternatively, the erosion may have been the result of decreasing sediment input from the dike face into the foreshore and nearshore zones. The September survey was scheduled just two weeks after reconstruction of the beach. Loss of so large a volume of sediment in such a short time period would represent a rapid readjustment of the new beach to its changed form.

The third set of cross-sectional profiles (Figs. D-21 through D-30) shows geomorphic changes to the beach between September 1988 and May 1989. The stretch of beach from profile 21+75 north to 30+00 was characterized by slight deposition in the foreshore and slight erosion in the nearshore. Deposition in the foreshore was due to erosion of the lower dike face or, possibly, surveying inconsistencies. (A number of different people participated in the surveys. Identification of abrupt changes in slope was the responsibility of the rod person. One rod person may have missed an elevational difference noted during a previous survey by a different rod person.) Between profiles 32+00 and 44+00, sediment was eroded from the foreshore and nearshore by wave activity. A wave-cut escarpment extended from profile 32+00 to the northern end of the beach. Profile 48+00 exhibited slight deposition in the foreshore and erosion in the nearshore. Profile 49+00 showed almost no change in the foreshore and slight erosion in the nearshore. The area of beach between profiles 48+00 and 49+00 is partially protected from wave action by Miller Pt., a recurved spit at the southwestern end of Miller Island. The beach in the lee of Miller Pt. was not exposed to the most damaging waves, generated by winds from northerly directions. That stretch of beach also benefitted from the reflection of waves approaching from the west and breaking at 44+00 (deposition to the north).

A total of 1514 yd^3 (1158 m^3) of material was eroded from the recreational beach between September 1988 and May 1989. (In calculating net sediment gains and losses for the period, the recently stabilized upper dike face was excluded.) Above 0 ft MLW, a net total of approximately 600 yd^3 (459 m^3) was eroded from the foreshore and lower dike face. South of 28+00, 345 yd^3 (264 m^3) were deposited; between 28+00 and 42+00, 1120 yd^3 (857 m^3) were eroded; and north of 42+00, 175 yd^3 (134 m^3) were deposited. Below 0 ft MLW, the entire beach underwent erosion, totalling approximately 914 yd^3 (699 m^3) for the period. In the past, erosion of sediment from the outer dike face nourished the foreshore and nearshore zones of the beach. Stabilization of the outer dike face arrested the influx of sediment to those zones. Less sediment was available to nourish the beach and, consequently, net erosion increased.

To understand the redistribution of sediments between the foreshore and nearshore, four profiles (21+75, 30+00, 40+00, and 49+00) were extended offshore, approximately 300 ft beyond 0 ft MLW. The results of the extended surveys are presented in the fourth set of cross-sectional profiles (Figs. D-31 through D-34). Erosion characterized each of the nearshore profiles. However, erosion was confined to the first 50-75 ft bayward of 0 ft MLW. Beyond that, the bottom remained unchanged. By September 1989, nearshore sediments present in June 1988 had been removed, carried away by longshore currents. These sediments were probably redistributed to the south of 21+75 or to the north of 49+00, behind Miller Pt. The reduced input of eroded sediment from the stabilized upper dike face and foreshore could not compensate for the erosional loss in the nearshore.

ESCARPMENT FORMATION

Escarpments are formed when wind-generated waves attack the beach, particularly during a tidal surge. Northerly winds blow over the greatest expanse of water or fetch and, consequently, produce the largest waves - those most damaging to the beach. Tidal surges may be caused by wind conditions during storms, lunar cycles (spring tides), or the sloshing (seiche) of water in the Chesapeake Bay basin.

The recreational beach was graded in May 1988, erasing gullies and the large escarpment that had formed during the preceding year. By June 1988, the first survey of this monitoring year, a small escarpment had begun to form at approximately 30+00. It rose in height northward, to 0.5-1 ft at the northern end of the beach.

Climatological data (wind parameters and amount of precipitation) were recorded by the Maryland Environmental Service (MES) at a weather station located 1 mi (1.6 km) east of the recreational beach. Wind roses were generated from the recorded information (Fig. 2-5). The precipitation data listed in Table 2-4 were used to correlate rain events with high winds and probable tidal surges.

Between May 27 and June 15, 1988, the wind blew from northerly directions at a velocities greater than 10 mi/hr on only two days.

Table 2-4: Precipitation data collected by MES.

Date	Rainfall (in.)	Date	Rainfall (in.)	Date	Rainfall (in.)
June 8	0.4	Dec. 11	0.01	Apr. 16	0.50
9	0.51	18	0.01	17	0.01
16	0.10	21	0.24	18	0.02
17	0.02	23	0.24	19	1.05
		27	0.14	20	0.03
July 11	0.03	28	0.22	29	0.12
12	0.03			30	0.60
17	0.01	Jan. 6	0.24		
19	0.01	15	0.86	May 1	0.03
21	1.60	26	0.12	2	1.90
23	2.75	30	0.40	3	0.02
24	0.10	31	0.05	4	0.02
26	0.40			5	0.38
27	0.19	Feb. 3	0.38	6	1.82
28	0.04	4	0.30	7	0.02
		14	1.10	10	0.25
Aug. 3	0.15	15	0.24	11	0.32
6	0.15	16	0.15	12	0.04
20	1.60	21	0.29	13	0.01
23	0.36	22	1.15	16	0.64
24	0.25	27	0.10	17	0.30
25	0.05			18	0.01
29	1.60	Mar. 4	0.20		
		5	0.02		
Sept. 4	1.50	6	0.70		
9	0.10	7	0.50		
13	0.10	19	0.38		
24	0.15	21	0.48		
25	0.60	22	0.05		
		24	0.70		
Oct. 2	0.51	25	0.50		
3	0.10	27	0.02		
18	0.01	30	0.07		
21	1.50	31	0.40		
24	0.15				
		Apr. 1	0.40		
Nov. 1	0.62	2	0.02		
5	0.30	3	1.00		
6	0.10	4	0.04		
7	0.10	5	0.03		
11	0.12	6	0.80		
16	0.10	7	0.03		
19	0.58	8	0.38		
20	0.03	9	0.13		
27	1.32	12	0.01		
28	0.82	15	0.10		

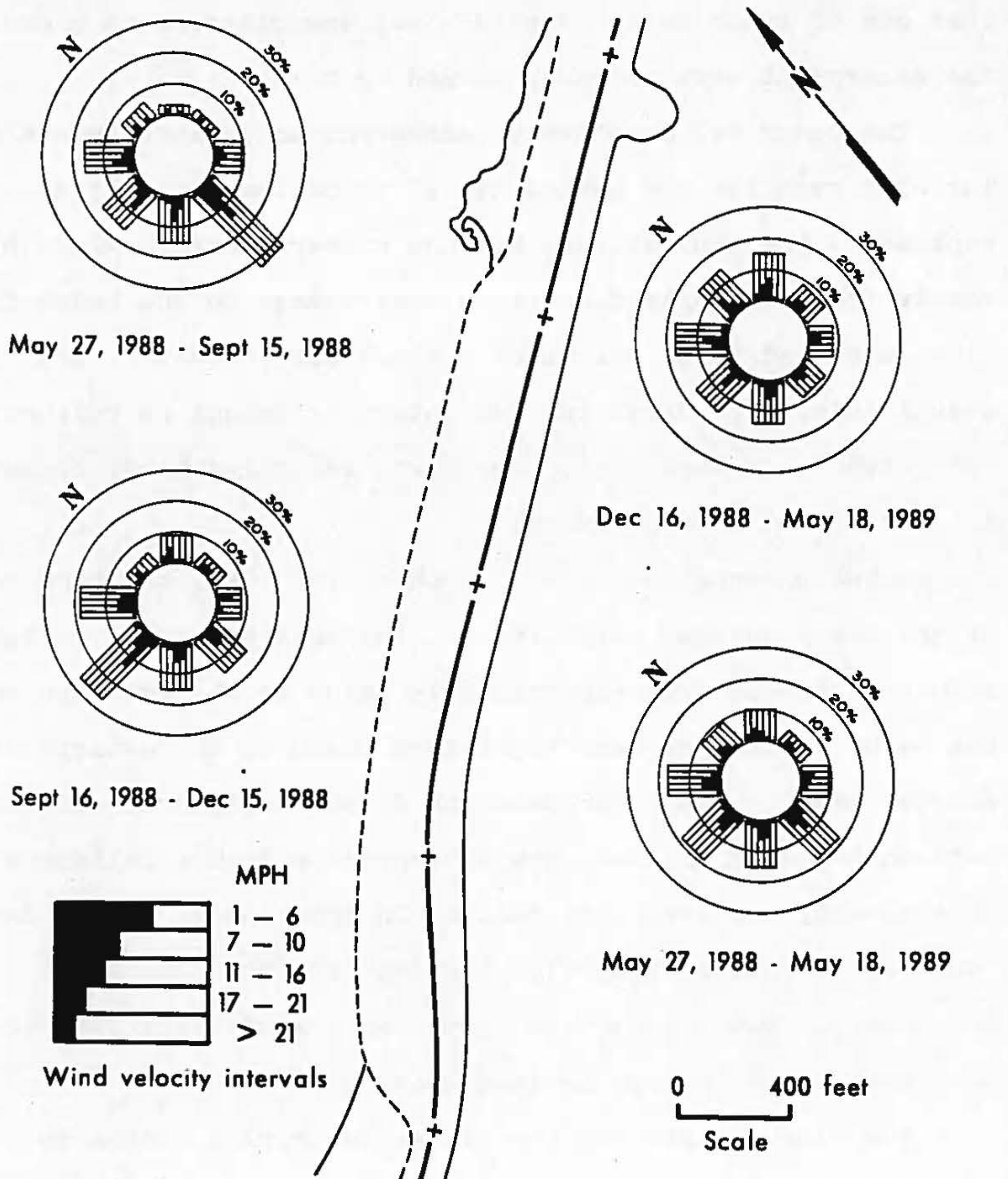


Figure 2-5: Wind climate in the vicinity of Hart-Miller Island for the period May 27,1988, to May 18, 1989, from MES records.

Just one of those days - June 8 - was associated with a storm. The escarpment most probably formed on that day.

The beach was completely reconstructed in late August 1988. The wind rose for the period May 27 to September 15, 1988, represents the wind climate for the summer months. Winds blew mostly from southerly directions, and damage to the beach from wind-generated waves was minor. Tidal data, however, are unavailable; wind direction and intensity cannot be related to tide stage. In September, vegetation was very thick, obscuring the escarpment in many areas.

Between September 15 and December 15, 1988, the appearance of the beach changed very little. The escarpment, of variable height, extended from approximately 28+00 to the northern end of the beach. Dying or dead vegetation obscured the escarpment in several areas. The escarpment was dissected by numerous gullies. Between adjacent gullies, the escarpment commonly collapsed and, as a result, was less well defined in appearance. Winds during that period shifted slightly, blowing from more westerly directions. Waves generated by westerly winds were incapable of producing a new, better defined escarpment.

The wind climate for the winter and spring months is represented by the wind rose for the time period December 16, 1988 to May 18, 1989. Winds shifted from southerly and westerly directions to northerly ones and generated beach-damaging waves. During the May 1989 survey, a well-defined escarpment extended the entire length of the beach. At profile 21+75, the escarpment was very small (≤2 in.). It rose in height to the north, with the greatest relief between 36+00 and 40+00. The dates when meteorological conditions were most favorable for escarpment formation were March 6, 7, and 24. On other stormy days, the wind was either blowing from a direction other than north or was of lesser intensity (<15 mph).

GULLY FORMATION

Gully development along the recreational beach is controlled by the intensity of rainstorms and the slope of the beach. Rainfall intensity, the criterion used to define a "storm" (at least half an inch of rain in half an hour (Barnett and Hendrickson (1960)), could not be determined from the weather data collected at the containment facility. Only the amount of rain falling in a 24-hour period is recorded (Table 2-4). Gully development was assumed to be limited to those days on which total rainfall exceeded 0.5 in. Based solely on the amount of precipitation, there were 28 storms during the monitoring year. A total of 42.43 in. of rain was reported. Storms accounted for 29.33 in. of that total, or 69 %. These values are similar to those for the preceding monitoring year (Hennessee et al., 1989).

A minimum average slope of 4.1-4.2° is prerequisite to gully formation on the recreational beach (Wells et al., 1986, 1987). Throughout the monitoring period, the slope of the dike face equalled or exceeded the critical minimum average on all profiles except 21+75 and, occasionally, 24+00 (Table 2-5). If no steps had been taken to deter erosion, gullying would have occurred on all profiles except 21+75.

Table 2-5: Average slope, in degrees, of beach profiles, by survey date, from center of roadway to water line (6/88) or from snow fence to water line (9/88 through 5/89).

Profile	Survey date 6/88	9/88	12/88	5/89
21+75	3.0	3.1	2.9	3.5
24+00	3.5	4.3	3.7	4.2
28+00	4.4	5.5	5.1	5.4
30+00	5.2	6.0	6.0	6.8
32+00	5.1	8.0	8.3	8.7
36+00	4.3	5.9	7.0	7.8
40+00	4.3	7.7	8.9	8.3
44+00	5.0	8.5	9.3	8.8
48+00	6.2	11.6	10.6	10.0
49+00	5.5	8.4	10.8	9.2

The beach was surveyed about two weeks after the May 1988 regrade. Very shallow (<2 in.) gullies were observed from 42+00 northward. Two days of rainfall - June 8 and 9 - probably initiated the development of these incipient gullies.

Between the first and second surveys of the monitoring year (June and September 1988), the beach was reconstructed. Although the beach was vegetated below the snow fence, vegetation was sparse or absent in two areas: (1) 32+00 to 35+00 and (2) 41+00 to 48+00. Both areas were subject to sheetwash as well as gully erosion.

Rainfall totalled 12.72 in. during the period. Five storms capable of producing sufficient rainfall to cause sheetwash and gully erosion accounted for 8.95 in., or 70% of the total rainfall. Sheetwash erosion stripped the dike face of sediment just below the snow fence. The combination of sheetwash erosion, beach reconstruction, and wave activity led to a dramatic increase in the average slope of the beach. From September 1988 onward, sheetwash and gully erosion became increasingly severe in response to the increase in slope along all profiles except 21+75 and 24+00.

By December 1988, the number, depth, and areal extent of gullies had increased. Gullies were present on the lower dike face between 27+00 and 36+00 and between 41+00 and 48+00. Increased slopes, due to intense rainfall, and a lack of vegetation promoted gully formation. The total rainfall for the period September to December 1988 was 7.12 in. Less rain fell than during the preceding period. There were, however, seven storms, accounting for 84% of the total rainfall (5.95 in.) Vegetation on the beach in December 1988 was either dead or dying. Only a few areas retained remnants of growth from the summer months.

Erosion of the recreational beach was greatest during the period December 1988 to May 1989. Gullies were present between 27+00 and 36+00 and between 41+00 and 48+00. Although the gullies were not deeply incised, they commonly intersected one another. The dike face below the snow fence appeared "washed out".

Average beach slopes from the snow fence bayward to the water line increased on profiles 21+75 through 36+00 and decreased on 40+00 through 49+00. However, except for 21+75 and 24+00, all the profiles exceeded the critical slope of 4.1-4.2°. Average beach slope was altered by storms. Sheetwash erosion, gully development, and escarpment formation all contributed to the increased erosion along profiles 21+75 through 36+00. The slight decrease in slope for profiles 40+00 through 49+00 was due to deposition of sediments from the lower dike face along the upper foreshore.

Total rainfall for the period was 21.92 in., or 52% of the yearly rainfall. Storms accounted for 13.82 in., or 63% of the rainfall for the period. In May 1989, vegetation was beginning to reappear along the beach. However, the run of beach from about 41+00 to 48+00 remained barren. Aerial photographs of that section of the beach indicate the presence of a much lighter-colored sediment. It is possible that much finer-grained sediments were exposed following erosion of the reconstructed beach.

CONCLUSIONS

Wind-induced waves, in combination with high tides, were responsible for most of the erosion to the foreshore and nearshore of the recreational beach. Waves assaulting the beach created erosional escarpments. Sheetwash erosion, though greatly reduced from past years by upper dike stabilization, occurred in certain areas due to the increase in the slope of the reconstructed beach. Gullies formed below the snow fence almost immediately after reconstruction, also as a result of the increase in slope.

Following stabilization of the beach, the volume of eroded sediment was much less than in previous years. Between June 1984 and June 1988, approximately 11,000 yd^3 (8410 m^3) of sediment were removed from the beach above the 0 ft contour. Approximately 600 yd^3 (459 m^3) of sediment above 0 ft MLW and 900 yd^3 (688 m^3) below 0 ft MLW were eroded during the period September 1988 to May 1989. Erosion in the foreshore decreased on all profiles except 30+00 and 32+00. Gully erosion was slight compared to past monitoring periods.

RECOMMENDATIONS

Although the upper dike face has been stabilized, the strip of beach below the snow fence is still subject to erosion, particularly by wave attack. Vegetating the area immediately downslope of the snow fence would reduce sheetwash erosion. With a reduction in the erosion of sediment from the upper and lower dike face, material lost from the foreshore and nearshore will not be replenished, and shoreline erosion will accelerate. To alleviate this situation, sand replenishment and/or the installation of an offshore breakwater may be necessary. Yearly renourishment of the foreshore and immediate nearshore would also reduce the beach slope, thereby deterring sheetwash erosion and creating an aesthetically-pleasing beach.

ACKNOWLEDGMENTS

The following people were among the survey crews that collected data along the recreational beach: Marguerite Toscano, Philip Allen, Lamere Hennessee, Sally Jones, Randall Kerhin, Dave Bibler, Kathryn Koczot, Darlene Wells, William Panageotou, Brian Maccubbin, and Laura Malinoski. Climatological data were supplied by the Maryland Environmental Service, and bench mark data were supplied by the Great Lakes Dredging Company.

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APPENDICES

Appendix A: Xeroradiographs of the gravity cores.

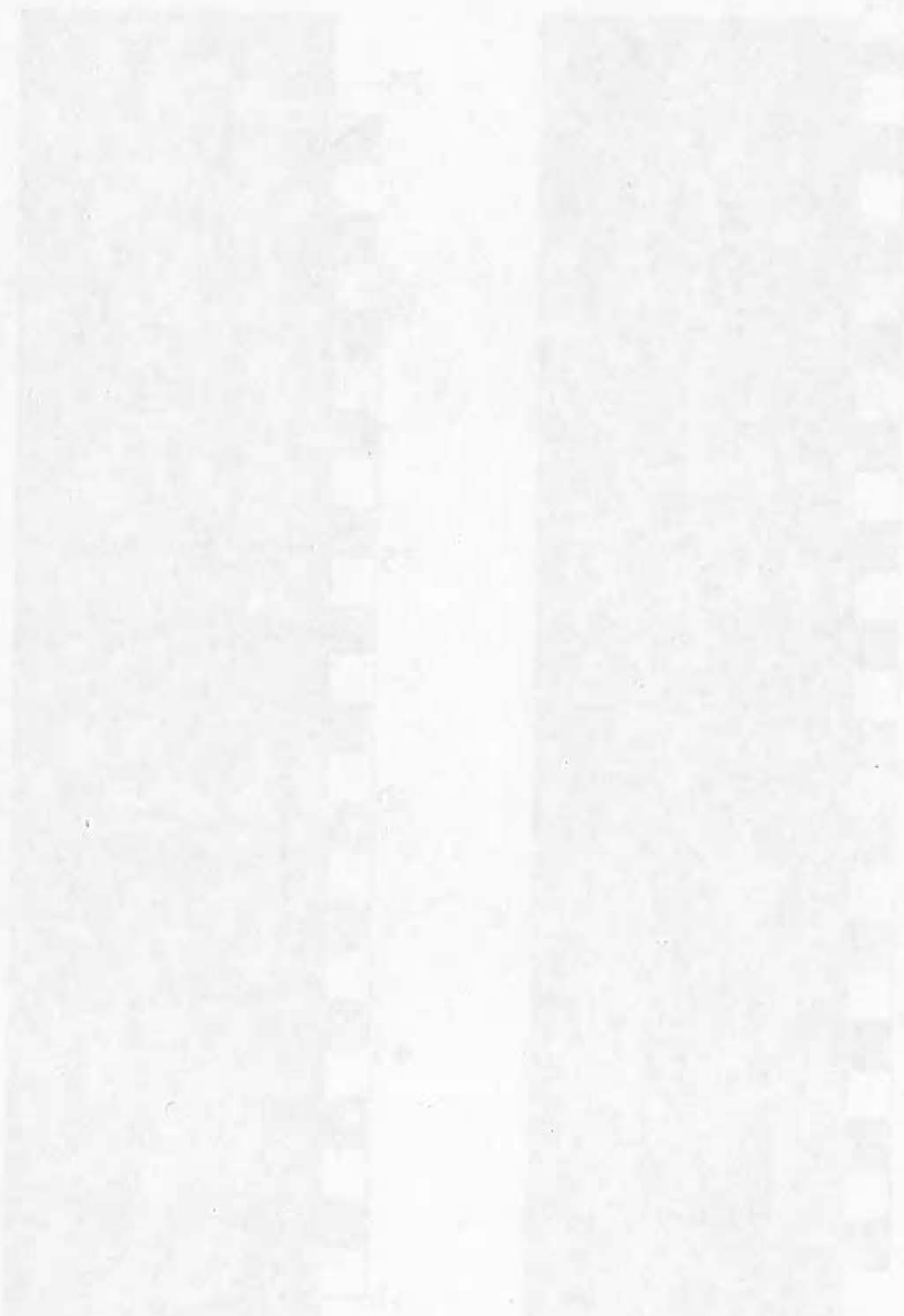
Appendix B: Shepard's diagrams and component (sand-silt-clay) plots of selected stations.

Appendix C: Contour maps of the recreational beach.

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

APPENDIX A

Xeroradiographs of the gravity cores.



HART-MILLER ISLAND - 8th Year
Core BC-1 April 4, 1989

Figure A-1

HART-MILLER ISLAND - 8th Year
Core BC-2 April 4, 1989

Figure A-2

HART-MILLER ISLAND - 8th Year
Core BC-3 April 4, 1989

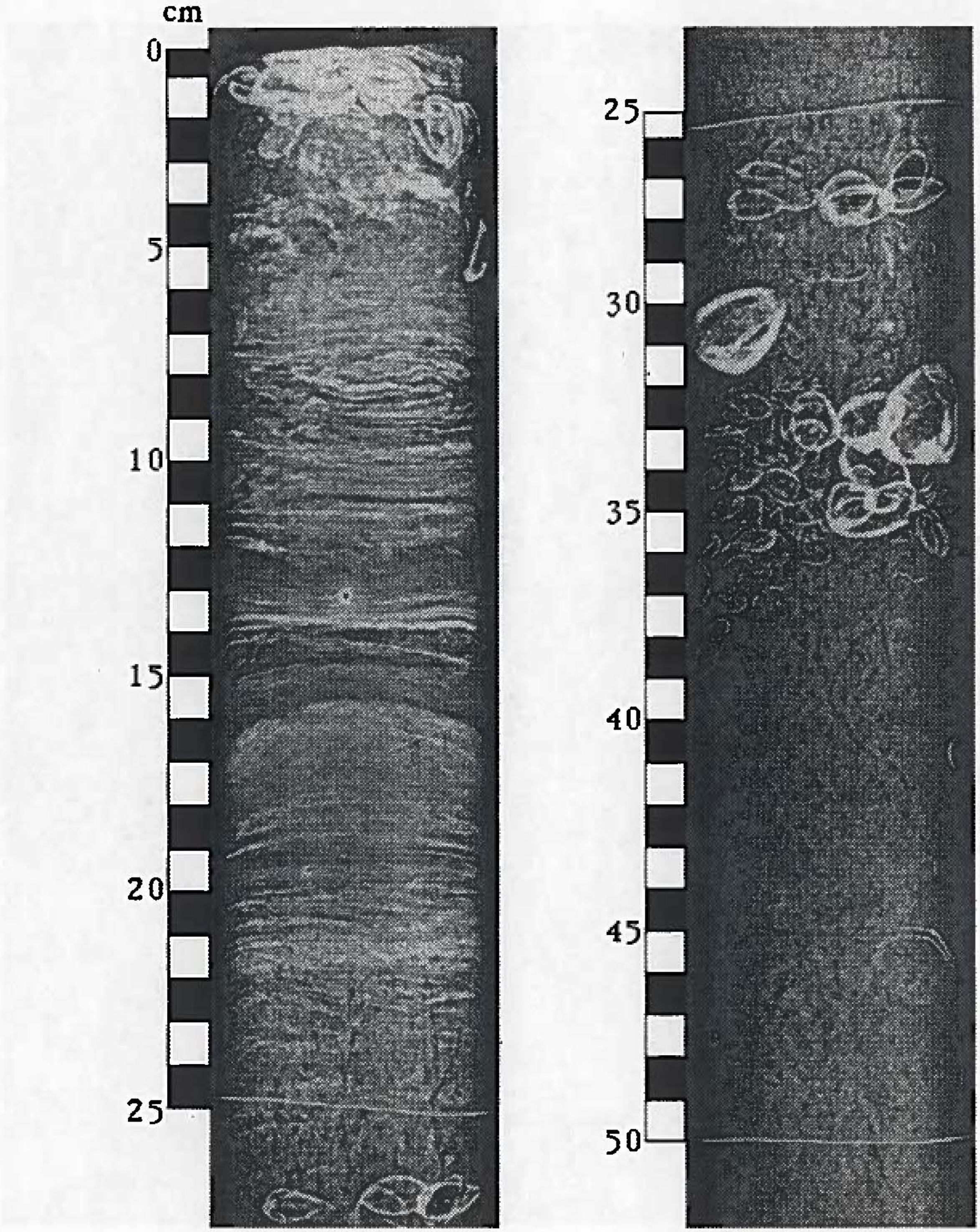


Figure A-3

HART-MILLER ISLAND - 8th Year
Core BC-4 April 4, 1989

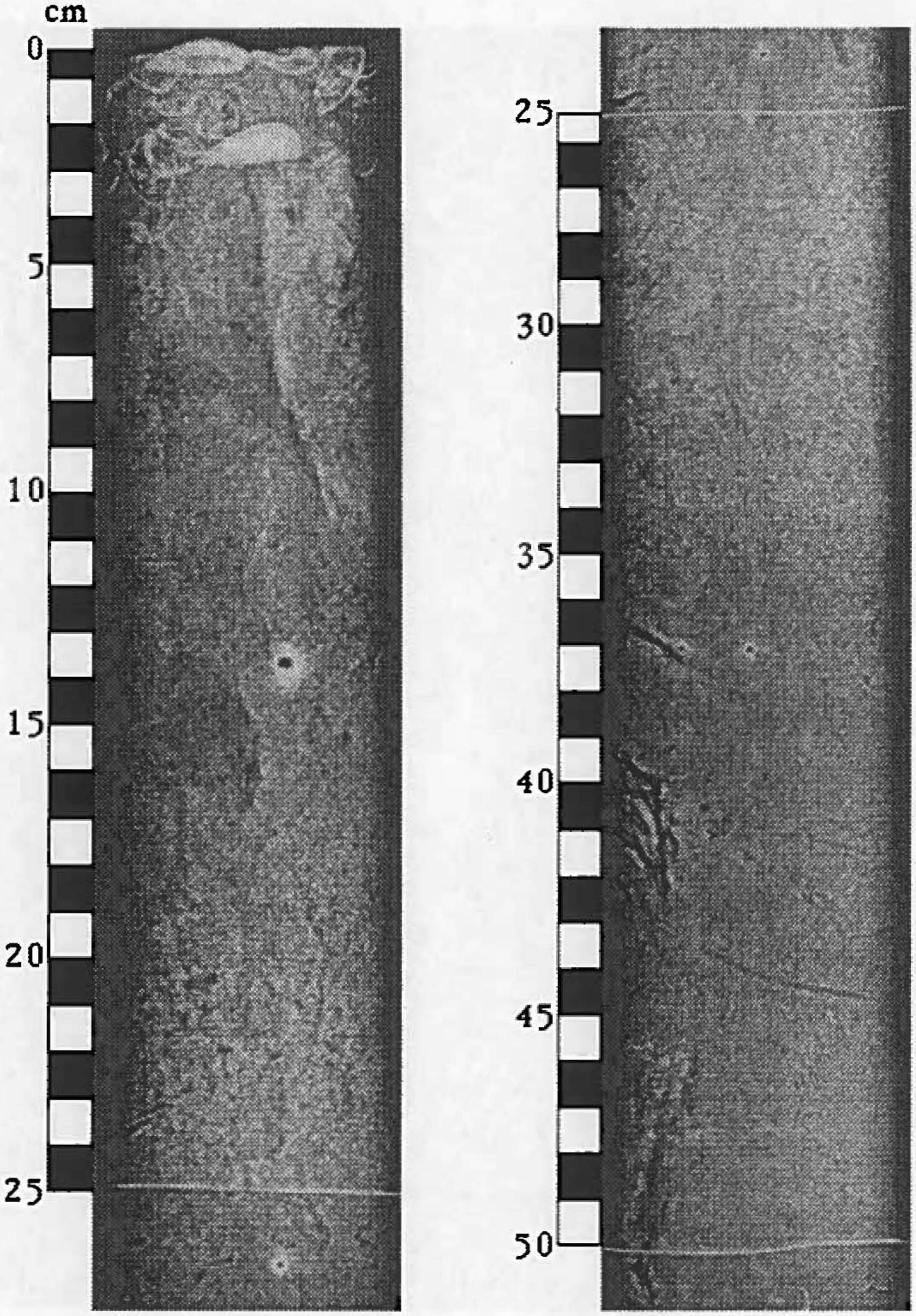


Figure A-4

HART-MILLER ISLAND - 8th Year
Core BC-5 April 3, 1989

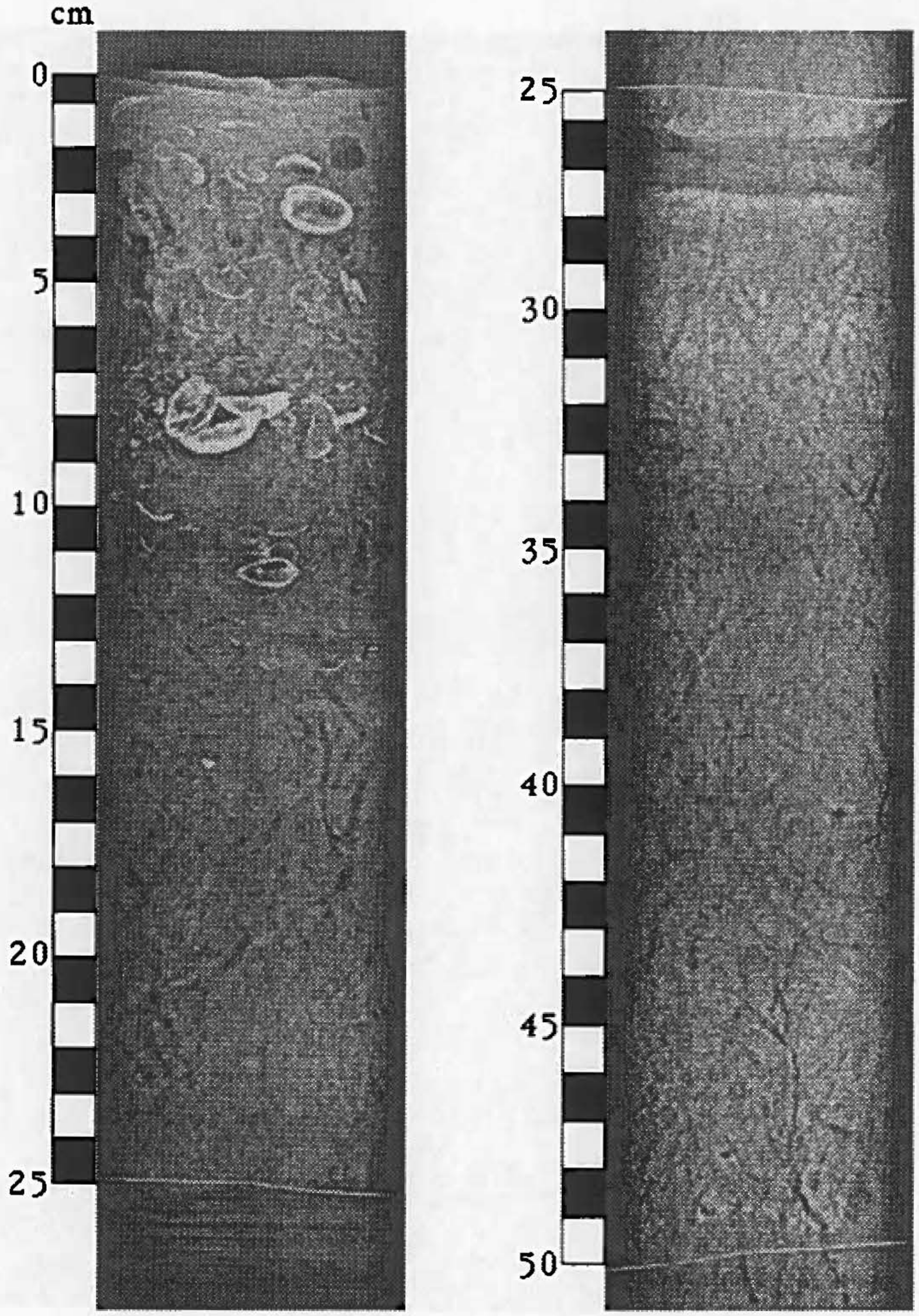


Figure A-5

HART-MILLER ISLAND - 8th Year
Core BC-6 April 3, 1989

Figure A-6

HART-MILLER ISLAND - 8th Year
Core BC-7 April 3, 1989

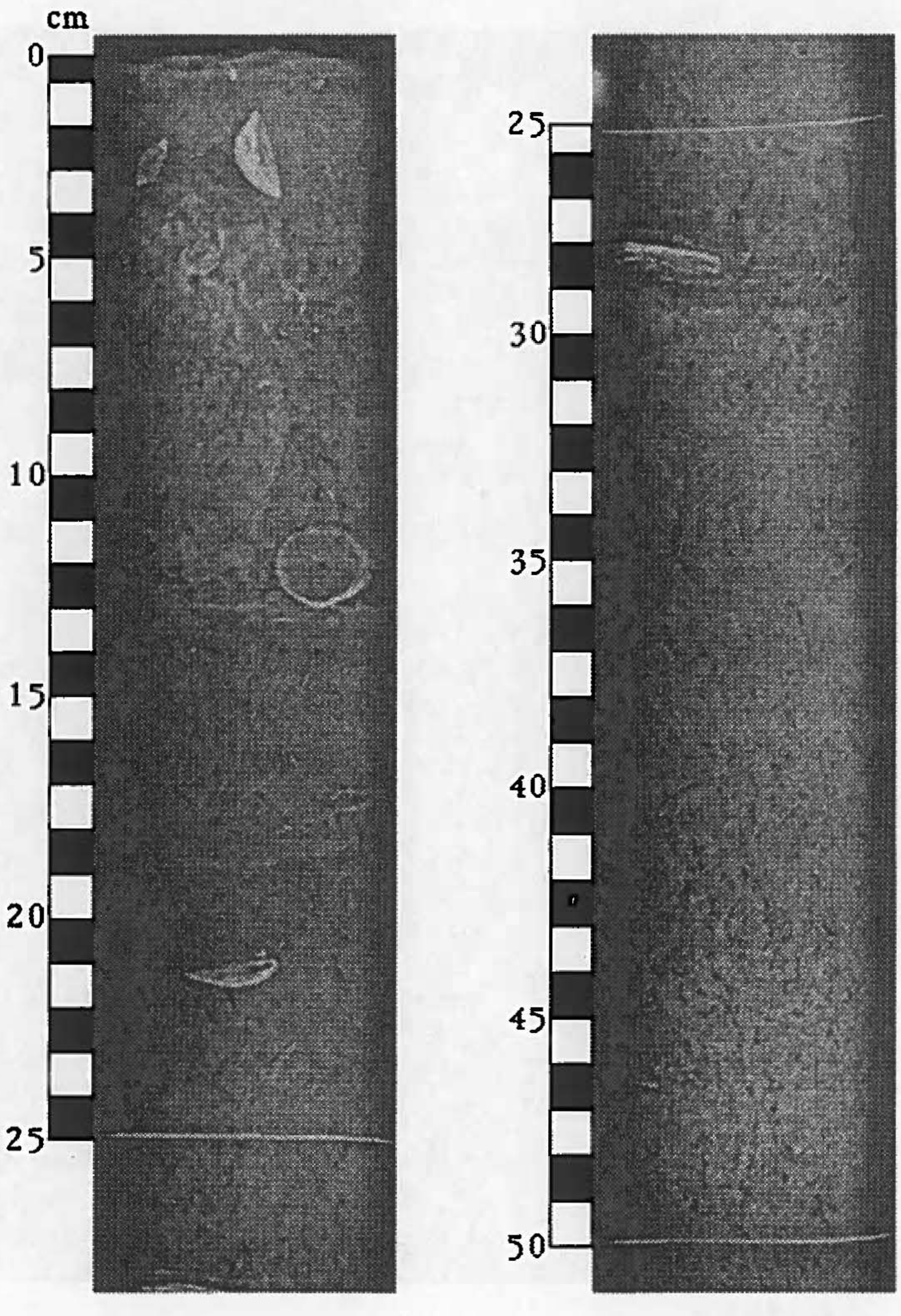


Figure A-7

HART-MILLER ISLAND - 8th Year
Core 12 April 4, 1989

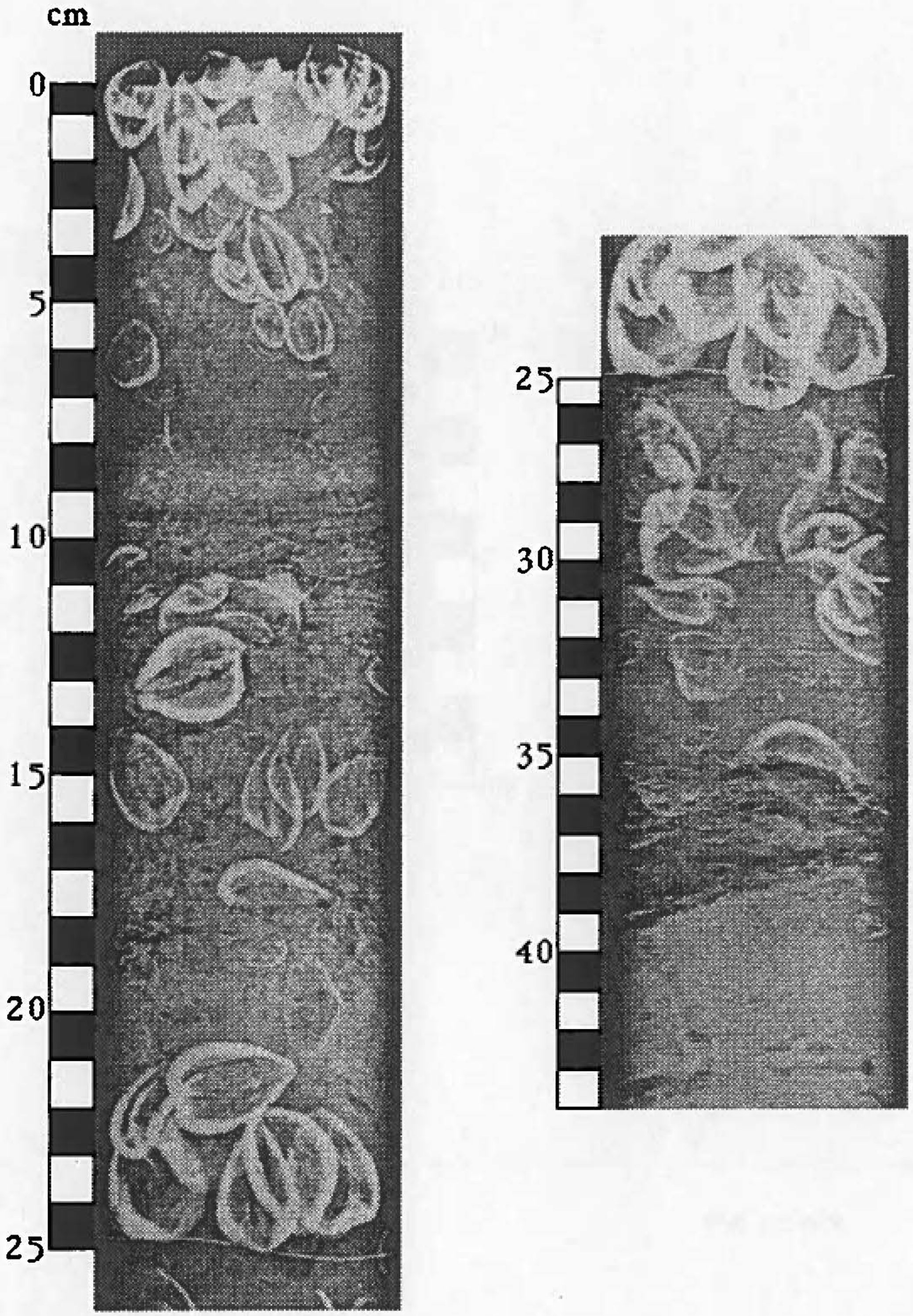


Figure A-8

HART-MILLER ISLAND - 8th Year
Core 12A April 4, 1989

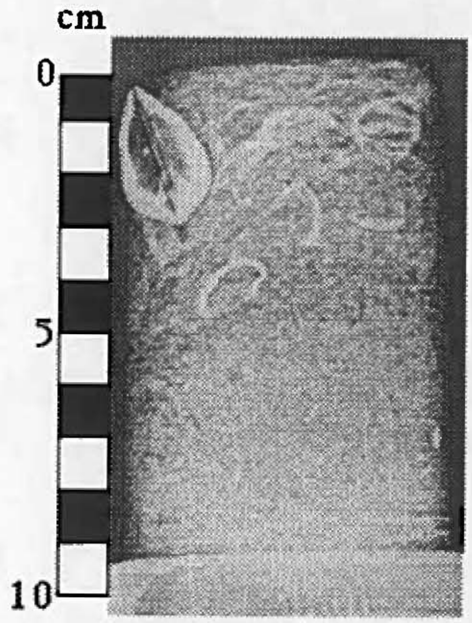


Figure A-9

HART-MILLER ISLAND - 8th Year
Core 12B   April 4, 1989

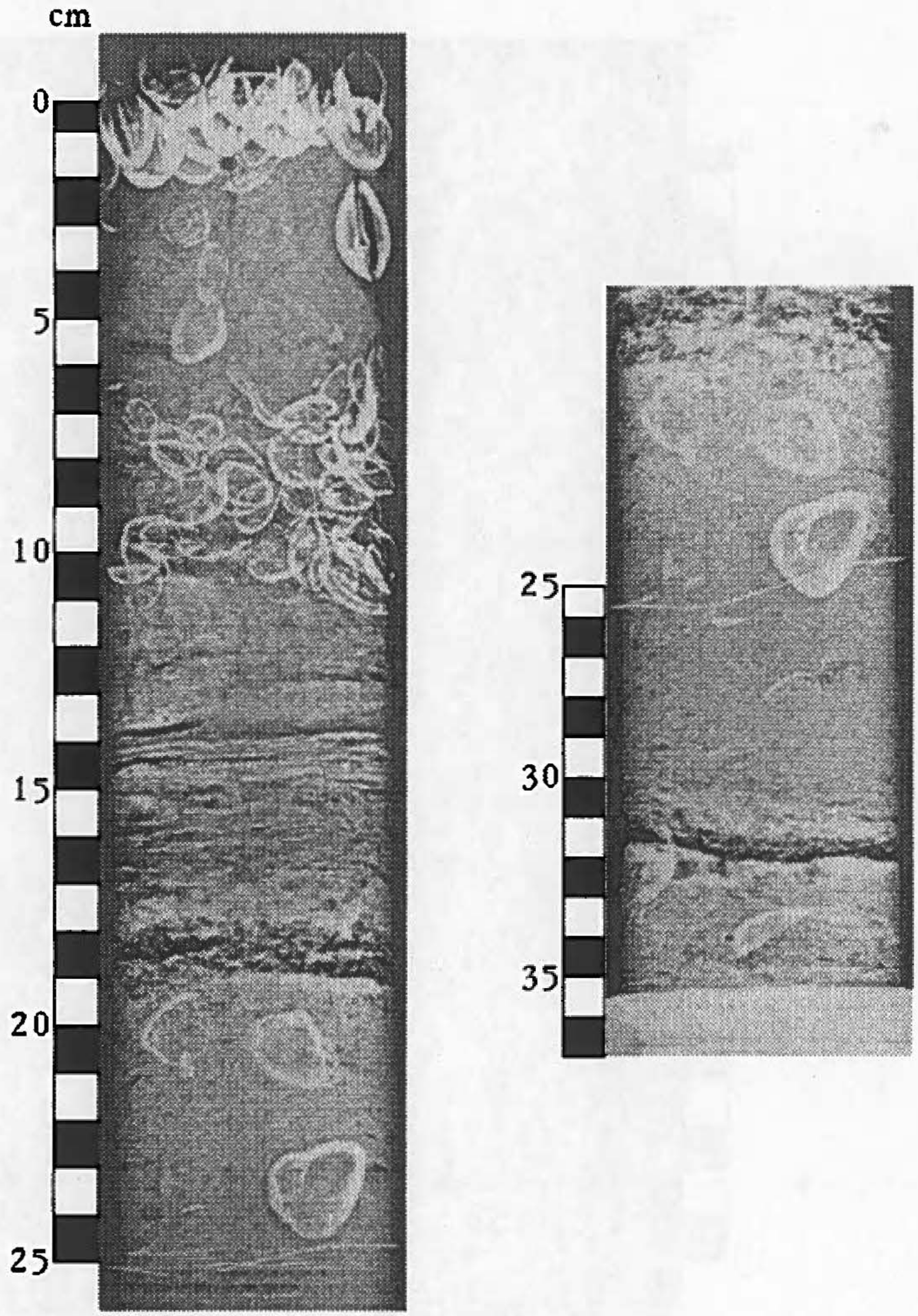


Figure A-10

HART-MILLER ISLAND - 8th Year
Core 12C April 4, 1989

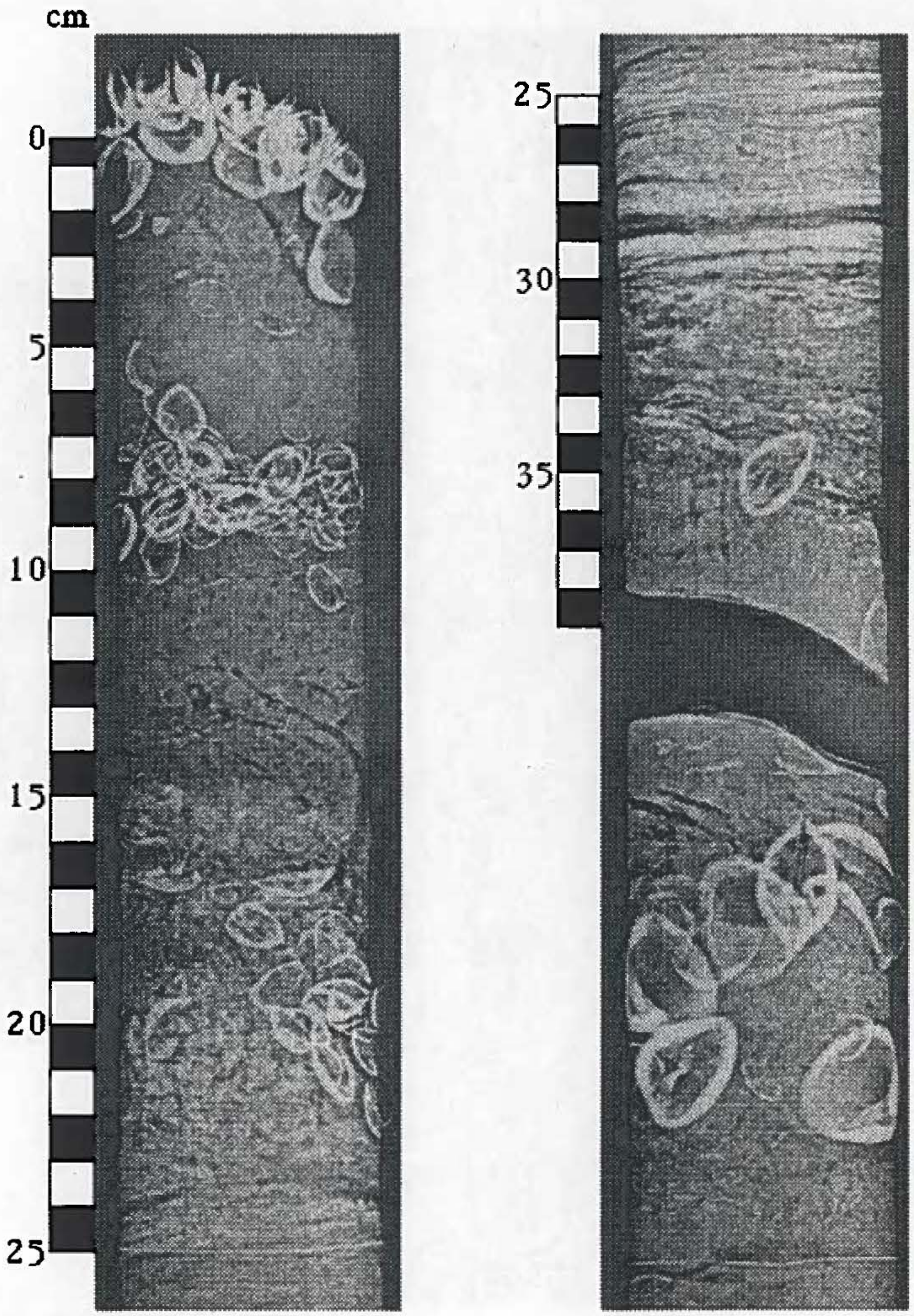


Figure A-11

HART-MILLER ISLAND - 8th Year
Core 12D April 4, 1989

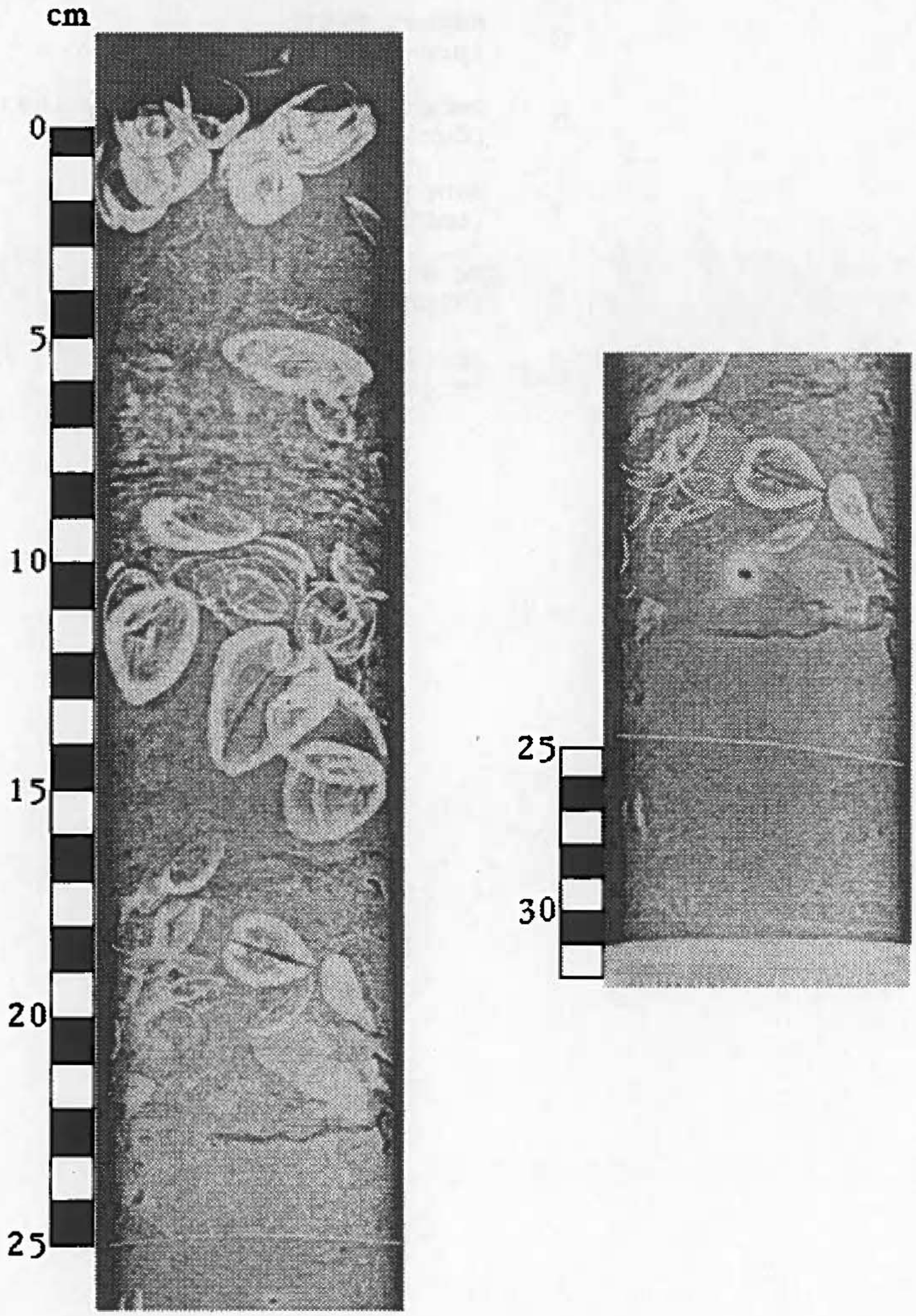


Figure A-12

APPENDIX B

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

LEGEND (Shepard's diagram)

○	August 1981 (pre-construction)
△	December 1981 - February 1983 (during construction)
+	June 1983 - April 1988 (post-construction)
×	November 1988 (eighth monitoring year)
◇	April 1989 (eighth monitoring year)

STATION 3

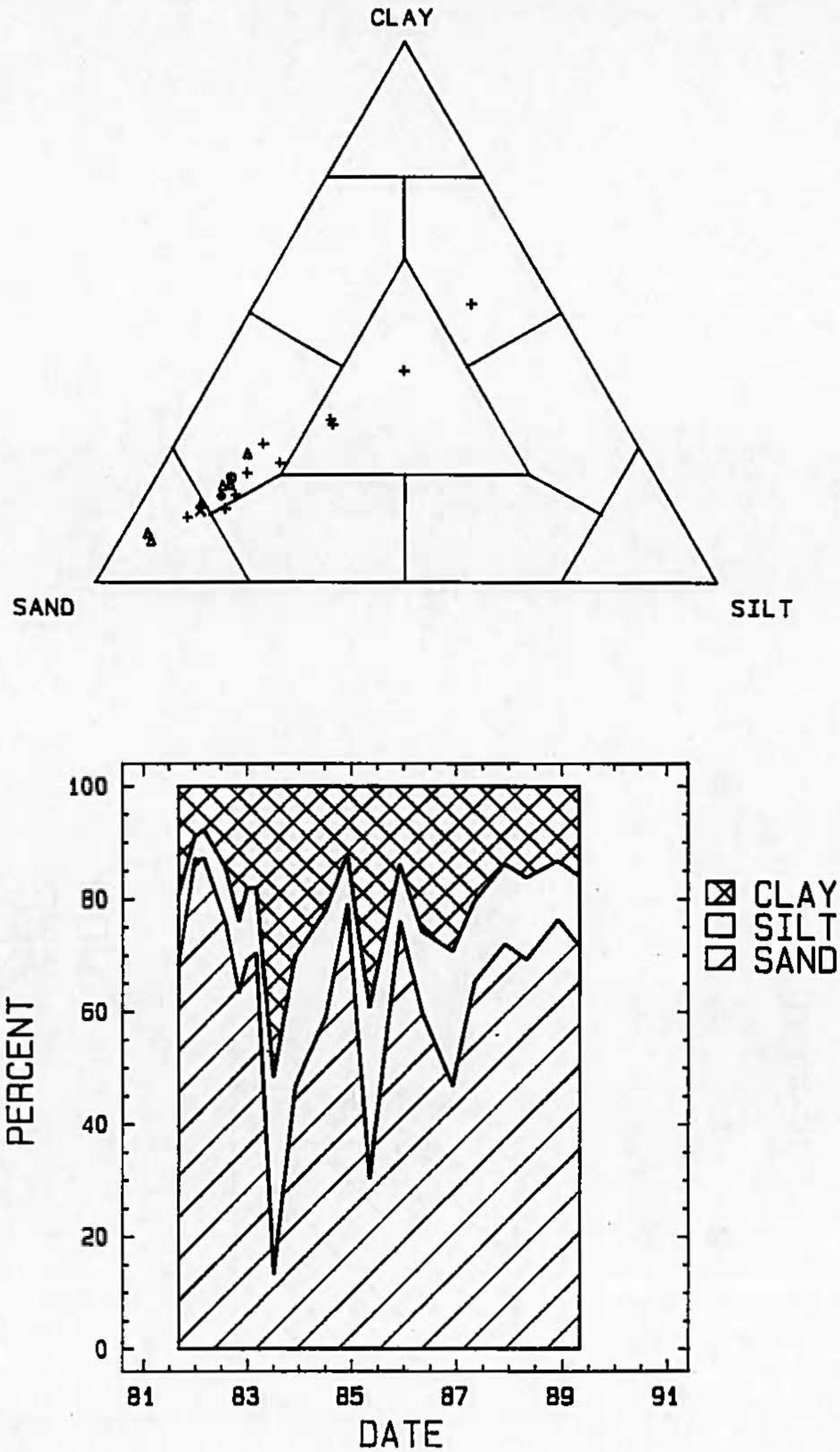
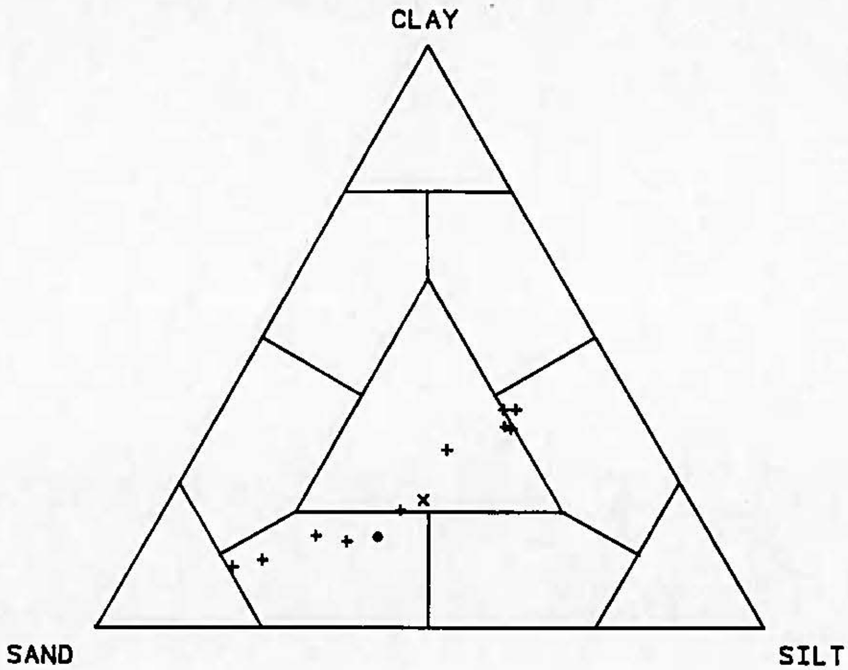


Figure B-1

STATION 8A



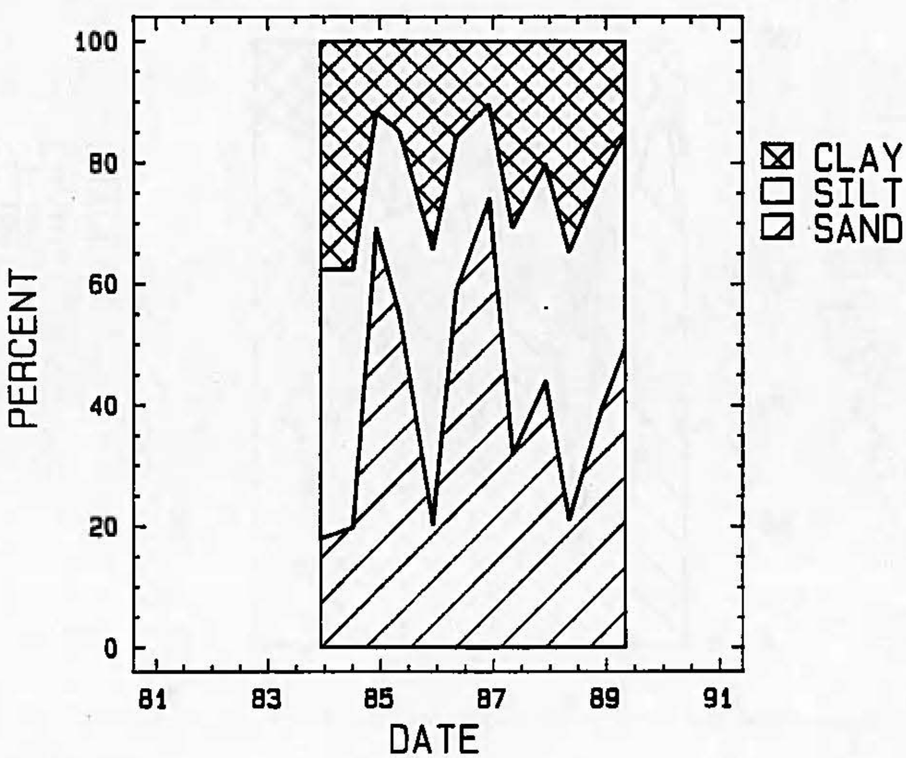


Figure B-2

STATION 12

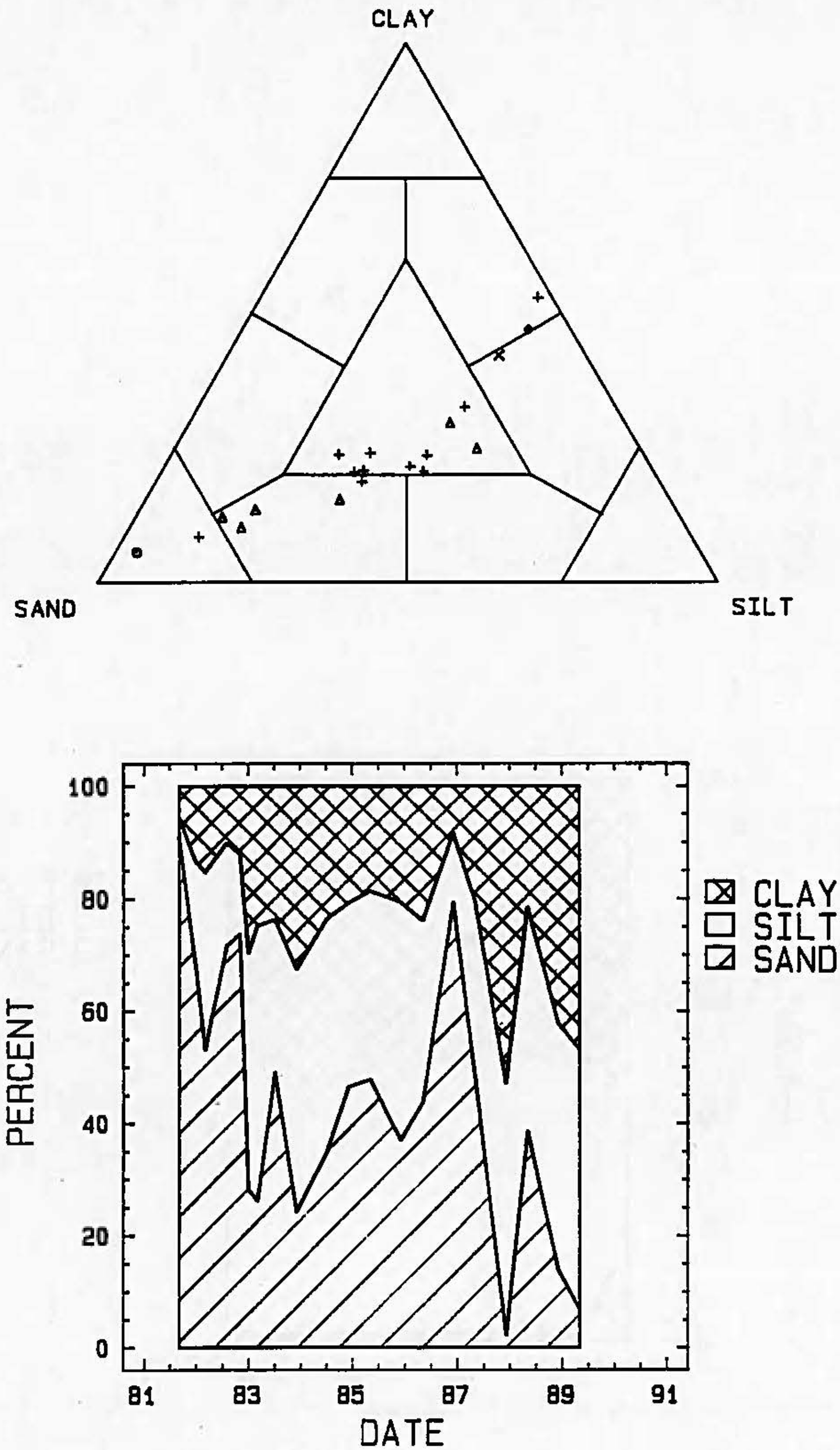
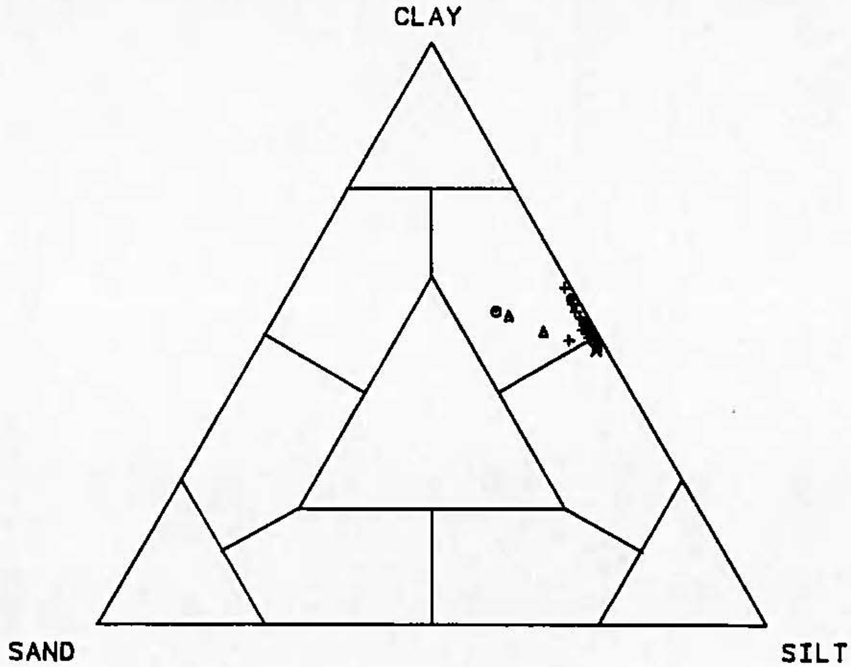


Figure B-3

STATION 14



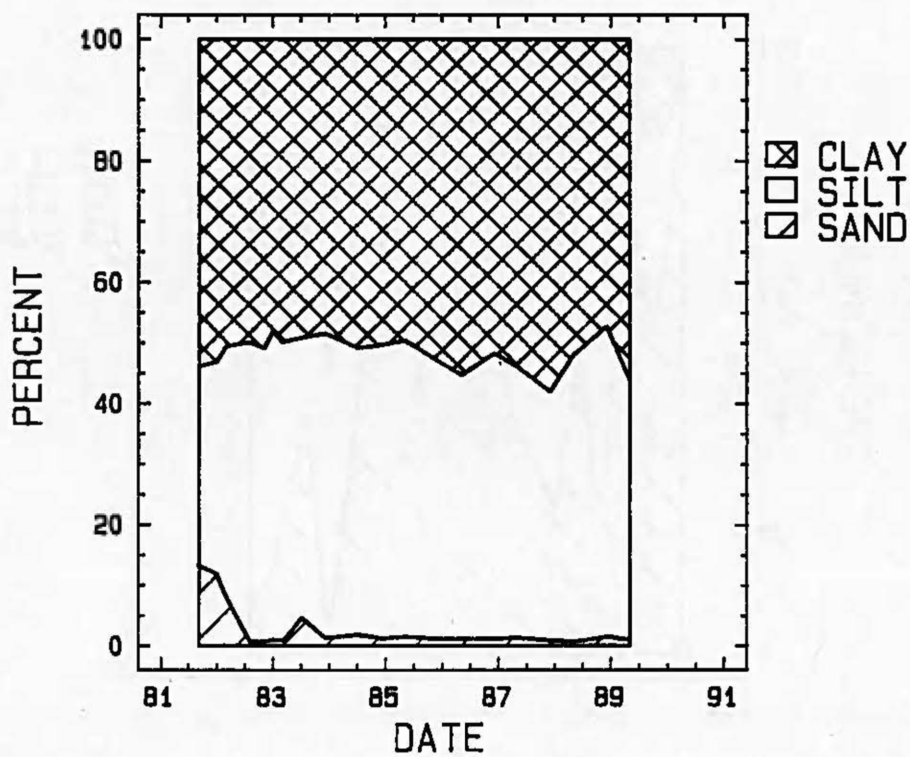
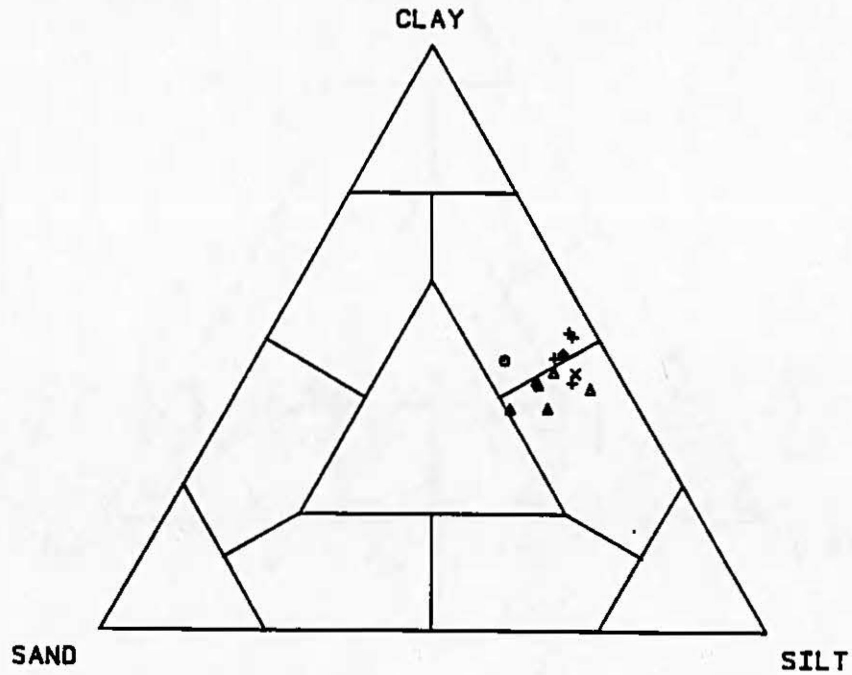


Figure B-4

STATION 18



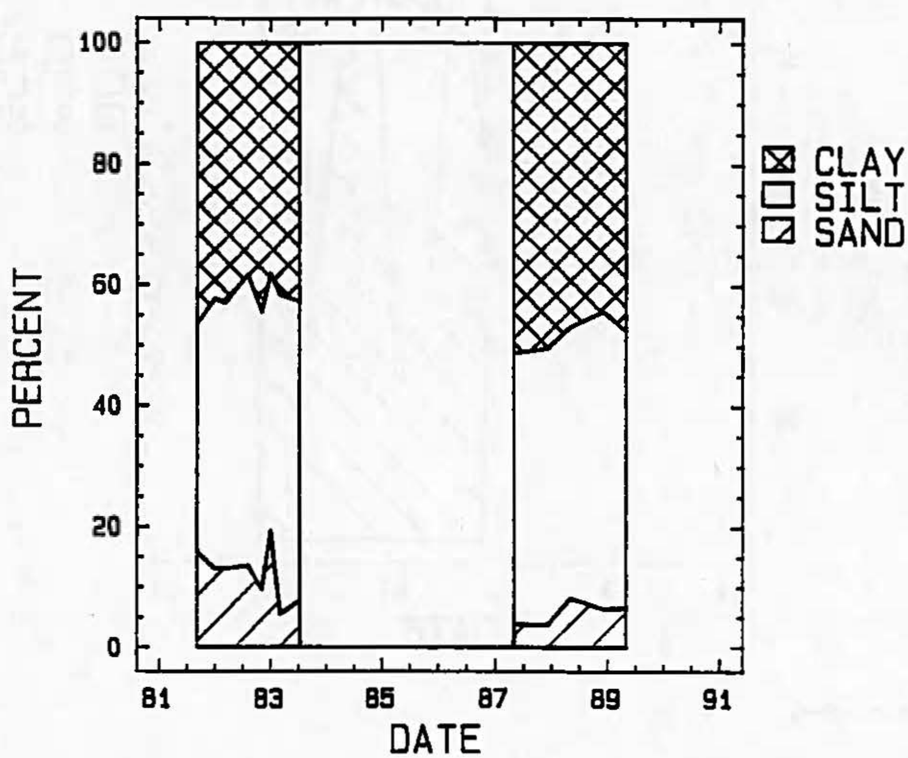
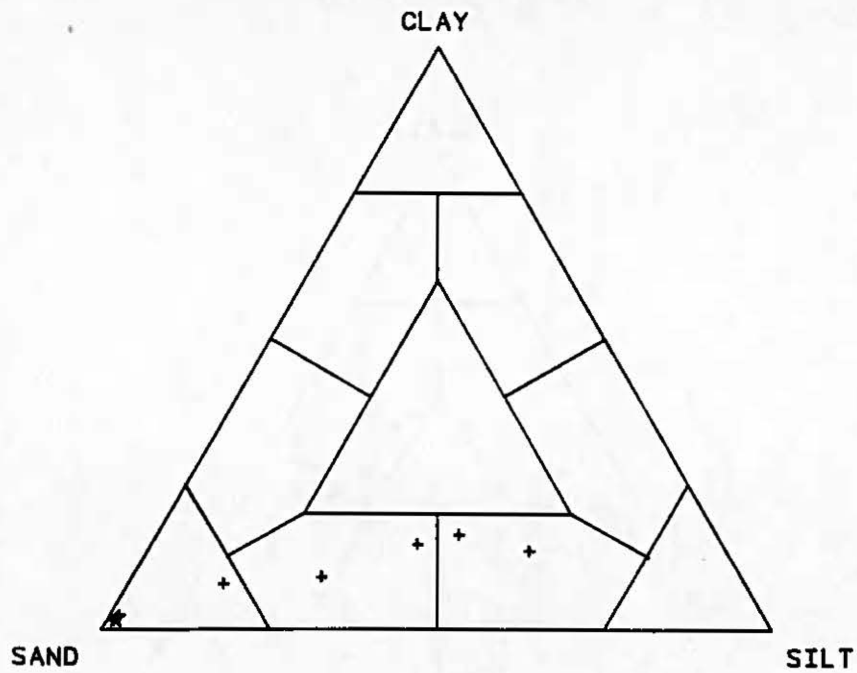


Figure B-5

STATION 21B



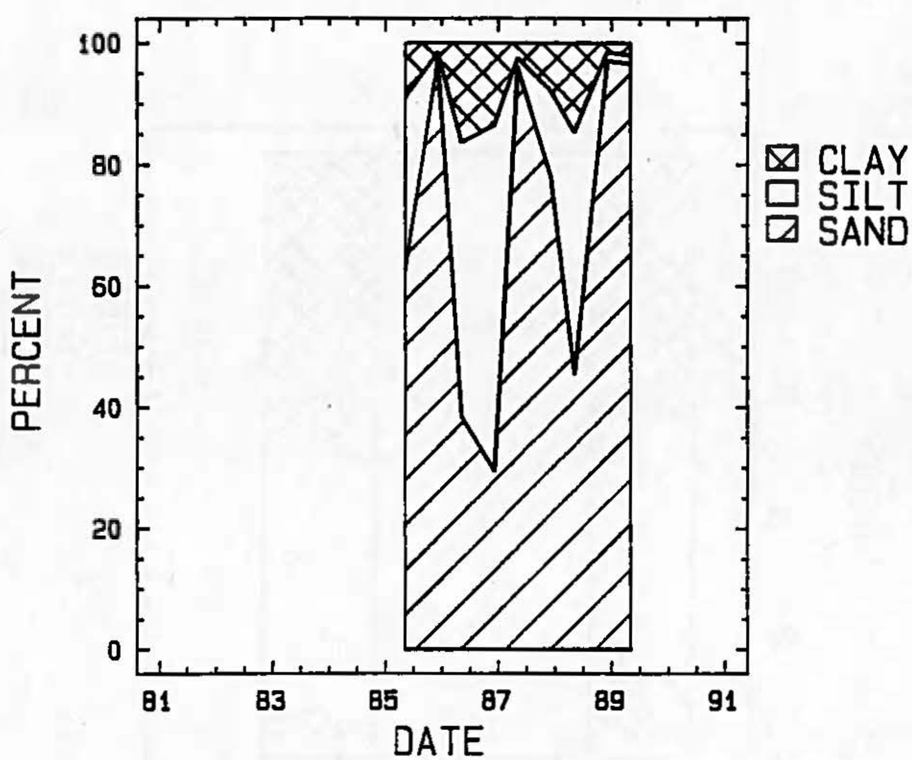
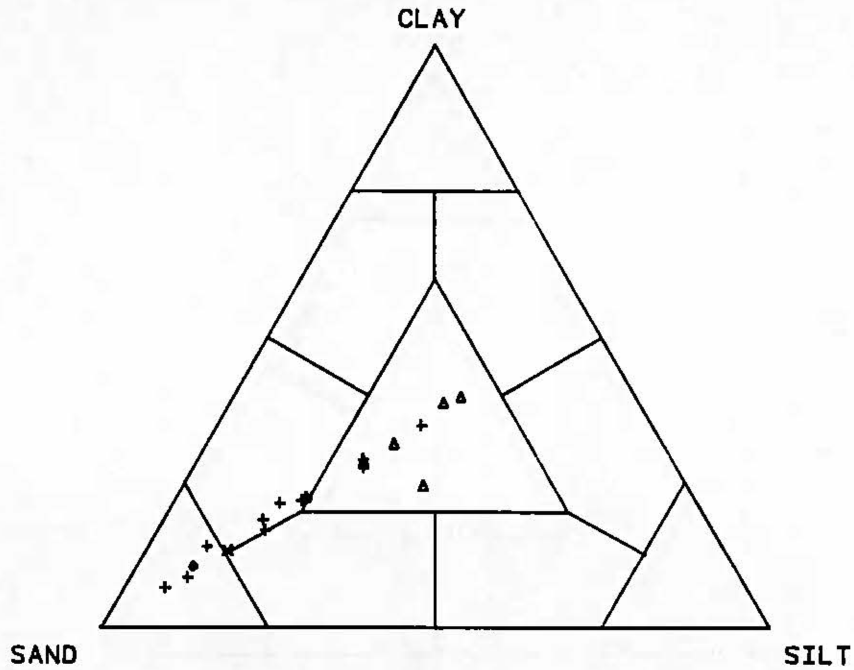


Figure B-6

STATION 22



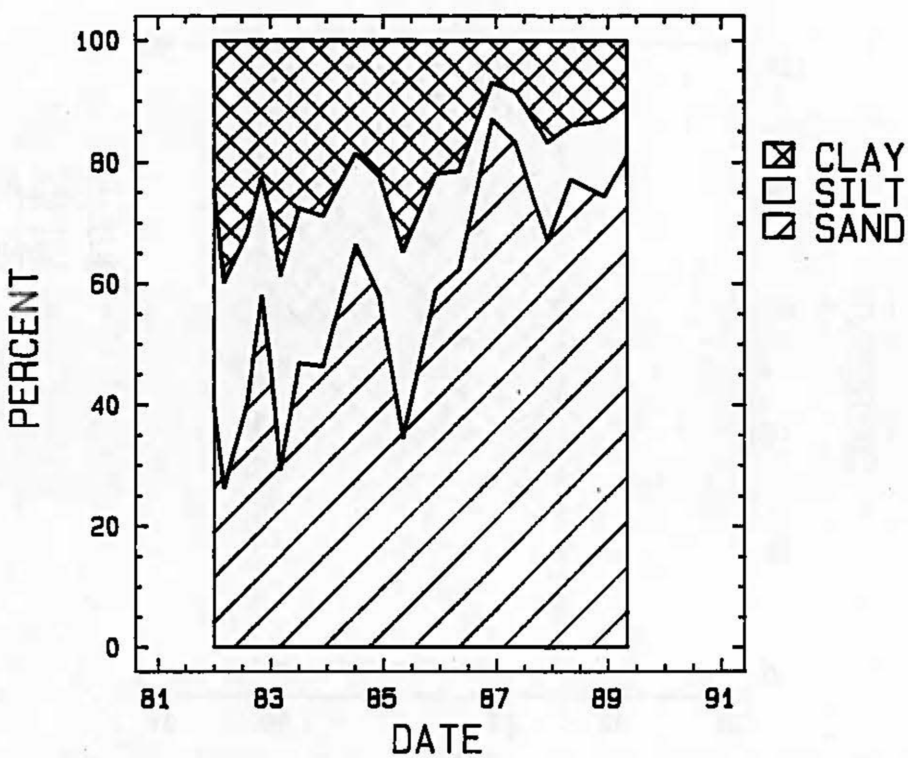
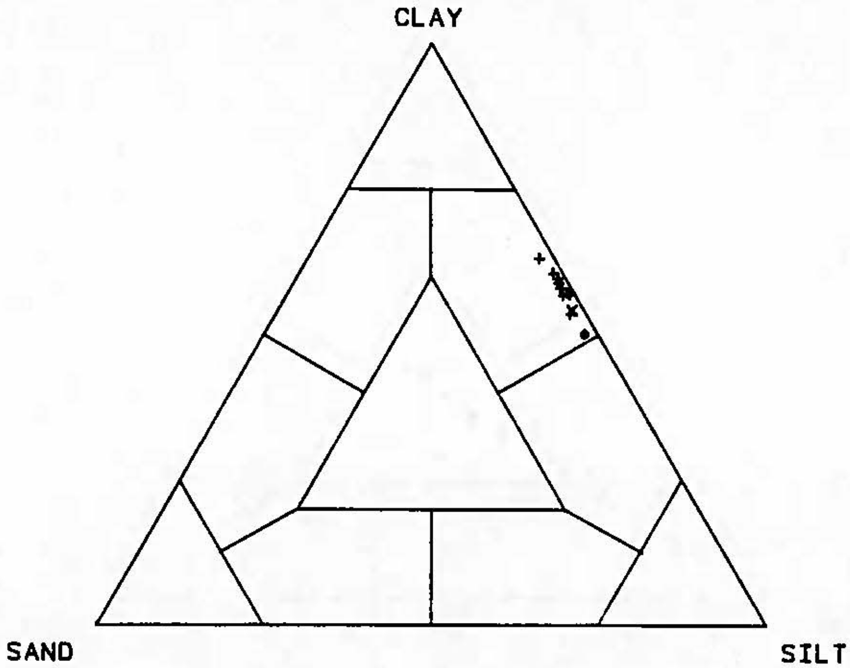


Figure B-7

STATION 25



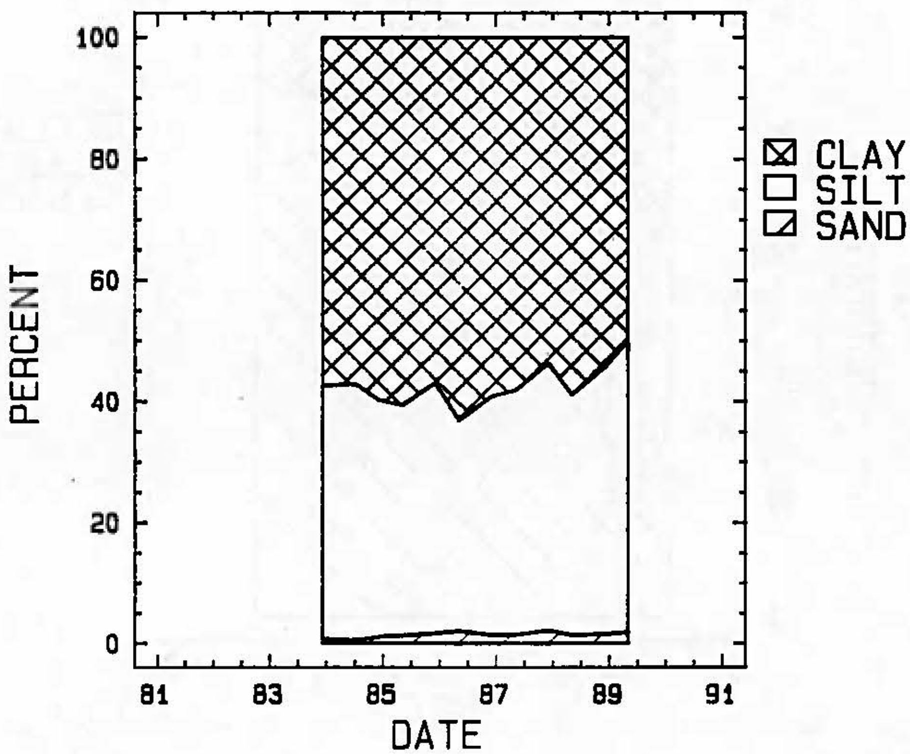


Figure B-8

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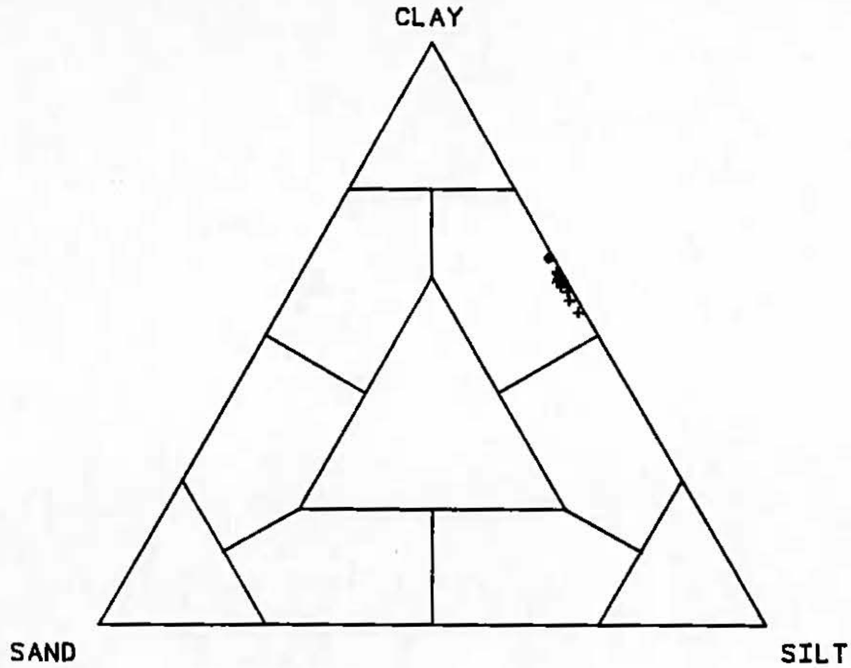


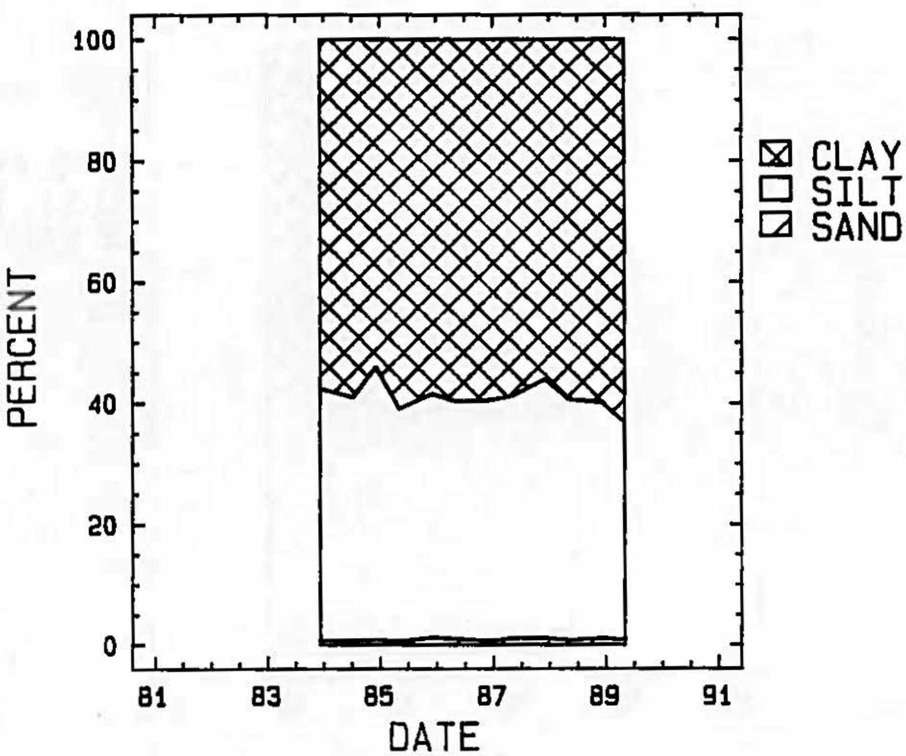
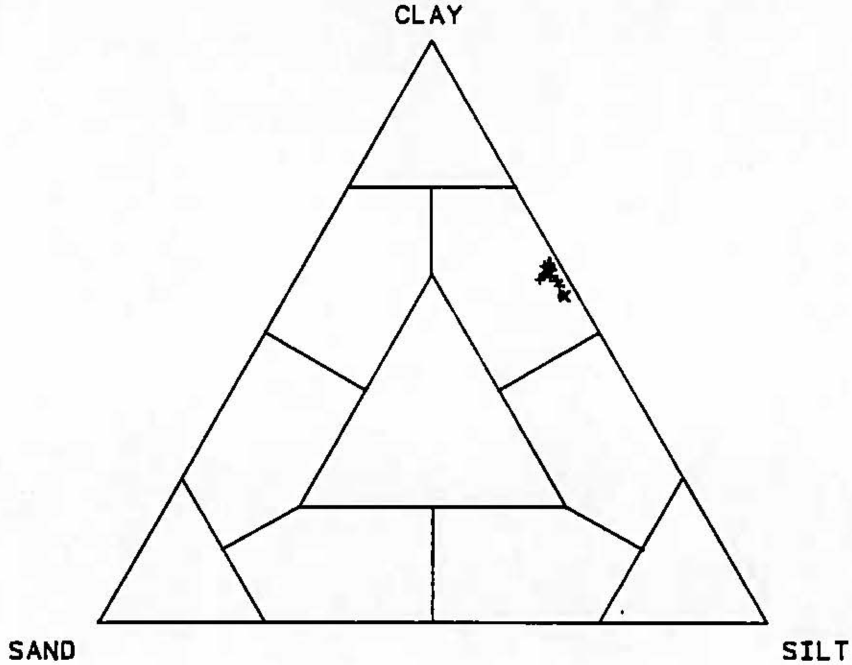


Figure B-9

STATION 27



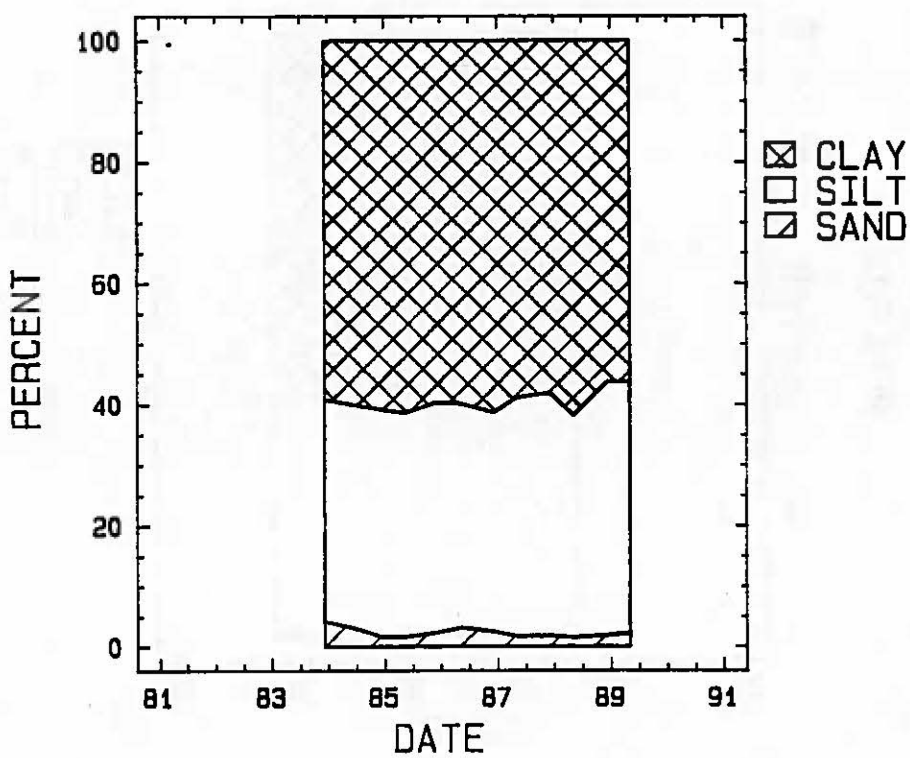
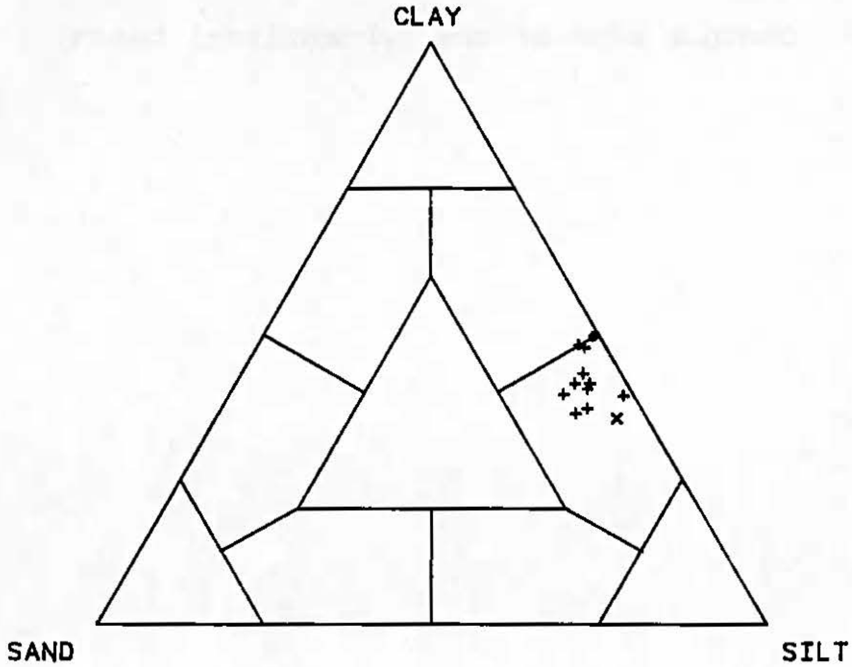


Figure B-10

STATION BC-3



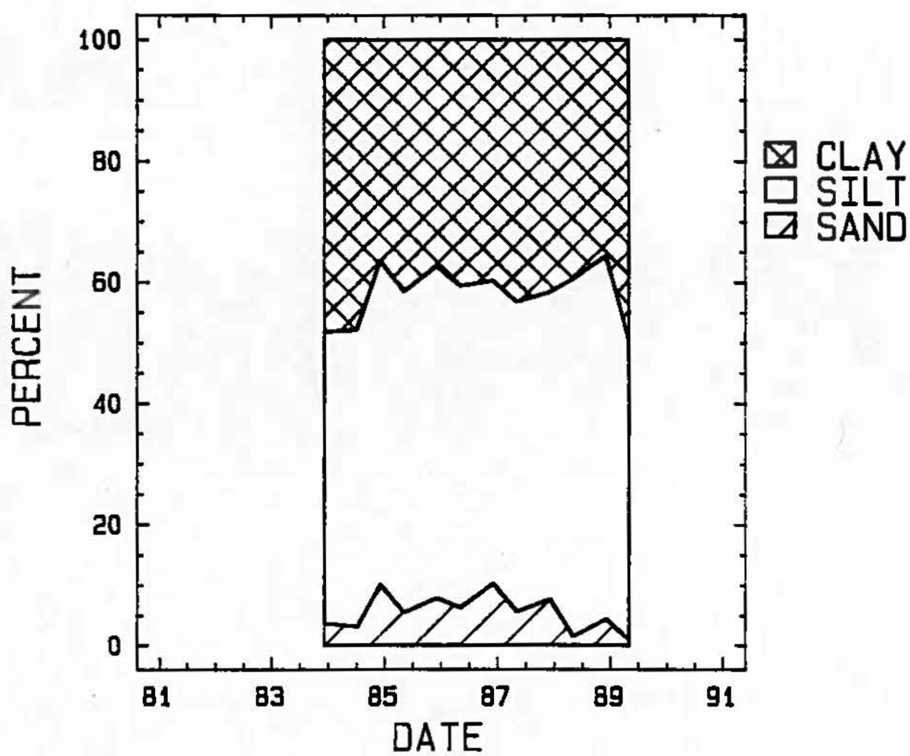


Figure B-11

APPENDIX C

Contour maps of the recreational beach.

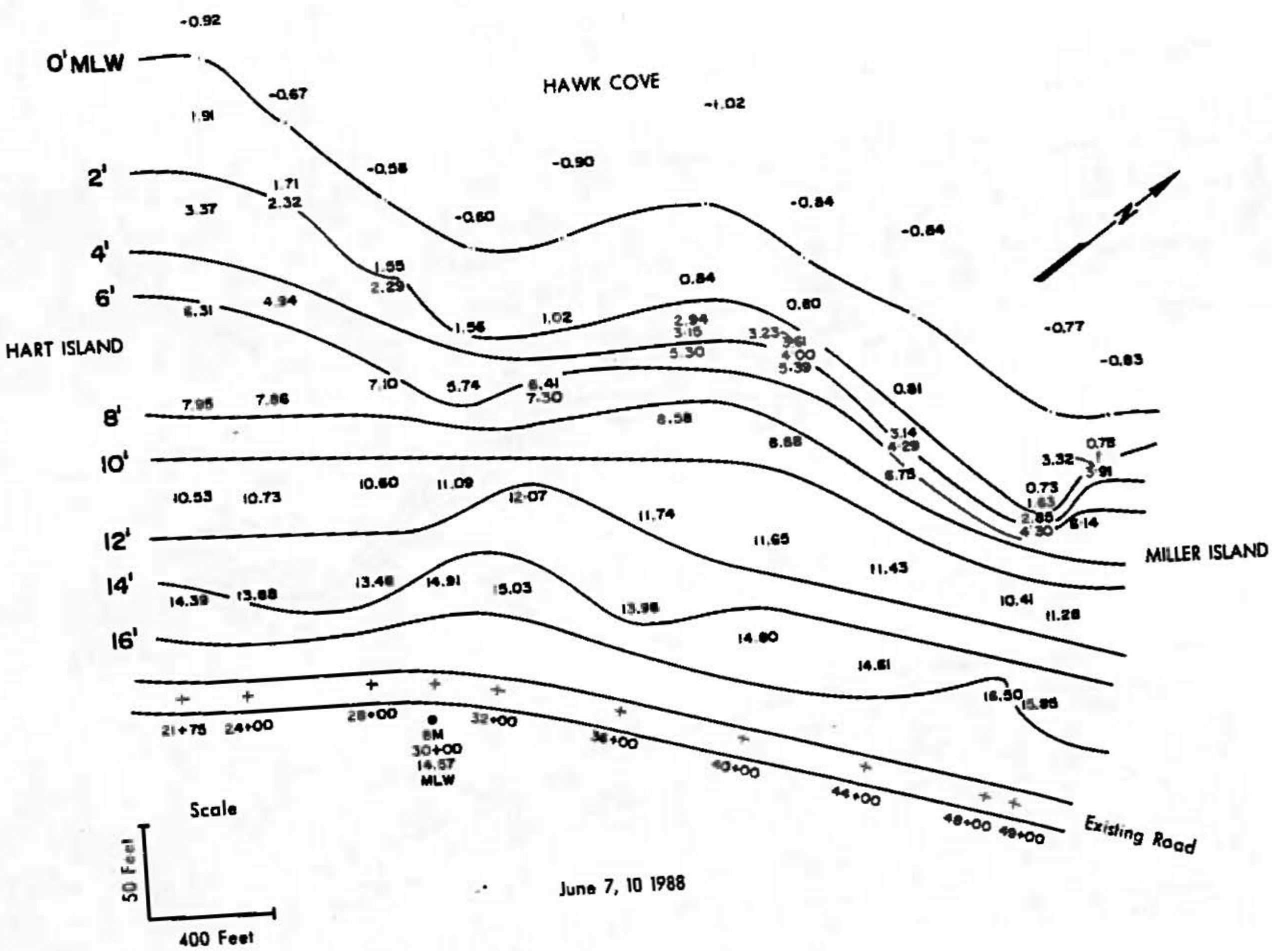
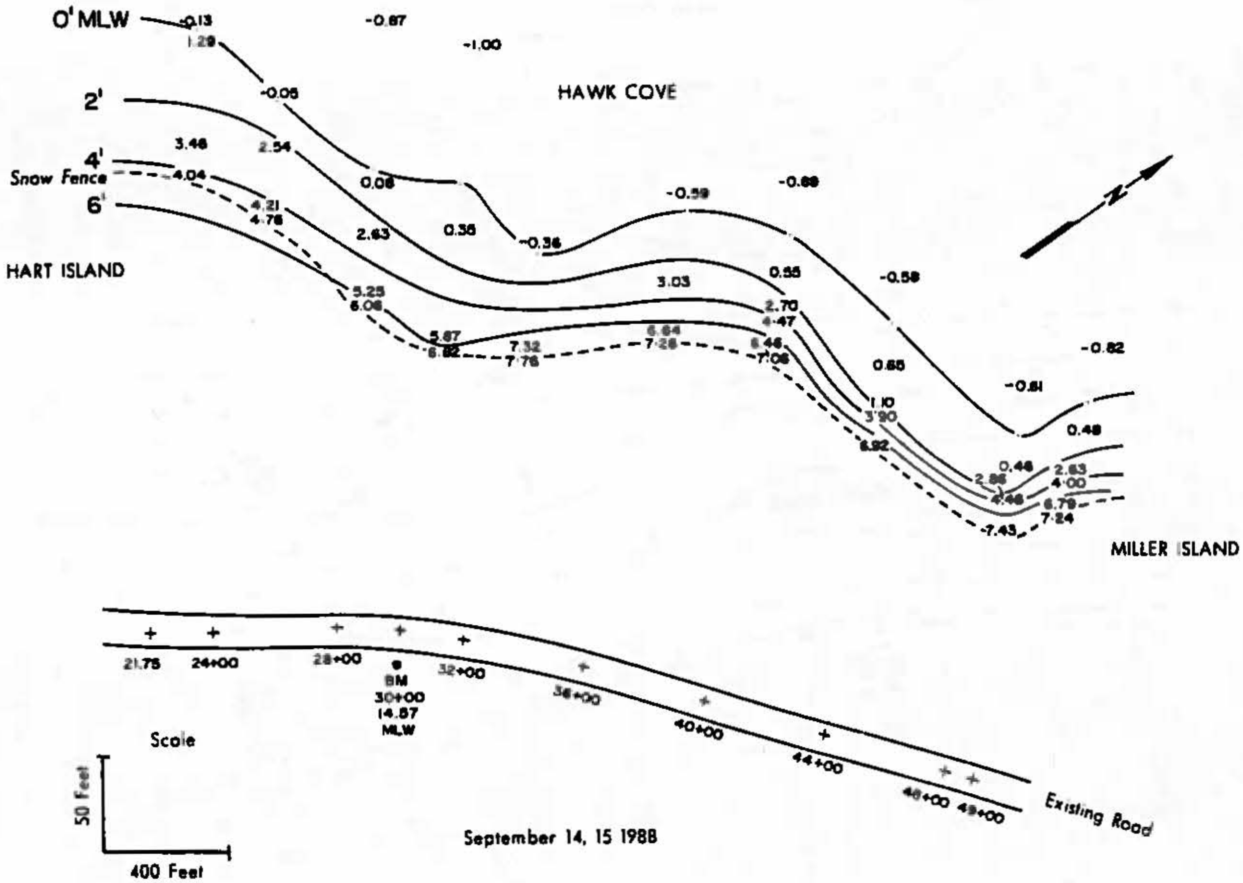
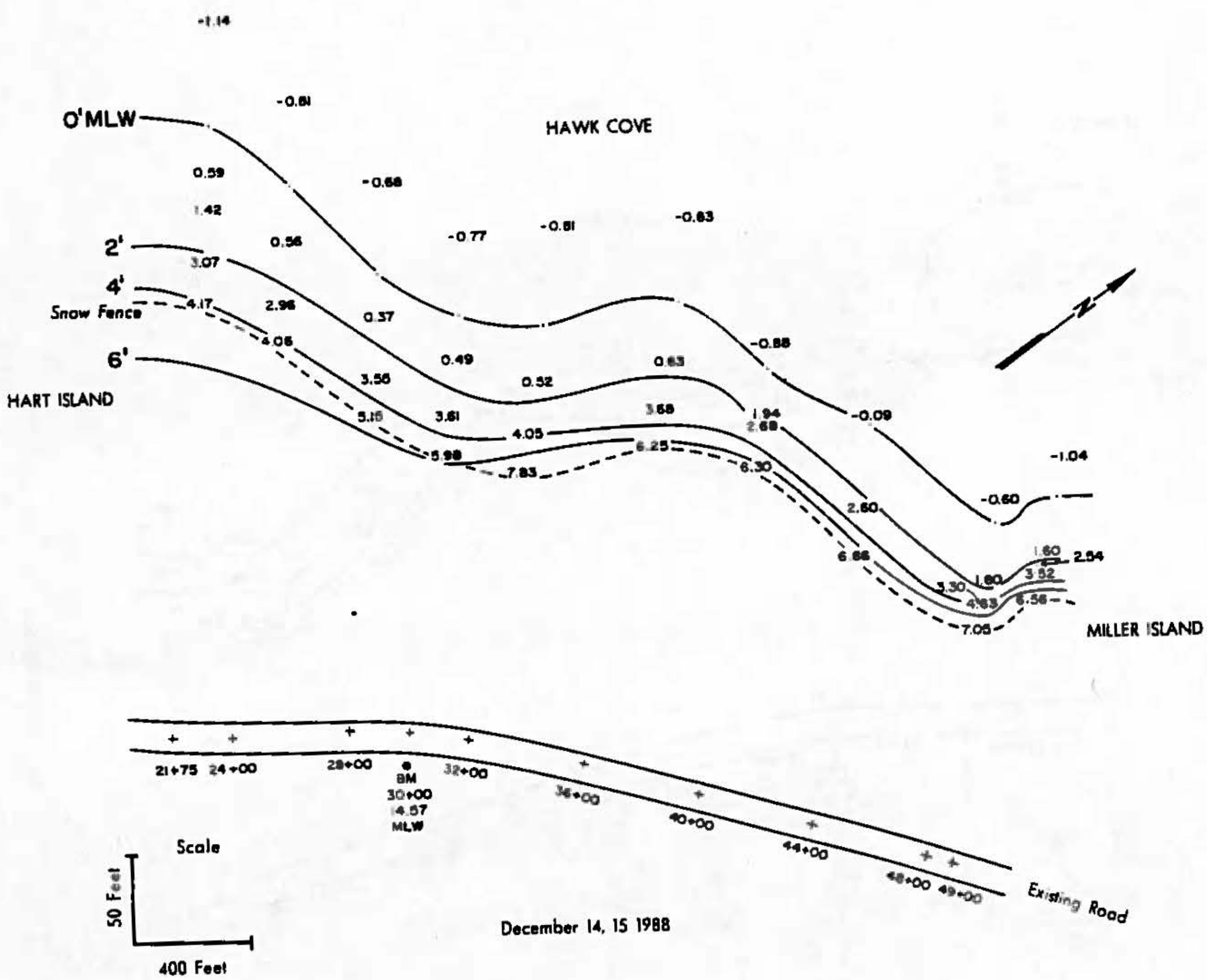

HAWK COVE
HART ISLAND
MILLER ISLAND
0' MLW
2'
4'
6'
8'
10'
12'
14'
16'
Existing Road
BM
30+00
14.57
MLW
Scale
50 Feet
400 Feet
June 7, 10 1988

Figure C-1



0' MLW
2'
4'
Snow Fence
6'
HAWK COVE
HART ISLAND
MILLER ISLAND
21.75
24+00
28+00
BM
30+00
14.87
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
September 14, 15 1988

Figure C-2



O'MLW
2'
4'
Snow Fence
6'
HART ISLAND
HAWK COVE
MILLER ISLAND
-1.14
-0.81
0.59
1.42
-0.68
0.56
-0.77
-0.81
-0.83
3.07
4.17
2.96
0.37
4.06
0.49
0.52
0.63
-0.88
3.56
5.16
3.61
4.05
3.68
1.94
2.68
-0.09
5.98
7.83
6.25
6.30
-1.04
2.60
-0.60
6.66
1.60
2.54
3.30
1.60
3.52
4.63
6.56
7.06
21+75
24+00
28+00
BM
30+00
14.57
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
December 14, 15 1988

Figure C-3

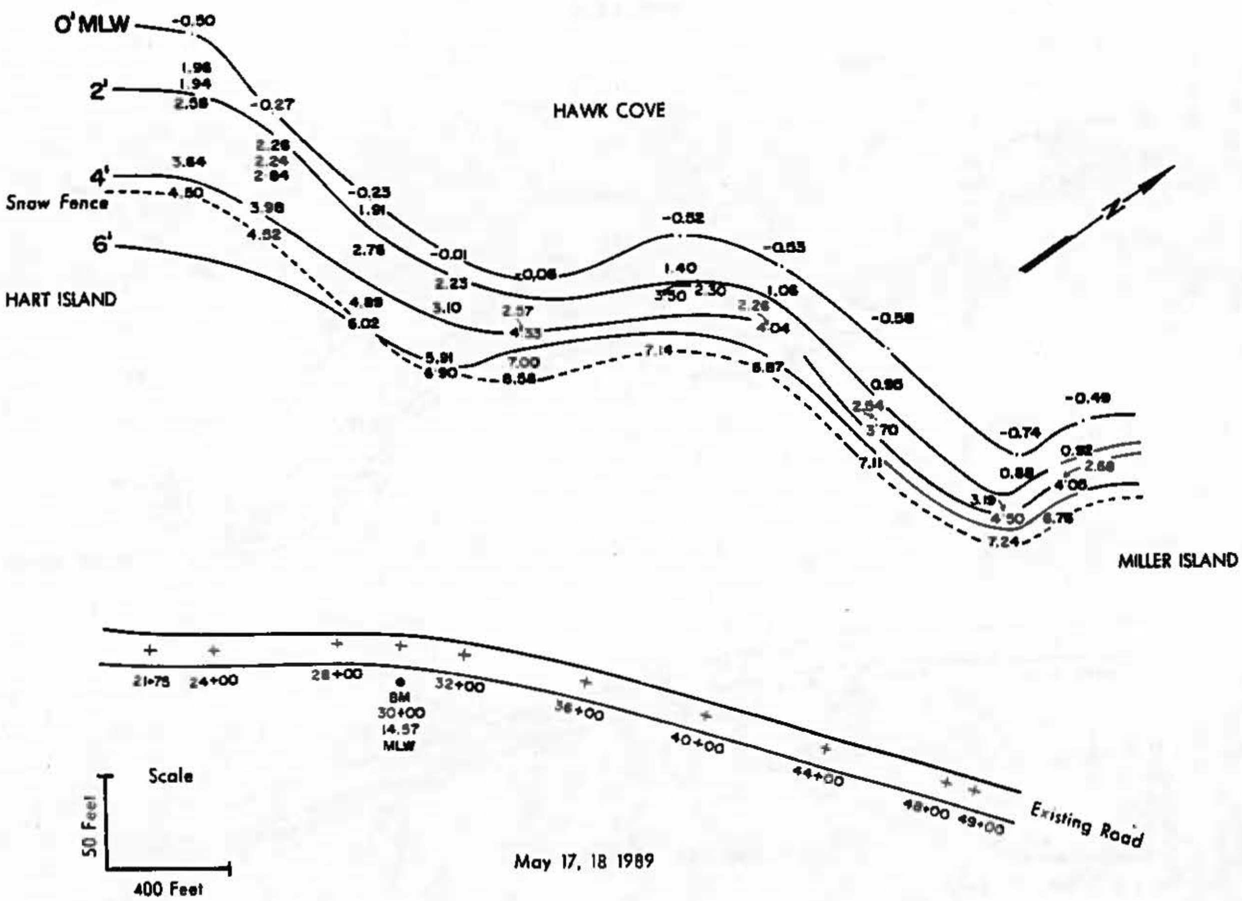

O'MLW
2'
4'
Snow Fence
6'
HART ISLAND
HAWK COVE
N
MILLER ISLAND
21+75
24+00
28+00
BM
30+00
14.57
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
May 17, 18 1989

Figure C-4

APPENDIX D

Cross-sectional profiles of the recreational beach.

Figures D-1 through D-10
Cross-sectional profiles for each of the profile stations, based on surveys conducted in June 1984 and June 1988.

Figures D-11 through D-20
Cross-sectional profiles for each of the profile stations, based on surveys conducted in June 1988 and September 1988.

Figures D-21 through D-30
Cross-sectional profiles for each of the profile stations, based on surveys conducted in September 1988 and May 1989.

Figures D-31 through D-34
Extended cross-sectional profiles for stations 21+75, 30+00, 40+00, and 49+00, based on surveys conducted in June 1988 and September 1989.

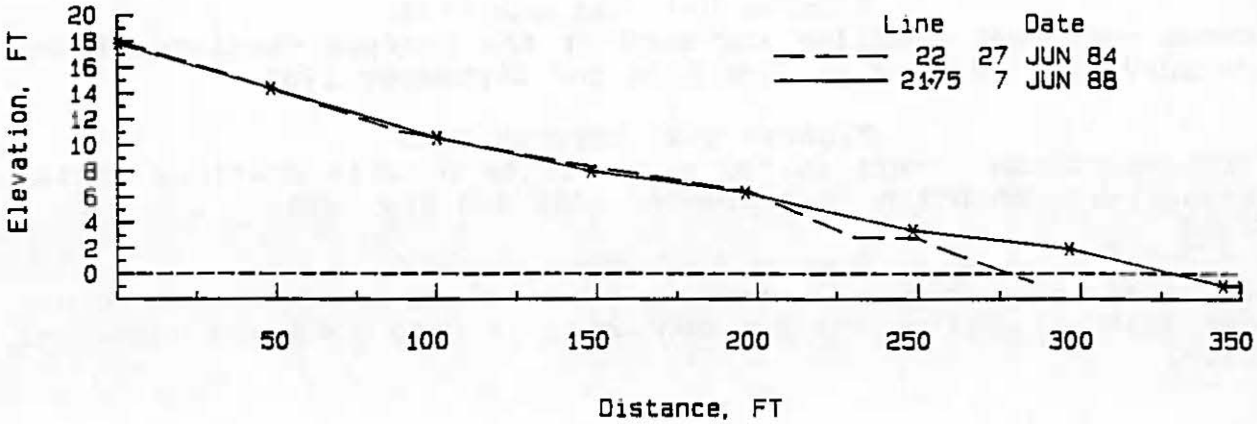


Figure D-1

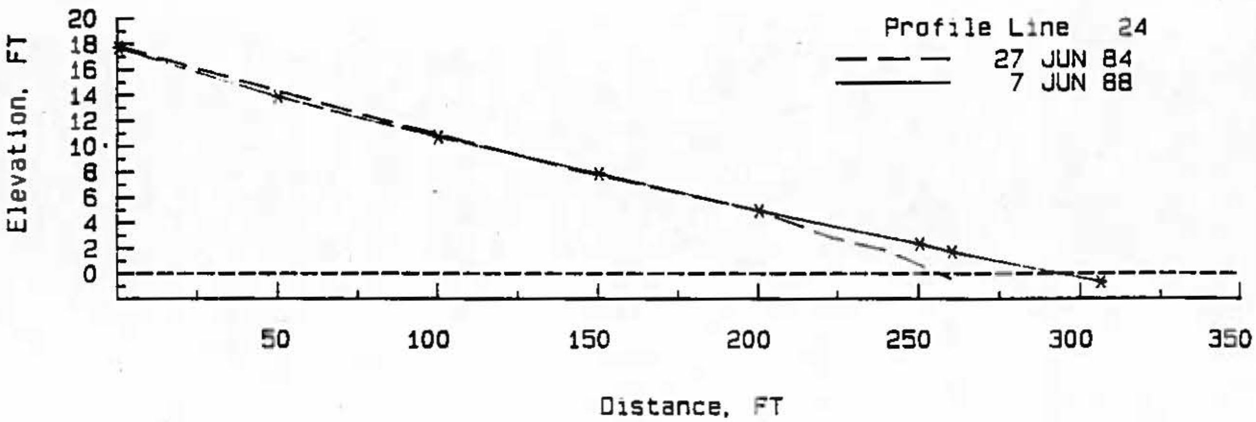


Figure D-2

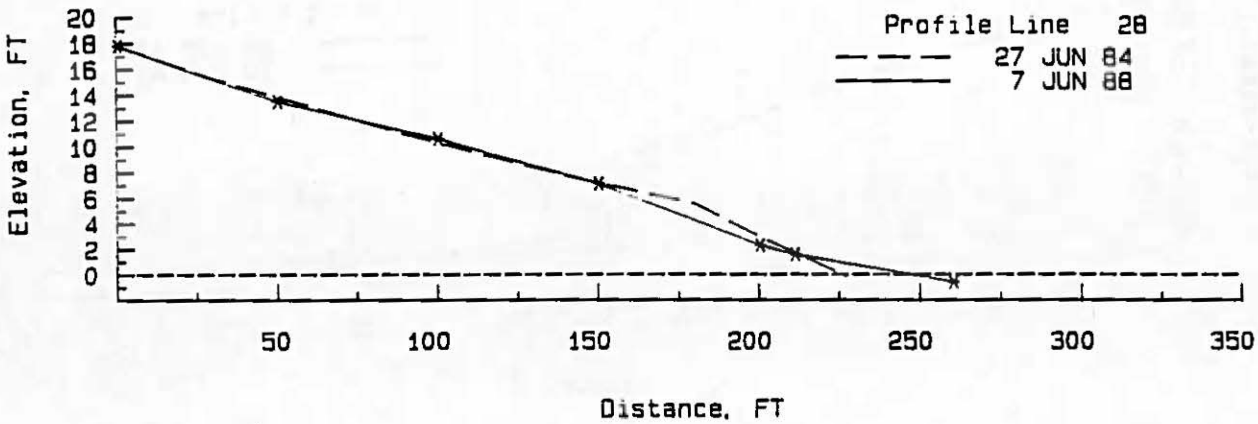


Figure D-3

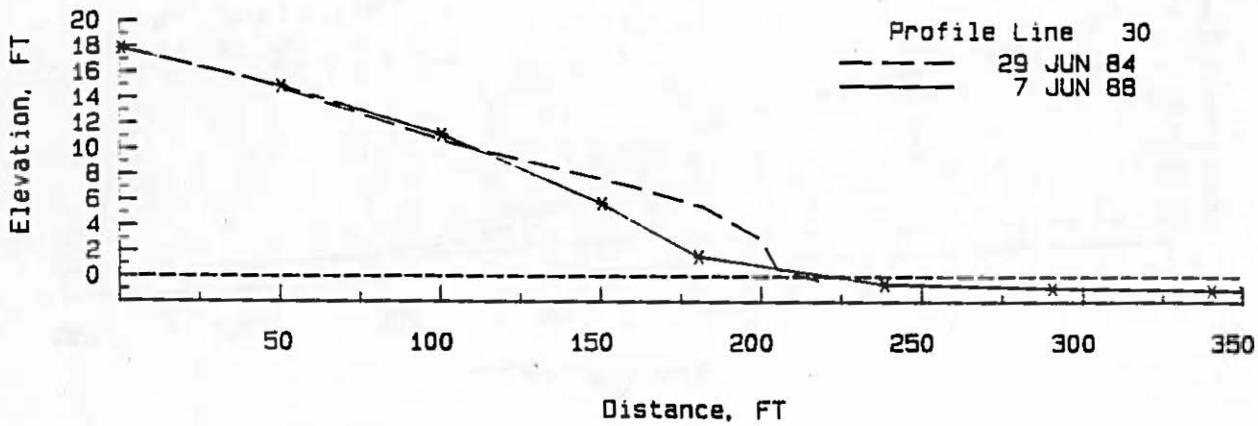


Figure D-4

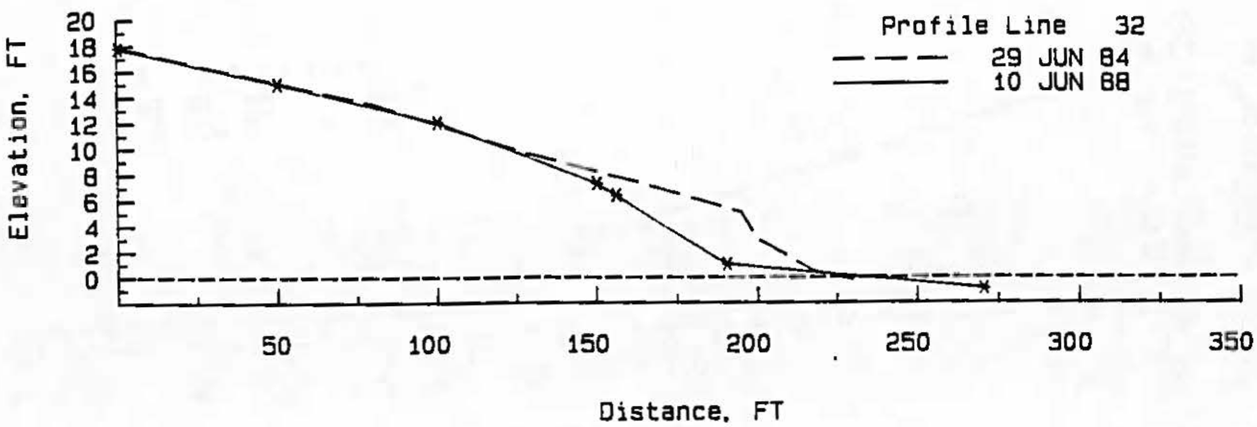
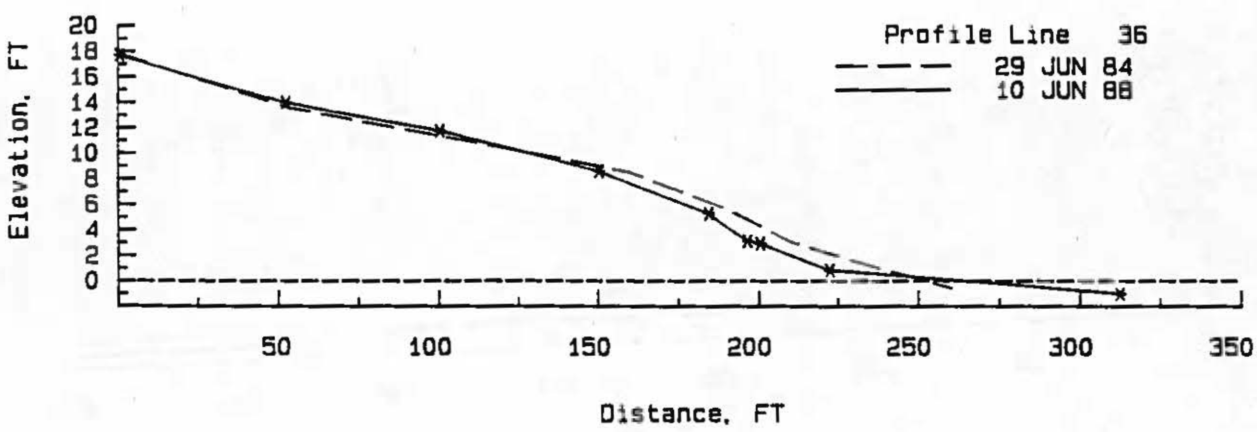


Figure D-5



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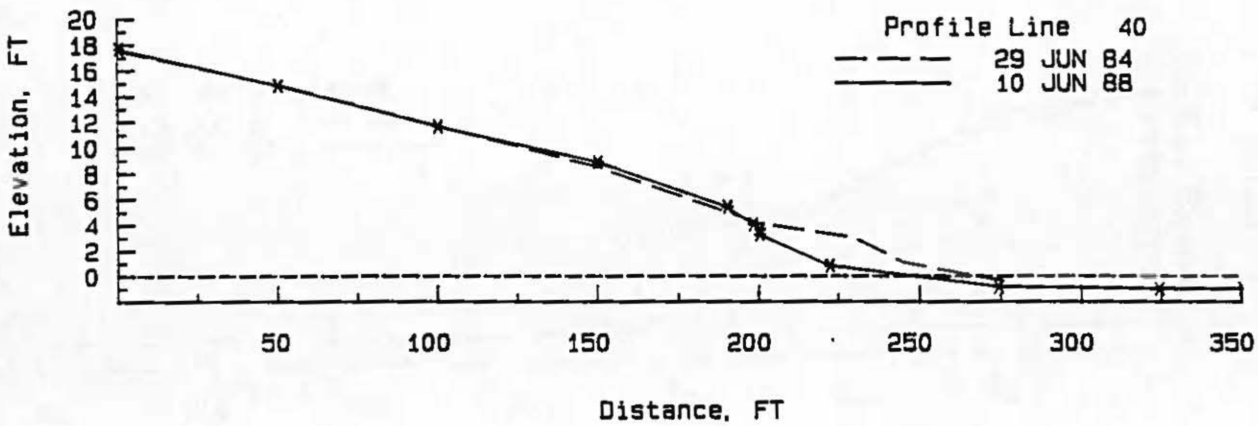

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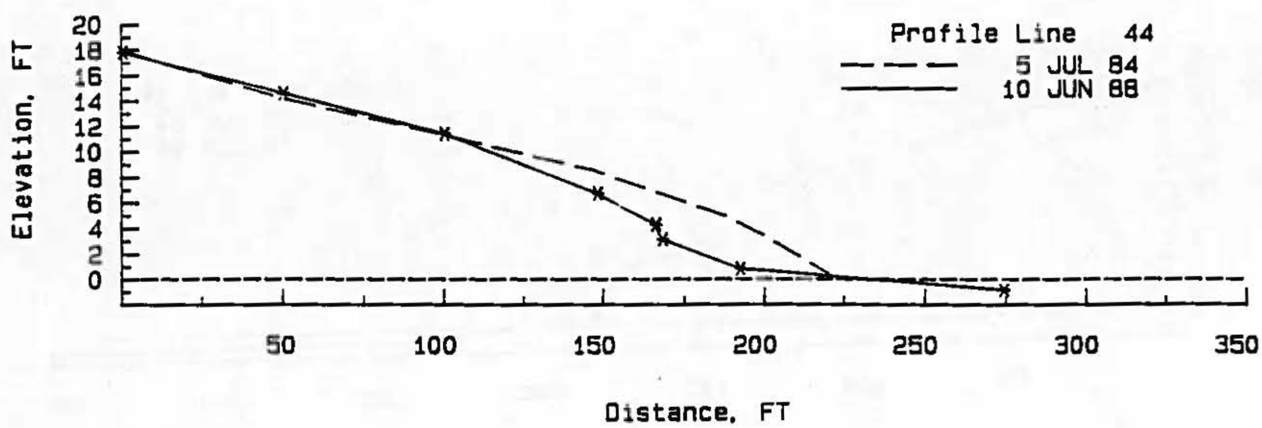

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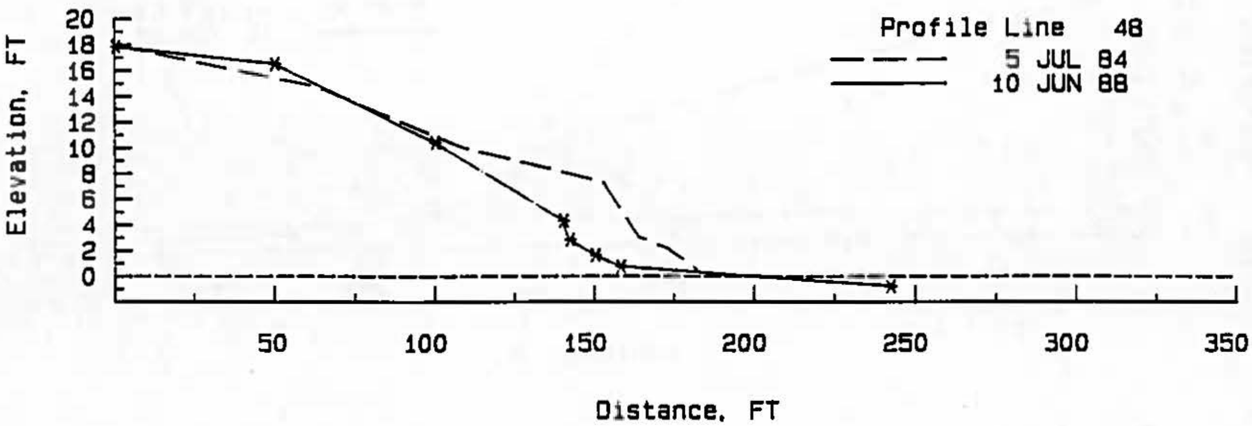

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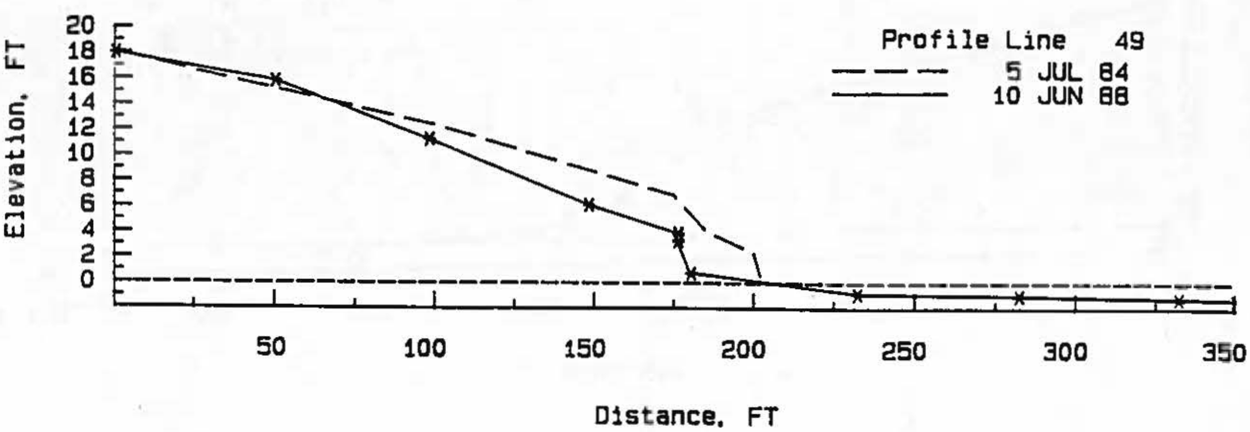

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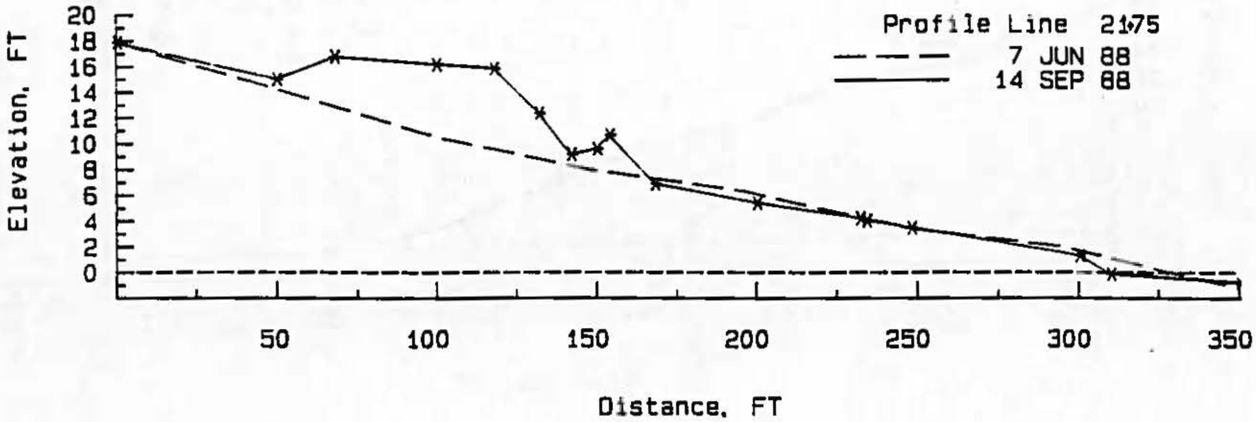

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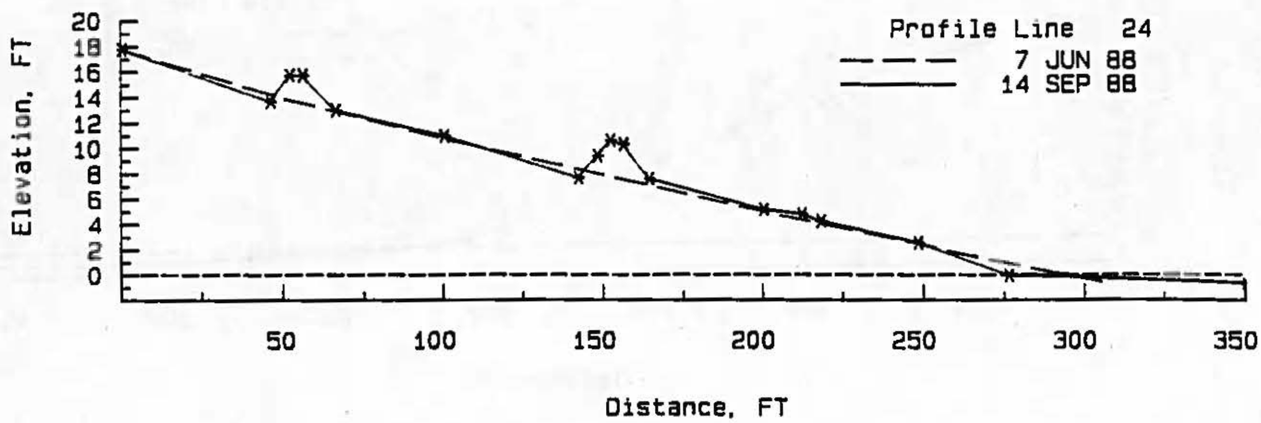

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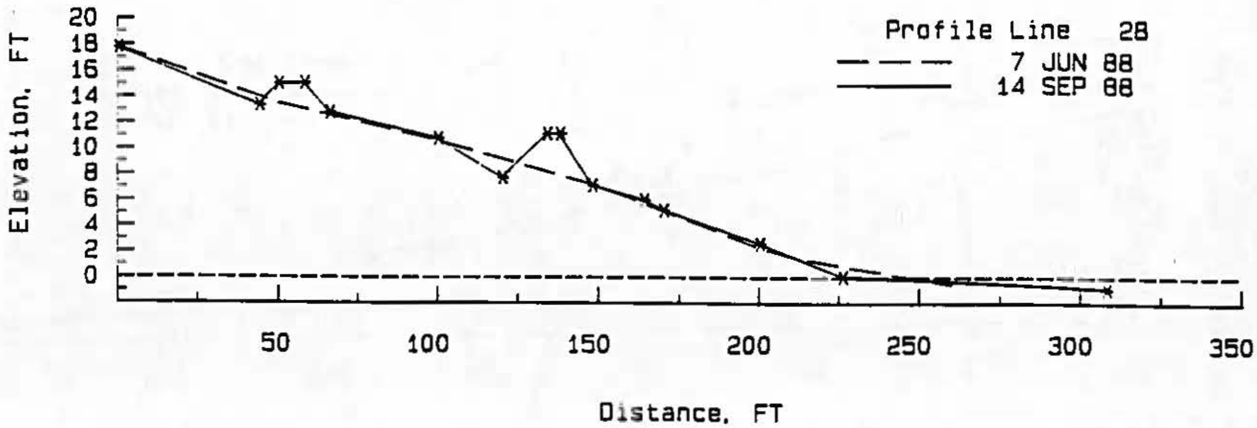

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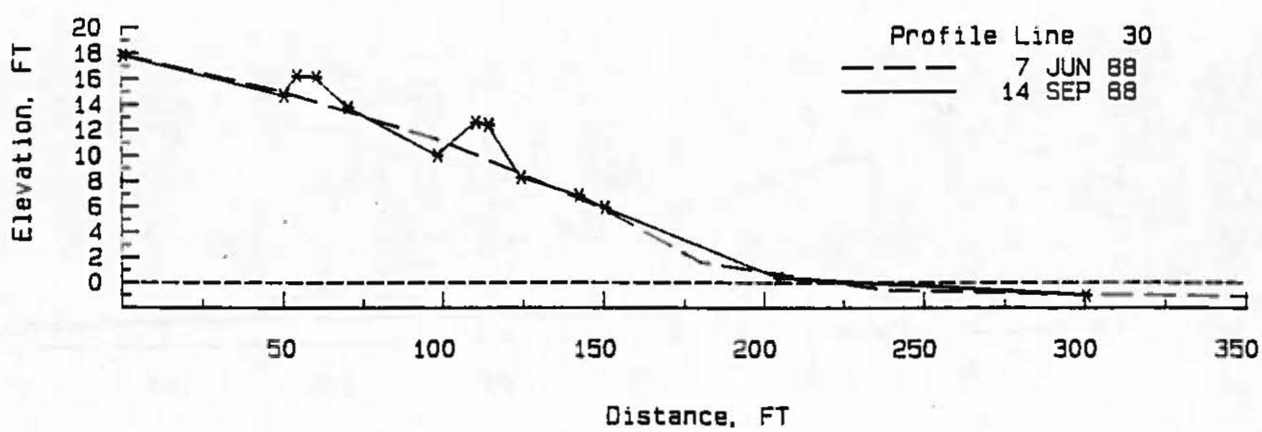

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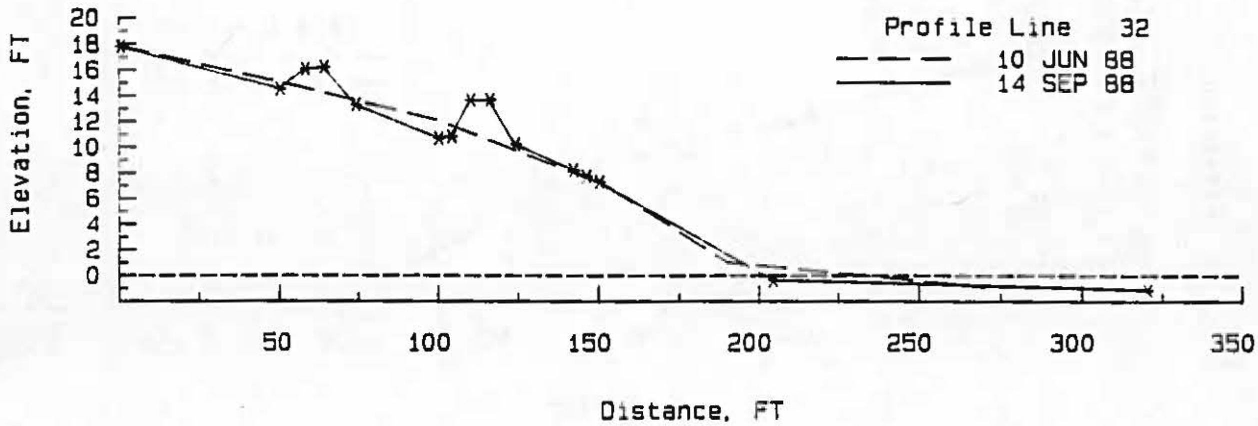

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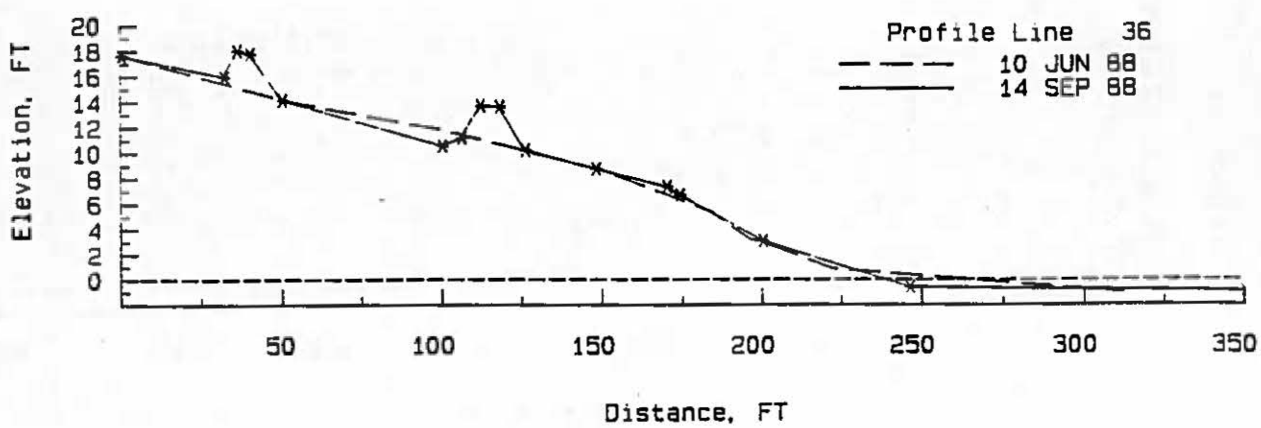

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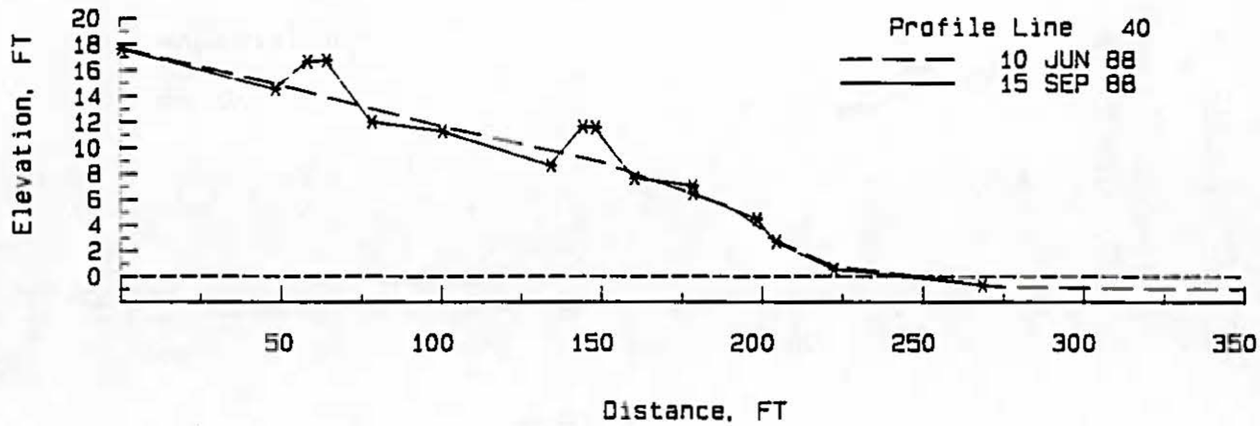

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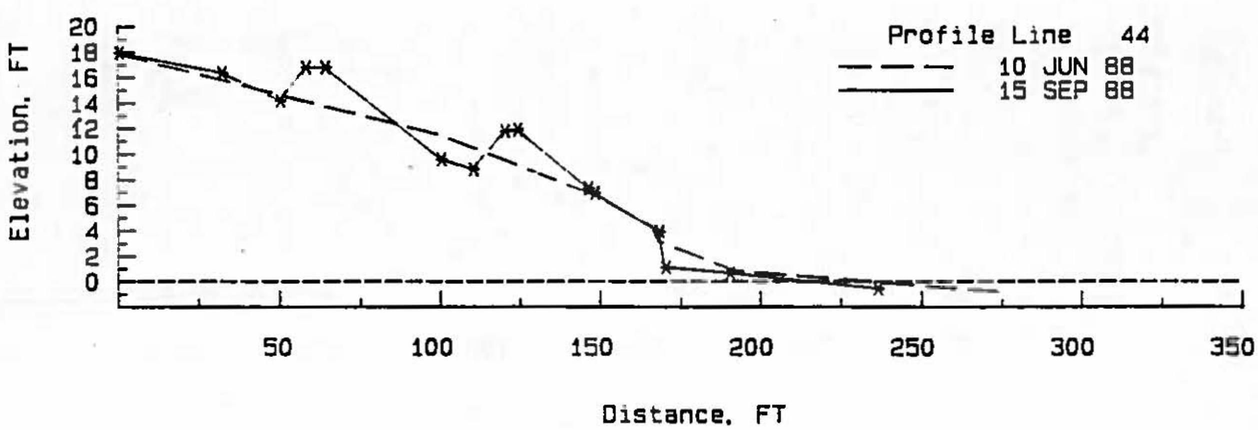

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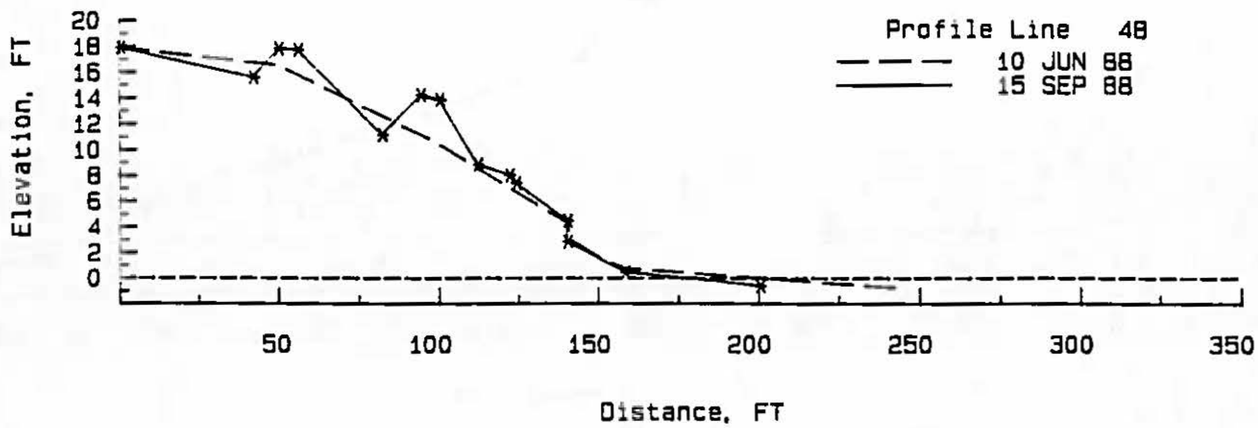

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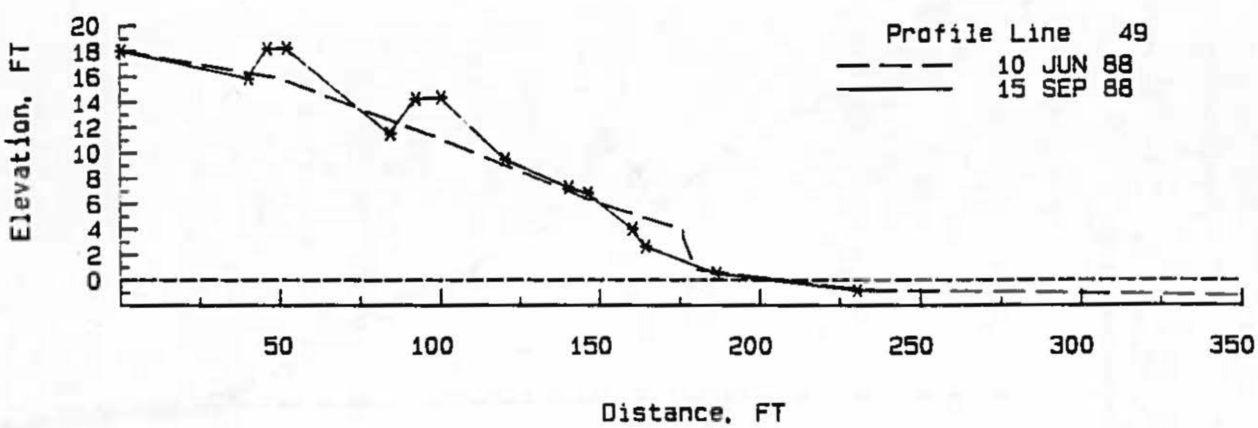

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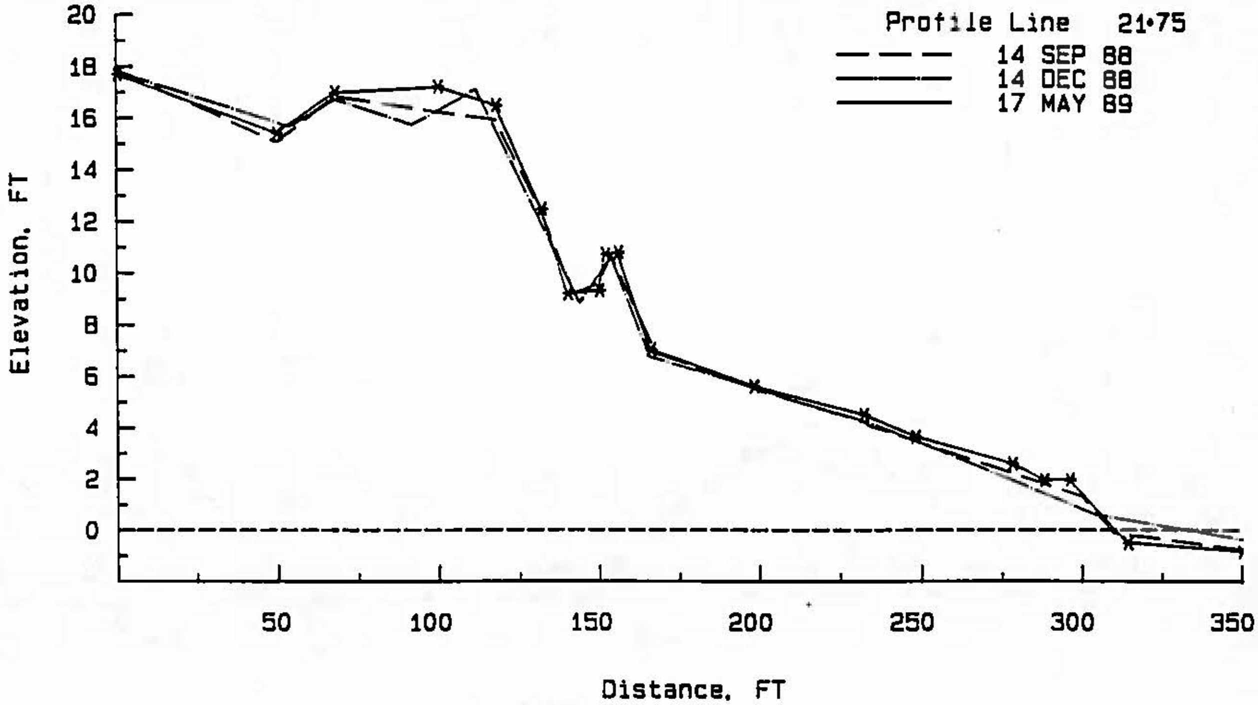

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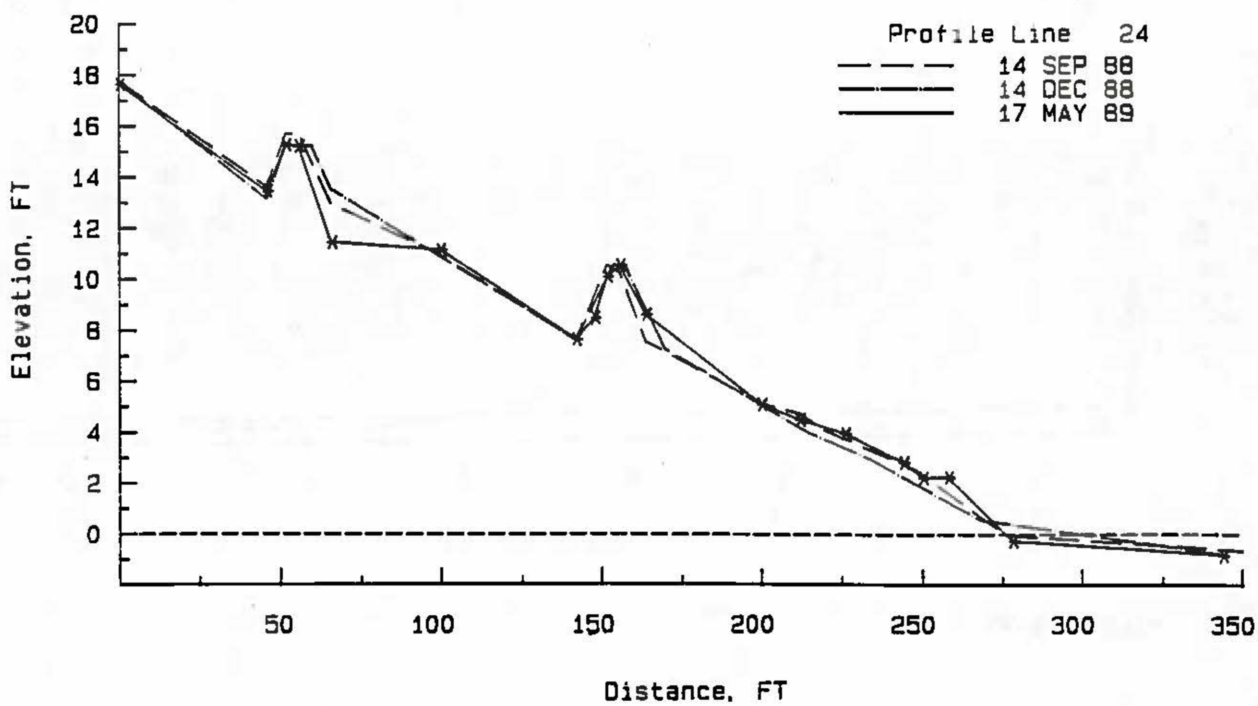

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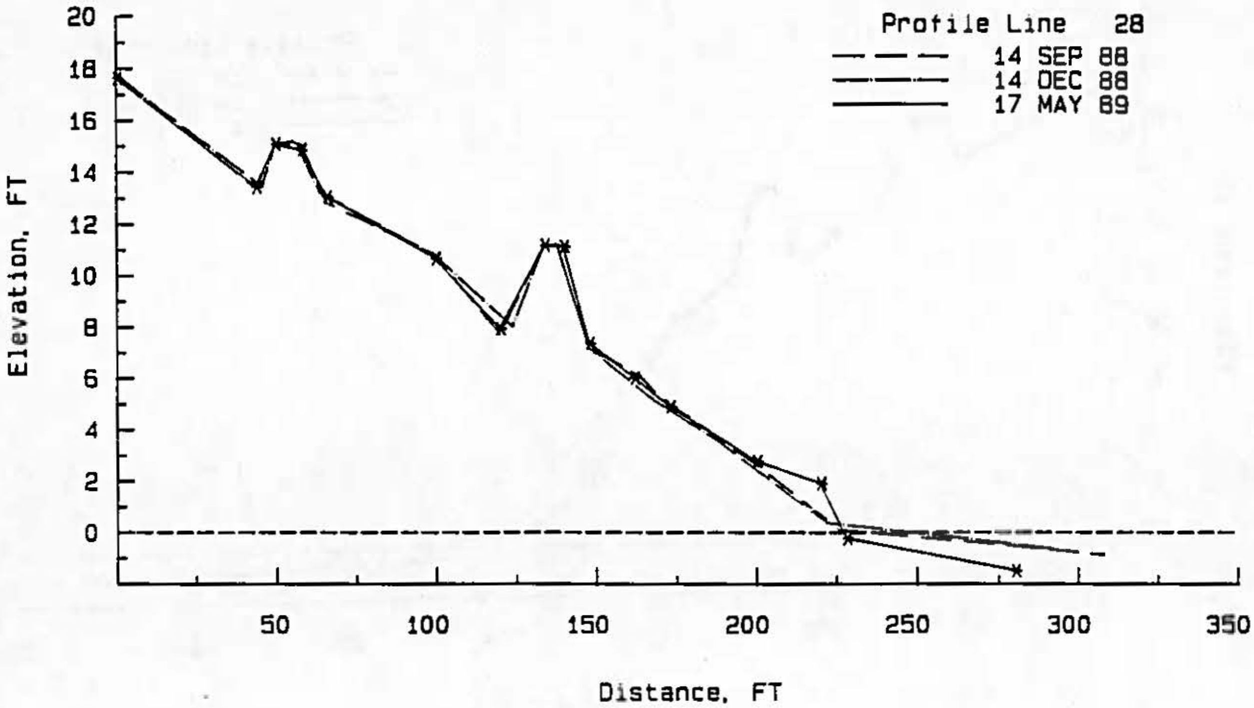

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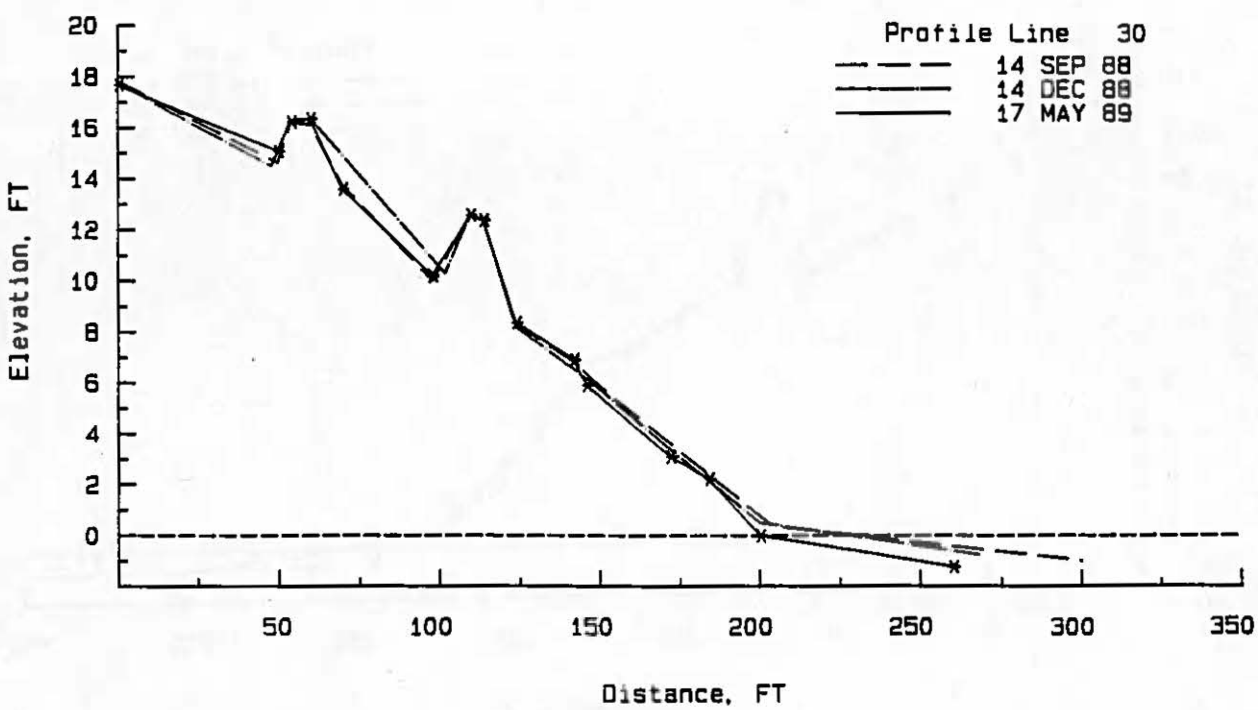

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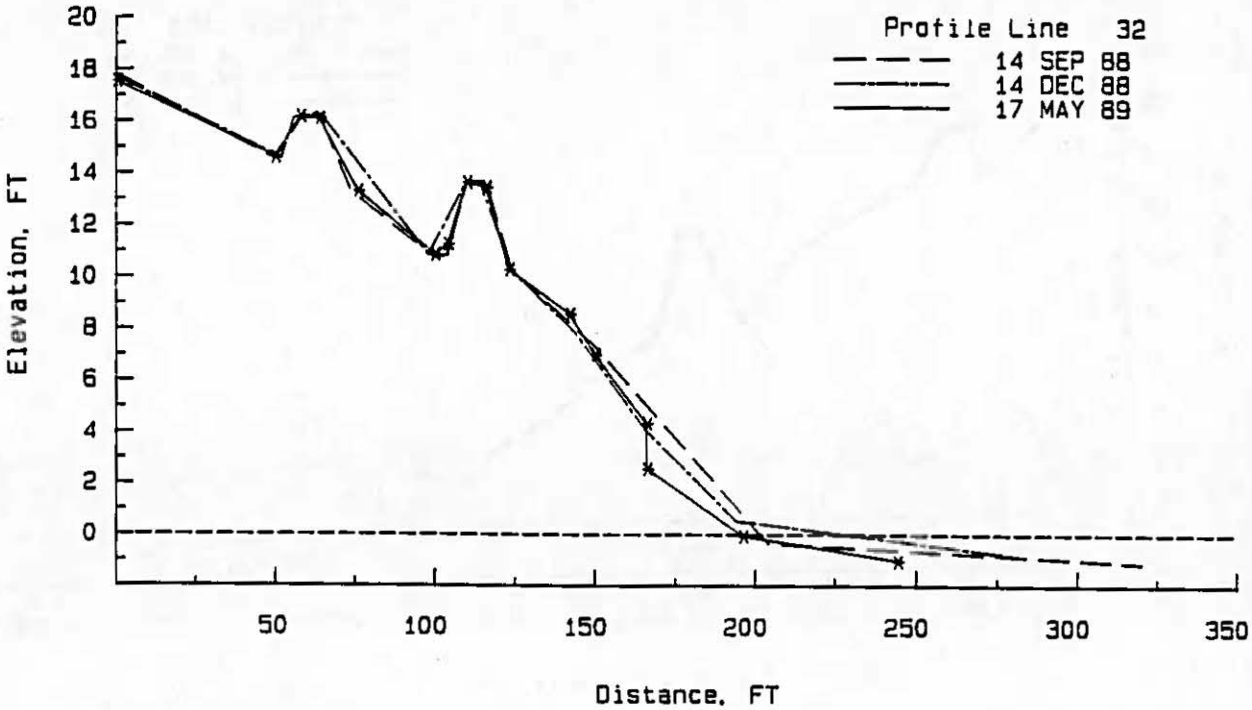

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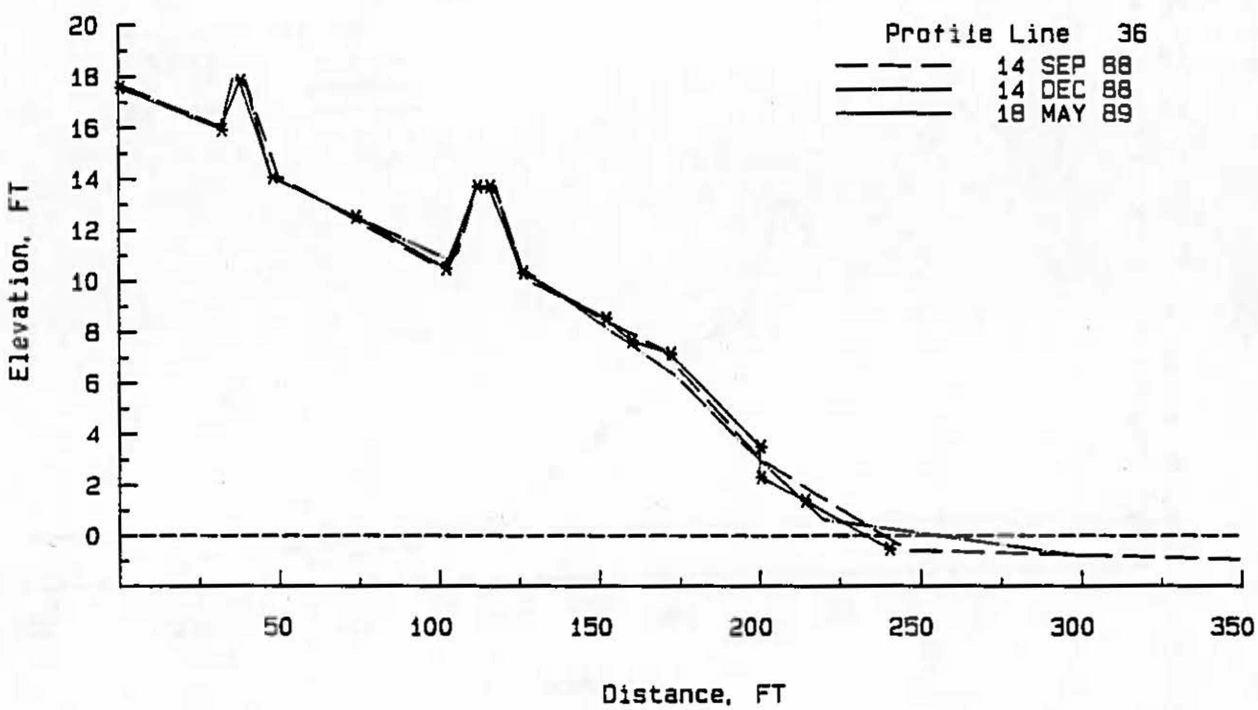

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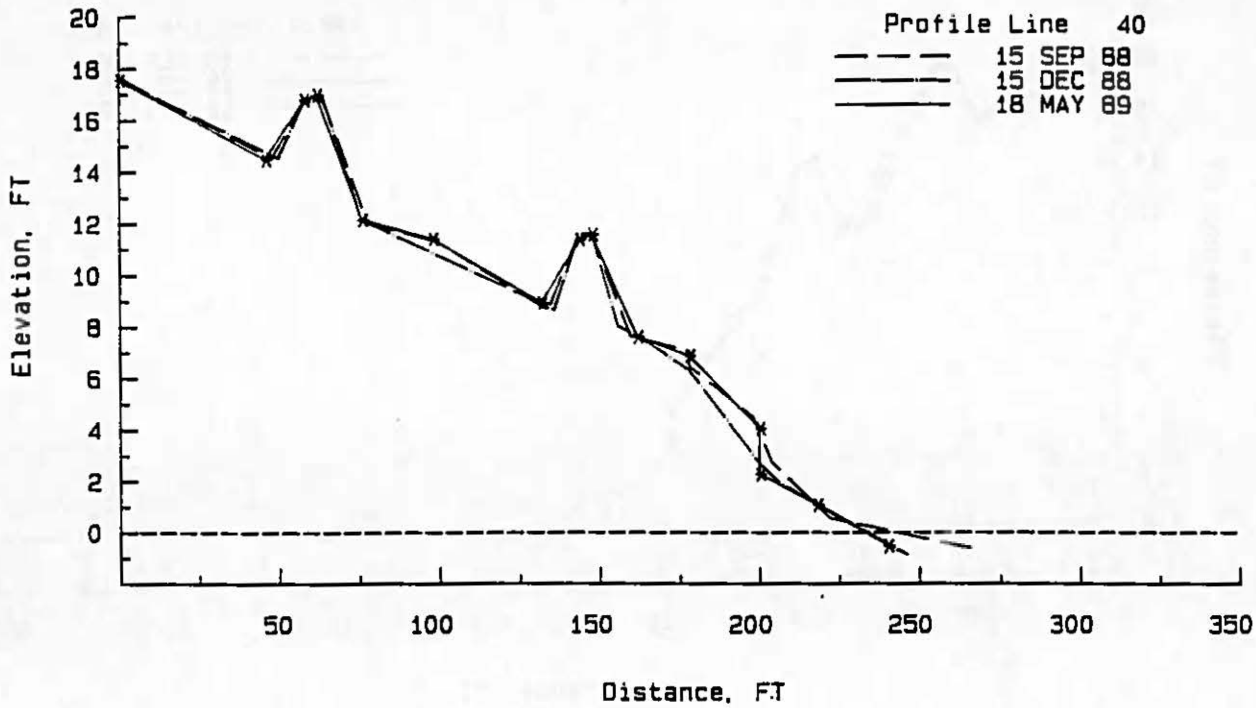

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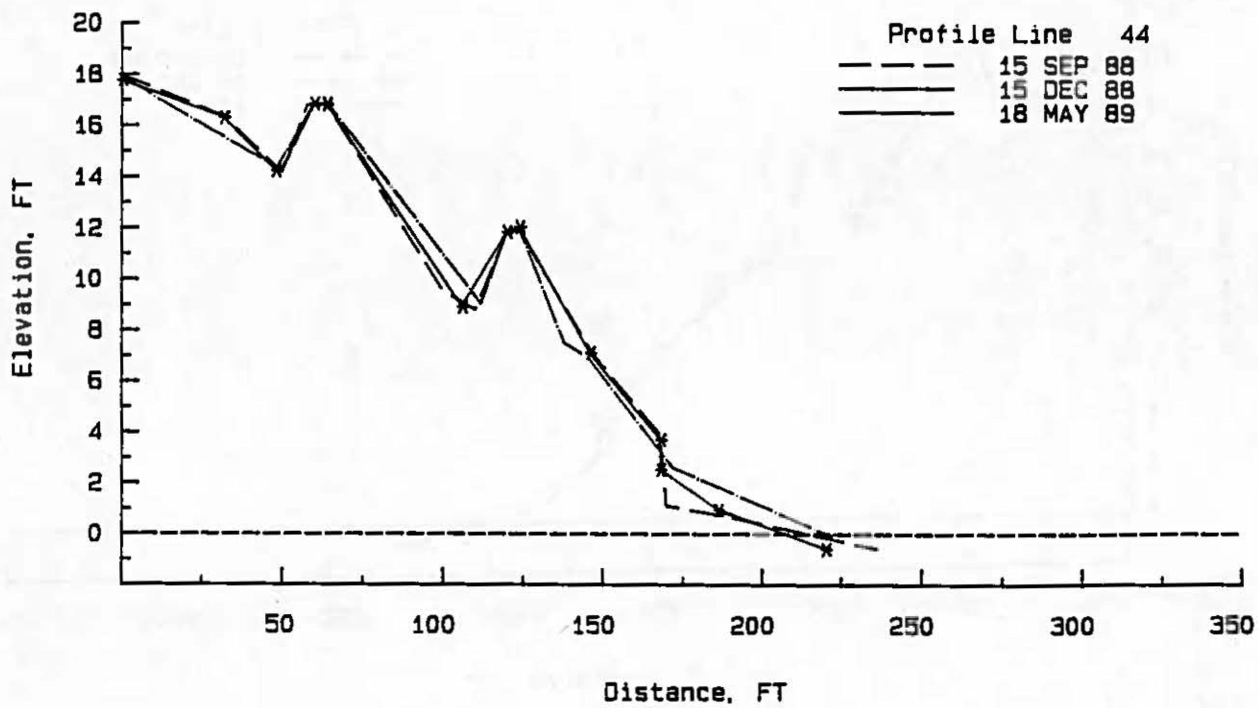

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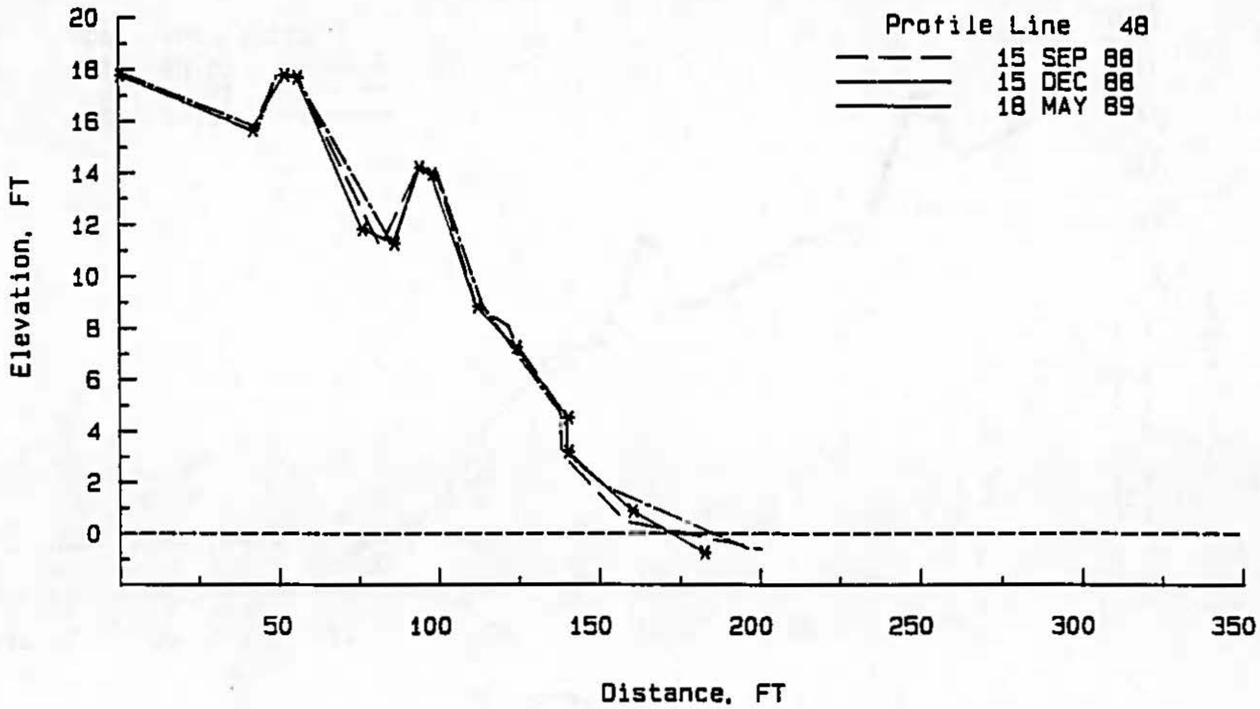

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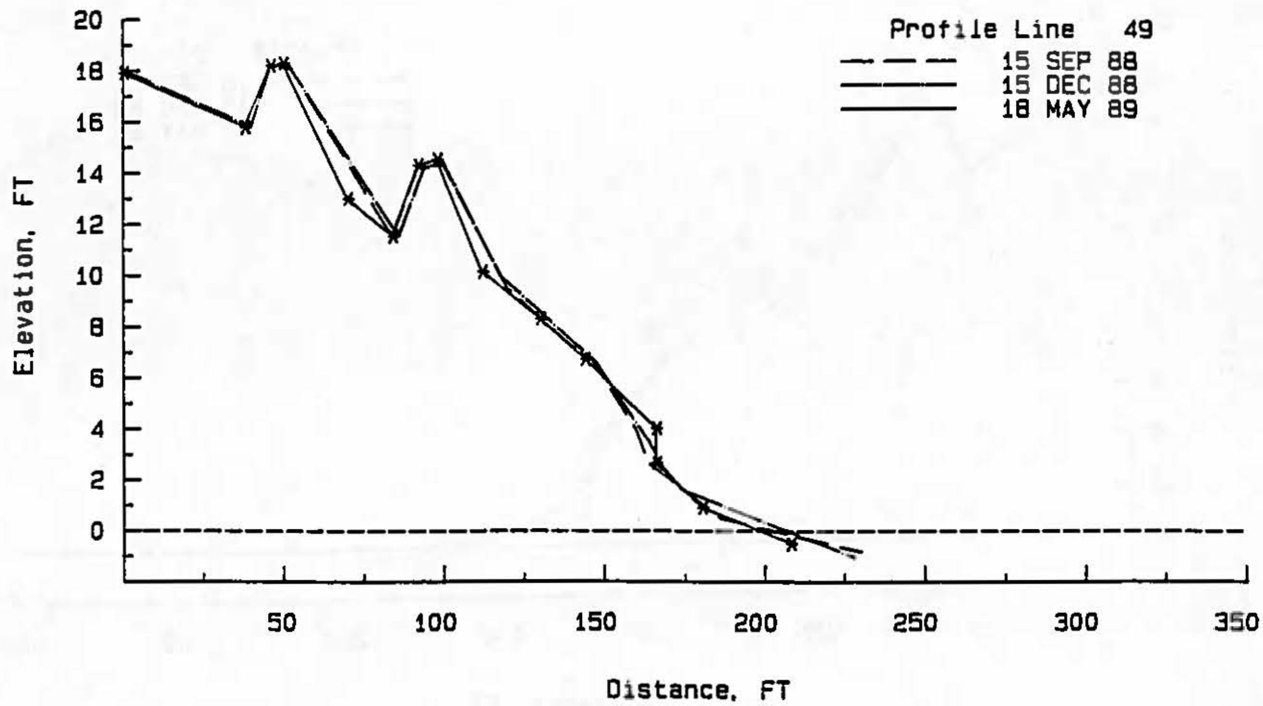

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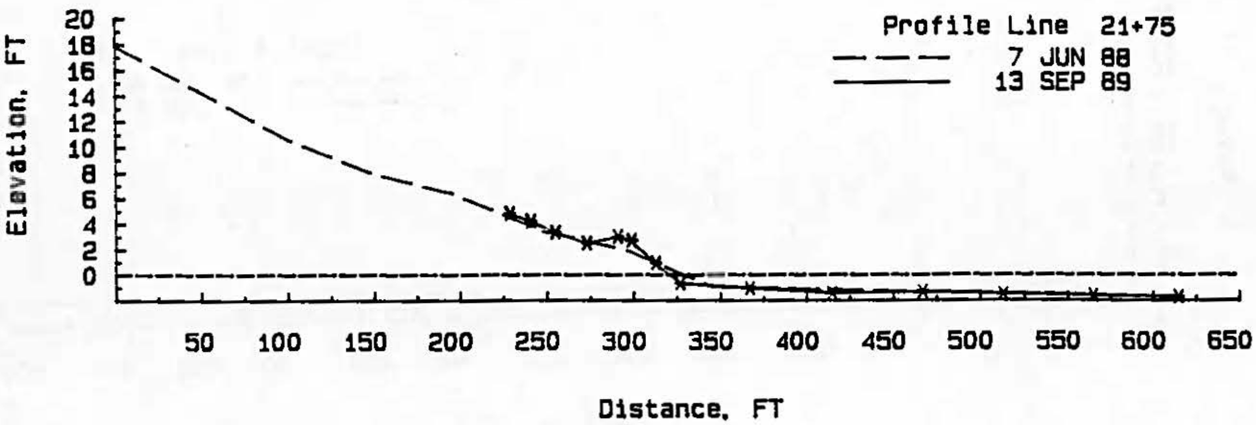

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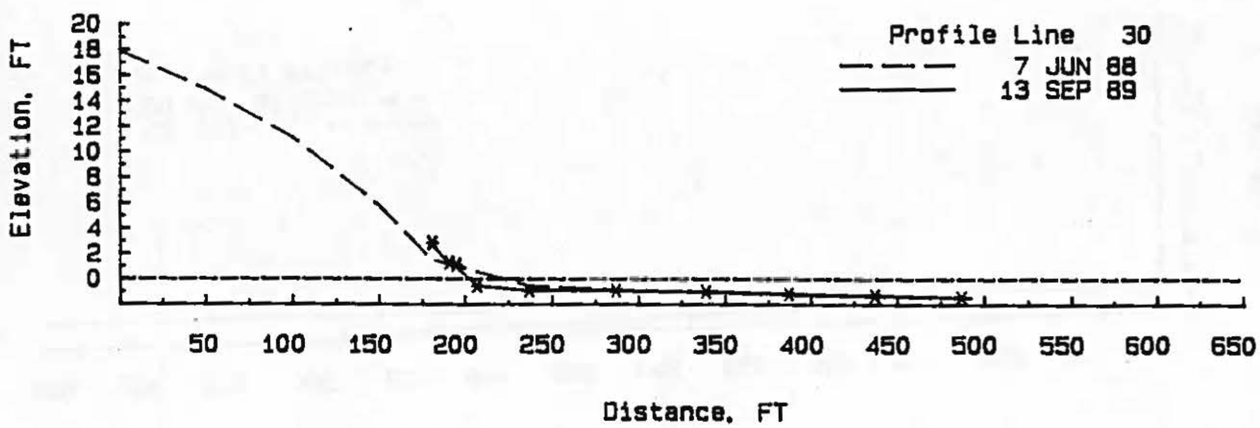

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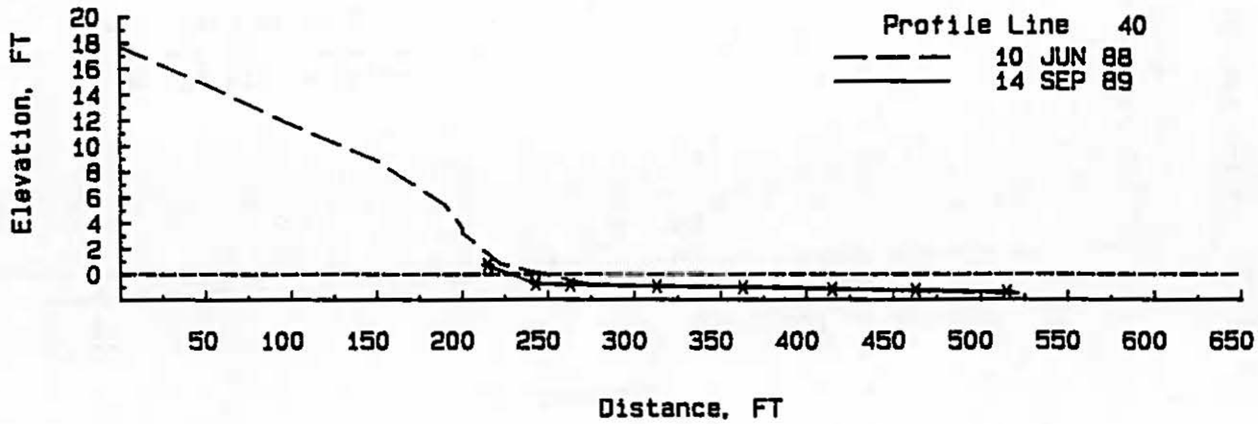

Figure D-33

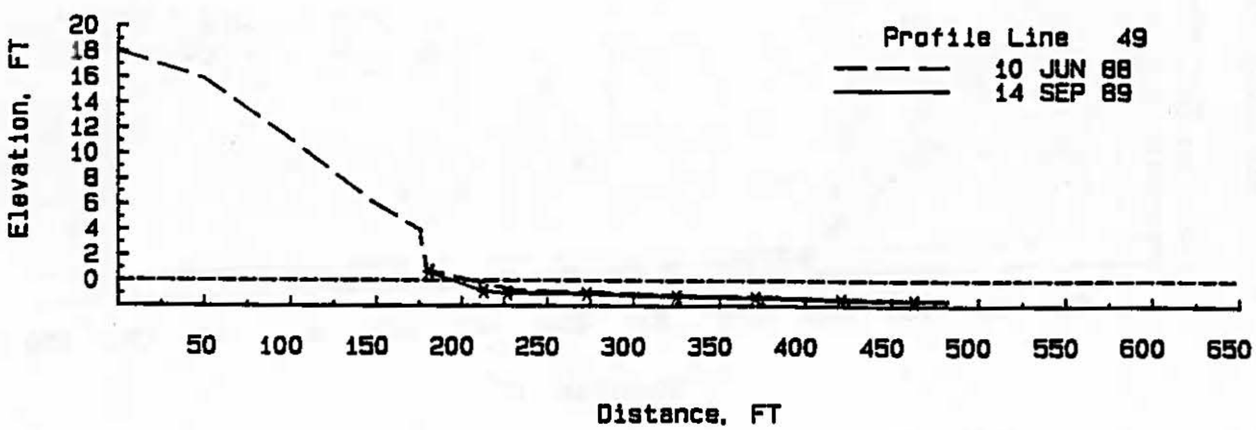

Figure D-34

Ref. No. [UMCEES]CBL 90-003

Project III of 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

JUNE 1990

ACKNOWLEDGMENTS

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 Mary Thomas for assistance on the cruises and to Ms. Kathy Speith and Mr. Ingo Wehrtmann for assistance on the cruises and the actual 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 University of Maryland, Center for Environmental and Estuarine Studies (UMCEES) Research Fleet.

ABSTRACT

Benthic invertebrate populations in the vicinity of the Hart-Miller Island dredge containment facility in the upper Chesapeake Bay were monitored for the eighth successive year in order to assess any possible effects on the biota from the operation of the containment facility. Nearfield infaunal and epifaunal samples were taken along with reference samples in December 1988 and April and August 1989. The infaunal samples were collected with a 0.05 m^2 Ponar grab and washed on a 0.5 mm screen. Epibenthic samples were scraped from pilings which support a series of piers around the facility with a specially designed scraping apparatus . Thirteen infaunal stations were sampled on each cruise (8 nearfield/experimental and 5 reference). The stations include nine silt-clay stations, three oyster shell stations and one sand substrate station. A total of 31 benthic species was collected from these thirteen stations. The most abundant species were again the annelids, *Scolecolepides viridis*, *Tubificoides sp.*;and *Heteromastus filiformis*; the crustaceans, *Leptocheirus plumulosus*, and *Cyathura polita*; and the clams, *Rangia cuneata* and *Macoma balthica*.

Species diversity (H') values were evaluated at each of the thirteen infaunal stations. The highest diversity value (3.1358) was obtained for a nearfield oyster shell station (S2) in December; whereas, the lowest diversity value (0.1183) occurred at the nearfield sand station (S1) in April. For the three

sampling dates the overall highest diversity values occurred in December and, like last year, the lowest overall diversity values occurred in April.

The length-frequencies of the clams, *R. cuneata*, *M. balthica*, and *Macoma mitchelli* were examined at the nearfield and reference stations. There was good correspondence in terms of numbers of clams and the size groupings for the three sampling dates. *Macoma mitchelli* was the least abundant of the three species of clams as it has been in past years. Cluster analysis of the stations over the three sampling periods usually associate stations in response to bottom type. Variations in recruitment might explain why some specific stations did not form tight groupings. The clusters were consistent with studies from previous years, indicating no unusual groupings. Rank analysis of differences in the mean abundances of selected species at the stations with the silt/clay substrates indicated significant differences for the nearfield stations in December and for the reference stations in April. Significant differences in means for the combined silt/clay nearfield and reference stations occurred only in April.

Epifaunal populations were similar to that observed in previous years. Samples were collected at two depths (1 m and 2-3 m, depending on the station depth) below the winter ice scour zone. The epifaunal population persisted throughout the year at these deeper locations along the pilings. The nearfield and reference populations were very similar over all three sampling periods. As previously reported the amphipod, *Corophium lacustre*, was one of the most abundant organisms, present at both the reference and nearfield stations at all sampling periods. The colonial bryozoan, *Victorella pavida*, was likewise present at both reference and nearfield stations on almost all sampling periods, but was absent from reference station R5 in April.

The results of the current monitoring effort suggest that once again, only localized and temporary effects on the benthos result from the containment facility. These effects are limited primarily to the area where dredged material is transferred from barges into the facility, and they are believed to be caused by a washing-away of the bottom by the propellers of the tug boats. Discharge of effluent from the facility occurred during this sampling year and to date no adverse effects on the benthic populations have been observed. However, it is still early and continued monitoring of the area is necessary during this period of final filling in of the containment facility.

INTRODUCTION

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

Since it is an area that is environmentally unpredictable from year to year, it is important to maintain as complete a record as possible on all facets of the ecosystem. Holland (1985) and Holland et al. (1987) completed long term studies of more stable mesohaline areas further down-Bay. They found (1) most macrobenthic species showed significant year-to-year fluctuations in abundance, primarily as a result of slight salinity changes and (2) that the spring was a critical period for the establishment of both regional and long-term distribution patterns. One can thus expect even greater fluctuations in the benthic organisms inhabiting the region of the Hart and Miller Island containment facility, which is located in the highly variable oligohaline portion of Chesapeake Bay. Indeed past studies (Pfitzenmeyer and Tenore, 1987; Duguay, Tenore, and Pfitzenmeyer, 1988; and Duguay, 1989) 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 study presented in this report were:

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

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

3. To continue monitoring of benthic and epibenthic populations at established reference stations for intercomparisons with the nearfield stations surrounding the containment facility.

4. 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 of organisms and to determine if there is any possible bioaccumulation occurring.

METHODS AND MATERIALS

Three cruises were conducted during the eighth monitoring year- on December 1-2 1988, April 10-11, 1989 and August 7-8, 1989. The sampling sites, which are shown in Figures 1 and 2 with CBL and STATE designations, were located in the field by means of the LORAN-C navigational system of the ship. Latitude and longitude of each station can be found in the *Eighth Year*

Data Report. Three replicate grabs were taken with a 0.05 m^2 Ponar grab at each of the 13 benthic infaunal stations (S1-S8 and HM-7, 9, 16, 22, and 26) at each sampling period. The samples were washed separately on a 0.5 mm screen and fixed in 10% formalin/seawater on board the ship. In the laboratory the samples were again washed on a 0.5mm sieve, then transferred to 70% ethyl alcohol. The samples were then sorted, and each organism was removed, identified, and enumerated. Length-frequency measurements were made on the three most abundant mollusks. A qualitative sample was scraped from the pilings at the epifaunal stations (R1-R5, see Figs. 1 and 2) by a specially designed piling scraping device constructed of aluminum. In general, the scrape samples were preserved and handled similarly to the infaunal benthic samples. However, only a qualitative or relative estimate of abundance was made for each species using the following numerical ratings:

1 (very abundant),
2 (abundant or common),
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 through-hull 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 ppt.

The quantitative infaunal sample data was analyzed by a series of statistical tests. A method of rank analysis was 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 eleven most abundant species, between the slit/clay, nearfield and reference, stations. Then the two sets of stations were added together and retested.

RESULTS AND DISCUSSION

Since the beginning of the benthic survey studies in 1981, a small number of species has dominated the populations of benthic invertebrates collected at the various nearfield and reference sites in the vicinity of the containment facility. Variations in the range and average number of *S. viridis*, *L. plumulosus*, and *R. cuneata* at the reference stations since August 1981 are presented in Table 1. The populations, particularly of the first two species, have remained relatively stable over this monitoring period. Variations in dominant or most abundant species occur primarily as a result of the different bottom types (Table 2). The most abundant species this year were the annelid worms, *Scolecolepides viridis*, *Tubificoides sp.*, *Heteromastus filiformis*; the crustaceans, *Cyathura polita* and *Leptochierus plumulosus*; and the clam, *Rangia cuneata* (see Tables 3 and 4). Soft bottoms are preferred by the annelid worms, *S. viridis*, *Tubificoides sp*. and *H. filiformis*, as well as the crustaceans, *L. plumulosus* and *C. polita*. The most common inhabitants of the predominately old oyster shell substrates are more variable, with the barnacle, *Balanus improvisus*, and the worm, *Nereis succinea*, often among the dominant organisms. Sudden

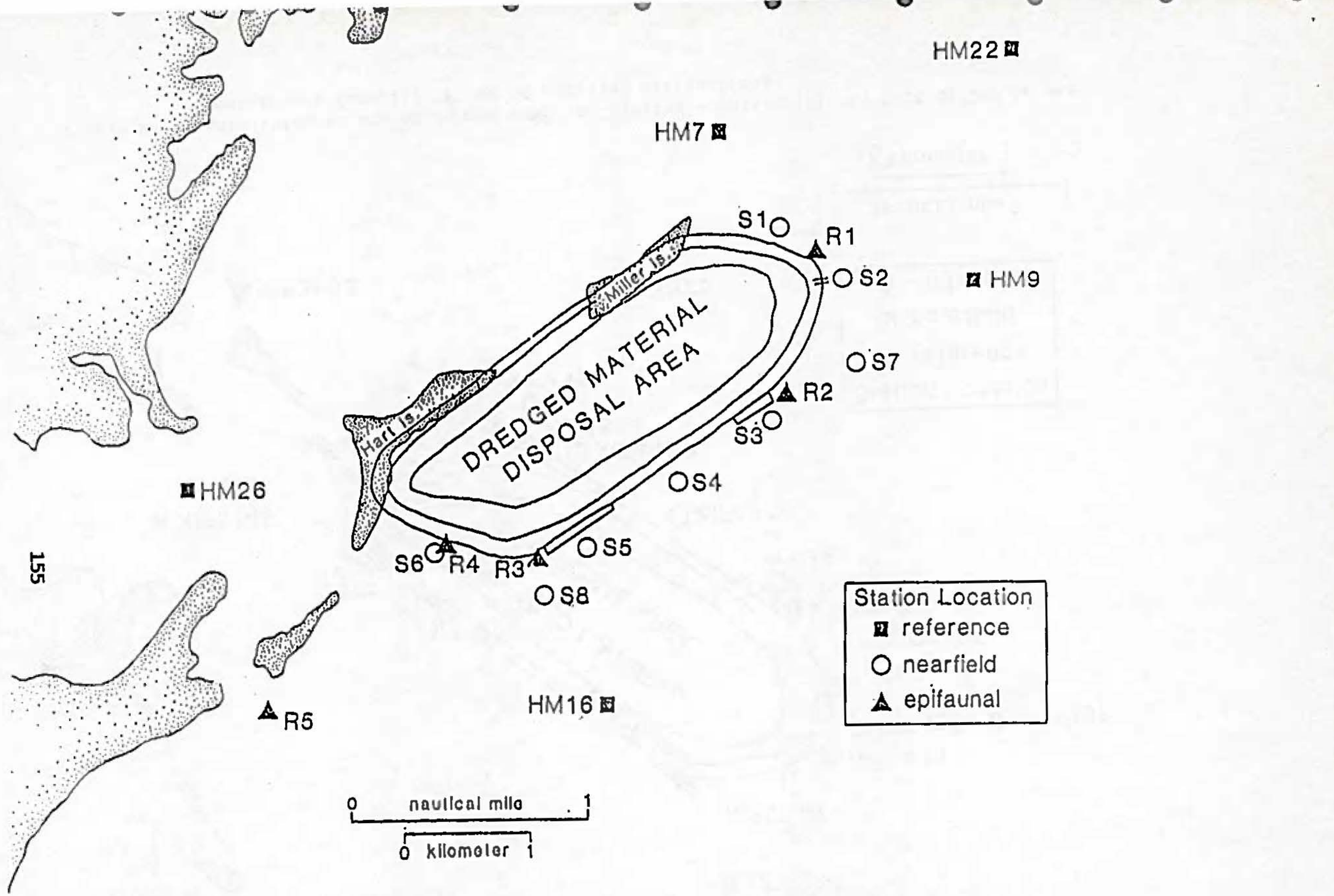

Figure 1: Benthic infaunal and epifaunal sampling station locations at the Hart-Miller Island containment facility. University of Maryland, Chesapeake Biological Lab designations.

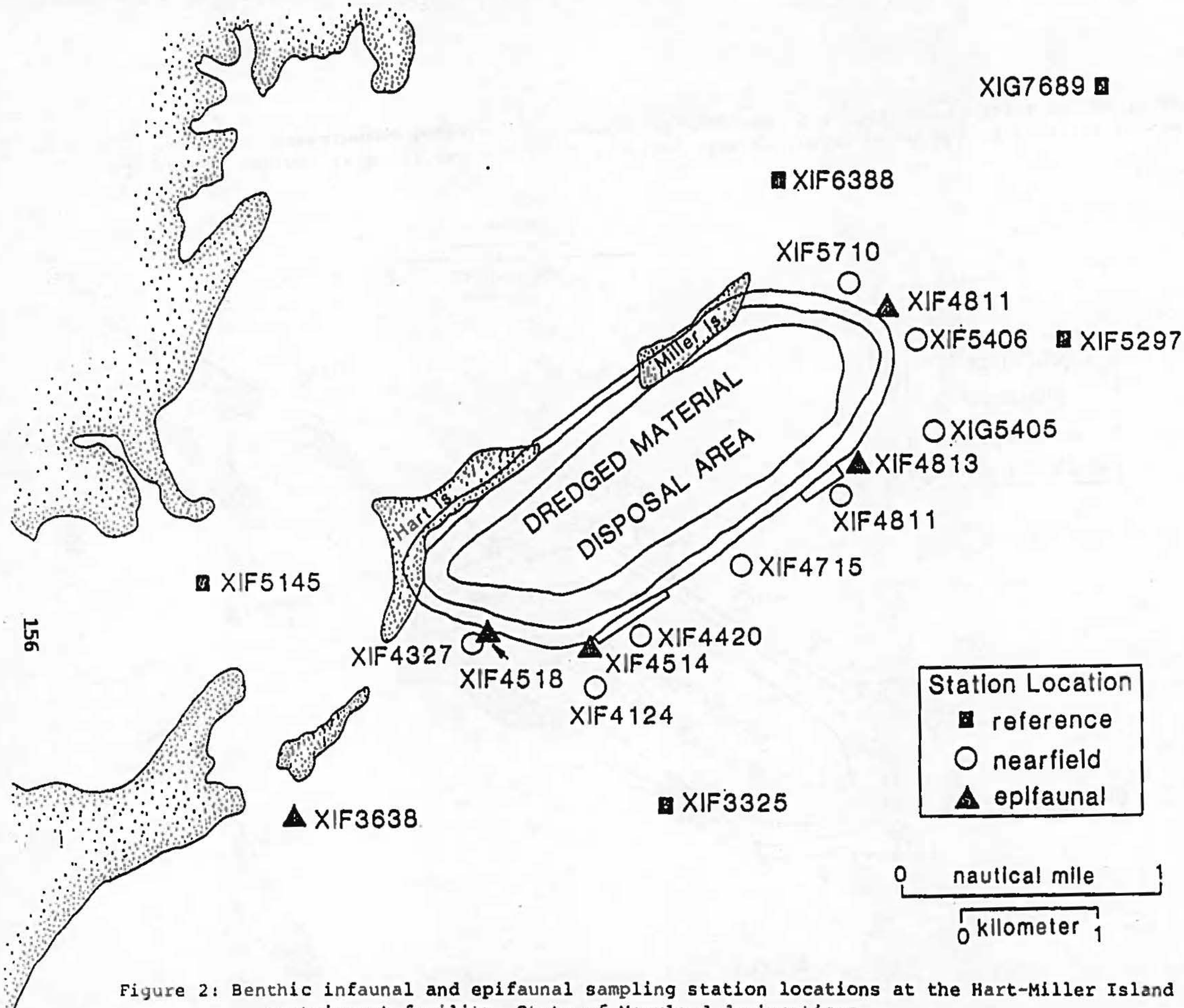

Figure 2: Benthic infaunal and epifaunal sampling station locations at the Hart-Miller Island containment facility. State of Maryland designations.

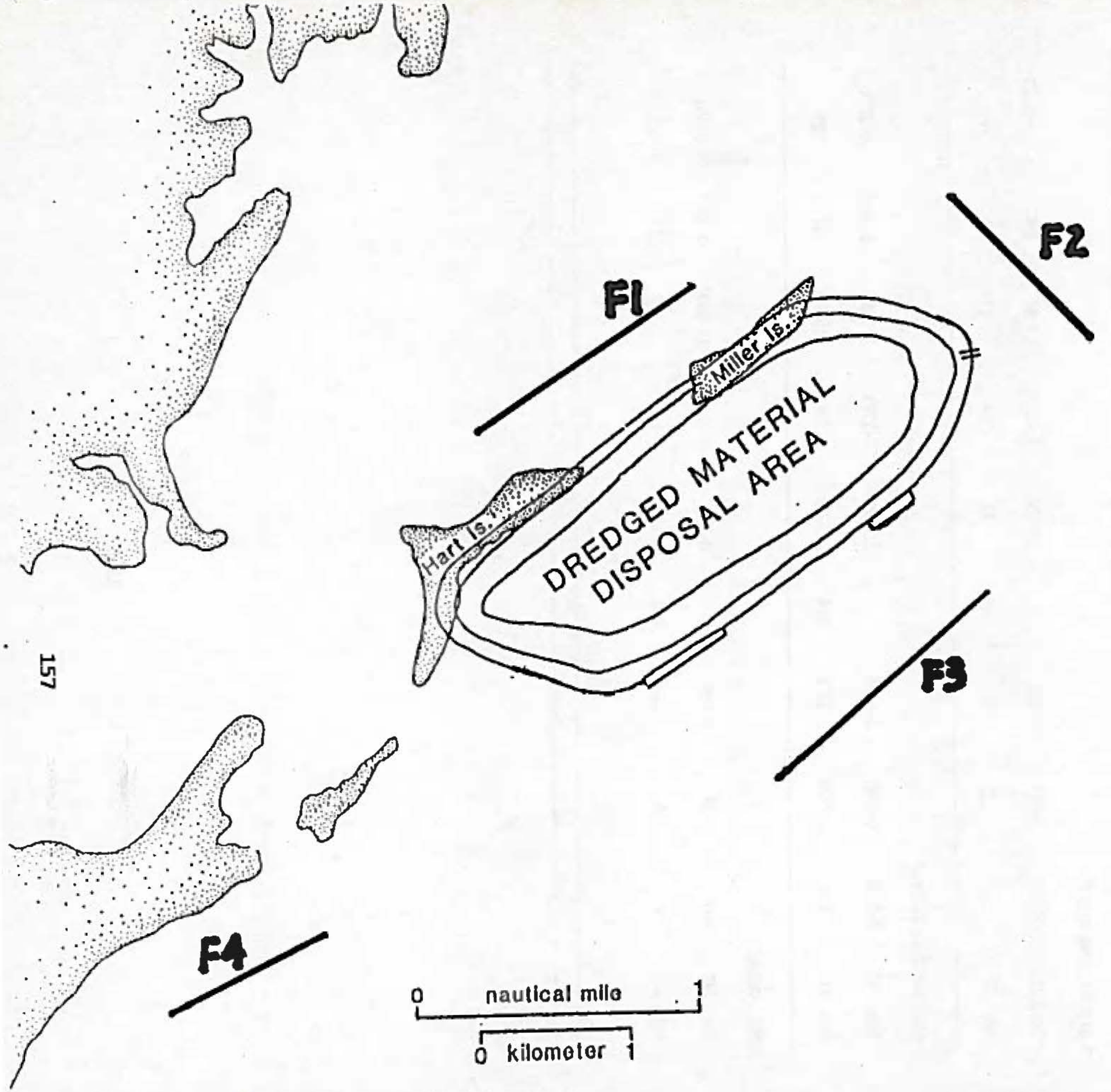

Figure 3: Fish trawling station locations at the Hart-Miller Island containment facility.

TABLE 1. Relative abundances (#/m2) of three of the most abundant species of benthic organisms which occurr at the Hart-Miller Island Reference stations over the 8 year study period from August 1981 to August 1989.

	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
Scolecolepides viridis									
Range/m2	0-1825	0-286	0-264		11-153	7-1287	13-447	0-657	20-3420
Avg./m2	229	121	69	546	92	398	179	178	998
Leptochierus plumulosus									
Range/m2	0-2960	0-5749	7-6626		20-441	7-1293	7-3312	0-3693	0-2474
Avg./m2	832	1459	2259	614	272	308	1,111	398	327
Rangia cuneata									
Range/m2	0-46	0-99	0-135		0-75	0-273	13-3007	0-2267	0-580
Avg./m2	9	9	22	455	27	102	687	359	123

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

STATION	December 1988	April 1989	August 1989
NEARFIELD SOFT BOTTOM (S3,4,5,6,8)			
	Tubificoides sp.	Scolecolepides viridis	Scolecolepides viridis
	Heteromastus filiformis	Tubificoides sp.	Leptochierus plumulosus
	Streblospio benedicti	Heteromastus filiformis	Cyathura polita
NEARFIELD SHELL BOTTOM (S2,7)			
	Streblospio benedicti	Scolecolepides viridis	Scolecolepides viridis
	Balanus improvisus	Tubificoides sp.	Leptochierus plumulosus
	Nereis succinea	Nereis succinea	Corophium lacustre
REFERENCE SOFT BOTTOM (HM7,16,22)			
	Tubificoides sp.	Scolecolepides viridis	Leptochierus plumulosus
	Rangia cuneata	Tubificoides sp.	Scolecolepides viridis
	Cyathura polita	Macoma balthica	Cyathura polita
REFERENCE SHELL BOTTOM (HM9)			
	Streblospio benedicti	Tubificoides sp.	Scolecolepides viridis
	Heteromastus filiformis	Scolecolepides viridis	Leptochierus plumulosus
	Tubificoides sp.	Nereis succinea	Rangia cuneata
BACK RIVER REFERENCE (HM26)			
	Tubificoides sp.	Tubificoides sp.	Cyathura polita
	Streblospio benedicti	Scolecolepides viridis	Scolecolepides viridis
	Heteromastus filiformis	Cyathura polita	Tubificoides sp.

TABLE 3: Number of benthic organisms per m squared (m2) found at the Reference Stations for the eight year monitoring study (December 1988 - August 1989) for the Hart-Miller Island benthic studies.

SPECIES NAME	SPECIES#	HM7 Dec	HM7 Apr	HM7 Aug	HM9 Dec	HM9 Apr	HM9 Aug	HM16 Dec	HM16 Apr	HM16 Aug	HM22 Dec	HM22 Apr	HM22 Aug	HM26 Dec	HM26 Apr	HM26 Aug	TOTALS
RHYNCHOCOELA (ribbon worms)																	
Micrura leidyi	2	20	13					27	66	7	47	7	7	53	7		254
ANNELIDA (worms)																	
Heteromastus filiformis	3	20	48	40	67	66	187	140	133	27	100	93	67	220	147	194	1549
Nereis succinea	5		7	7		167	20	13	13	13	7				13	13	273
Eteone heteropoda	8		7					7	47			7		60	67		195
Polydora ligni	9	60									80	7		7	7		161
Scolecolepides viridis	10	47	3420	706	20	2473	1554	80	2253	634	20	1427	154	33	1593	560	14974
Streblospio benedicti	11	87			93	27	13		13		13	7		1853	620	207	2933
Limnodrilus hoffmeisteri	13							107						73			180
Tubificoides sp.	14	253	16	34	33	1280	13	833	1827	154	400	327		17913	17993	467	41543
Capitella capitata	15							7	13					60		7	87
MOLLUSCA (mollusks)																	
Ischadium recurvus	16						7										7
Macoma balthica	19		13	7			7	540	333	126		27		20	27		1100
Macoma mitchelli	20	7					7	180	13	13		7	7	20	7		261
Rangia cuneata	21	133	80	93	13		307		33	154	580	360		27	27	67	1874
ARTHROPODA (crustaceans)																	
Balanus improvisus	27					87											87
Balanus subalbidus	28					60											60
Leucon americanus	29															20	20
Cyathura polita	30	40	33	133	20	20	147	400	207	326	33	27	80	93	173	666	2398
Cassidinidea lunifrons	31					7										13	20
Edotea triloba	33							7						20	20	7	54
Gammarus palustris	35													7			7
Leptocheirus plumulosus	36	7	60	2474			394	160	207	1074		27	366	27	53	60	4909
Corophium lacustre	37		7		27	40	40						20	13		40	187
Gammarus daiberi	38						7			7			7				21
Melita nitida	40						13						7				20
Monoculodes edwardsi	42						13			7			7			7	34
Chironomid sp.	43		40				7			80			20	7	20	47	221
Rithropanopeus harrisi	44			13		67	13									40	133
Stylochus ellipticus	48														13		13
TOTAL NUMBERS		674	3744	3507	273	4294	2749	2501	5158	2622	1280	2323	742	20506	20787	2415	73575

TABLE 4: Number of benthic organisms per m squared (m2) found at the Nearfield Stations for the eighth year studies (1988 - 1989) around the Hart-Miller Island containment facility.

SPECIES NAME	#	S1 XIF5710 Dec	S1 Apr	S1 Aug	S2 XIF5406 Dec	S2 Apr	S2 Aug	S3 XIF4811 Dec	S3 Apr	S3 Aug	S4 XIF4715 Dec	S4 Apr	S4 Aug
RHYNCHOCOELA (ribbon worms)													
Micrura leidyi	2	13		40	13			140	60	72	47	33	32
ANNELIDA (worms)													
Heteromastus filiformis	3	353	7		33	47	92	440	380	60	267	140	40
Nereis succinea	5			20	127	127					13	7	7
Eteone heteropoda	8								180			13	
Polydora ligni	9	420			267	133		13	20				7
Scolecolepides viridis	10	100	12540	1506		7514	500	47	4480	786	167	2487	1972
Streblospio benedicti	11	133			353	20		420		66	60	13	27
Limnodrilus hoffmeisteri	13	7									553		
Tubificoides sp.	14	940	127	132	120	340	13	347	1020	226		320	60
Capitella capitata	15		7			7							7
MOLLUSCA (mollusks)													
Ischadium recurvus	16			7	20								
Congeria leucophaeta	17					7							
Macoma balthica	19					73		40	67	7	247	60	
Macoma mitchelli	20	7				13		13			33	13	
Rangia cuneata	21	913	7	1420	7	393	246	13		520	47	7	474
ARTHROPODA (crustaceans)													
Balanus improvisus	27				167								
Balanus subalbidus	28				47								
Leucon americanus	29												
Cyathura polita	30	67	13	252	7	87	126	67	40	294	127	80	234
Cassidinidea lunifrons	31			13	53								
Edotea triloba	33	13						7	7	13			
Gammarus palustris	35						26						
Leptocheirus plumulosus	36		7	26			246		53	866		73	
Corophium lacustre	37	33		9480	47	20	120	7	7	13			
Gammarus daiberi	38									13			
Gammarus tigrinus	39									80			
Melita nitida	40												
Monoculodes edwardsi	42						13						
Chironomid sp.	43			13									
Rithropanopeus harrisi	44			20	67	13	13				7		
Stylochus ellipticus	48				7								
TOTAL NUMBERS		2999	12708	12929	1335	8794	1395	1554	6314	3016	1568	3233	2860

TABLE 4: Number of benthic organisms per m squared (m2) found at the Nearfield Stations for the
CONT. : eighth year studies (1988 - 1989) around the Hart-Miller Island containment facility.

SPECIES NAME	#	S5 X1F4420 Dec	Apr	Aug	S6 X1P 4327 Dec	Apr	Aug	S7 X1G5405 Dec	Apr	Aug	S8 X1F4124 Dec	Apr	Aug	TOTAL ALL STATIONS ALL DATES
RHYNCHOCOELA (ribbon worms)														
Micrura leidyi	2	27	27	7	40	7	7			7	47	13	13	645
ANNELIDA (worms)														
Heteromastus filiformis	3	140	100	7	387	147	60	220	27	87	80	7		3121
Nereis succinea	5		47	7	27	7		160	374		7			930
Eteone heteropoda	8	7	13			27								240
Polydora ligni	9	20						67	40		40			1027
Scolecolepides viridis	10	60	1360	1546	267	7320	1146	13	334	1400	153	900	1546	48144
Streblospio benedicti	11	140		13	173	67	47	493	27		47	7	13	2039
Limnodrilus hoffmeisteri	13								7					567
Tubificoides sp.	14	447	313	7	5140	4554	360	140	586	67	53	20	114	15446
Capitella capitata	15		7						7					35
														0
MOLLUSCA (mollusks)														0
Ischadium recurvus	16							13	27					67
Congeria leucophaeta	17							20	13					40
Macoma balthica	19	60	60		13	260	7		7			27		928
Macoma mitchelli	20	7			13	27	67					13	34	240
Rangia cuneata	21	53		220			27			74			180	4601
														0
ARTHROPODA (crustaceans)														0
Balanus improvisus	27							227	120					514
Balanus subalbidus	28							27	27					101
Leucon americanus	29									80				80
Cyathura polita	30	127	133	213	140	200	394	27	7	60	73	187	906	3861
Cassidinidea lunifrons	31							33	13					112
Edotea triloba	33					67	7			7				121
Gammarus palustris	35													26
Leptocheirus plumulosus	36		53	346		47	1392			880		73	740	4802
Corophium lacustre	37	173		20	20	160		40	67	266	40	7		10520
Gammarus daiberi	38													13
Gammarus tigrinus	39									7				87
Melita nitida	40								13					13
Monoculodes edwardsi	42			13			7			20				53
Chironomid sp.	43			7		27	40						40	127
Rithropanopeus harrisi	44							33	100	7				260
Stylochus ellipticus	48													7
TOTAL NUMBERS		1261	2113	2406	6220	12850	3561	1513	1796	2962	540	1254	3586	98767

freshwater inflows during the spring spawning period have favored the recruitment success of *R. cuneata* in different years. During the sixth monitoring year high influxes into the population were observed at several stations during the August 1987 sampling which was reflected in high densities of small individuals in both the December 1987 and April 1988 samples. A similar influx was not observed in the August 1988 samples. If salinities exceeding 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 large number of larger sized clams were present in both August 1988 and in August 1989. The worm, *H. filiformis*, has a preference for the higher mesohaline area of an estuary. It is an opportunist with the ability to rapidly increase its progeny rapidly as favorable saline conditions arrive. It also has been acknowledged as a nitrate enrichment indicator (Dean and Haskin, 1964). Station HM26, at the mouth of Back River has the most diverse annelid fauna, with 8 different species present in December. The most abundant annelid at this station for December and April was *Tubificoides sp.* with levels of 17,913 and 17,993 individuals per m^2, respectively (Table 3). At HM26 in August *S. viridis*, (560 individuals/m2) was slightly more abundant than *Tubificoides* which had fallen to 467 individuals/m2.

The worm, *S. viridis*, and the crustacean, *C. polita*, occurred most frequently at both the nearfield and reference stations. *S. viridis* was absent only in December at station S2; *C. polita* 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 and 4). Over the course of these monitoring studies, the worm, *S. viridis* has frequently alternated with the crustaceans, *C. polita* and *L. plumulosus*, as the 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 higher total densities primarily due to a very large population (12540) at station S1 in April (see Table 4). As was the case, during the seventh monitoring year, *L. plumulosus* fell behind *C. polita* in terms of overall abundance, particularly as a result of a high density of *C. polita* at station S1 in August. The isopod crustacean, *Cyathura*, appears to be very tolerant of physical and chemical disturbances and repopulates areas such as dredged material disposal piles more quickly than other species (Pfitzenmeyer, 1985).

All of the dominant species, with the exception of *R. cuneata*, brood their young. This is an advantage in an area of unstable and variable environmental conditions such as the upper Chesapeake Bay. Organisms released from their parents as juveniles are known to have high survival and often reach high densities of individuals (Wells, 1961). The total number of individual organisms collected at the various reference and nearfield stations are quite comparable and ranged for the most part between 1000 and 5000 individuals per meter square. The highest recorded values occurred at stations HM26, S1 and S6 (12,000-20,000) as a result of high concentrations of the worms *S. viridis* and/or *Tubificoides*. The lowest recorded values occurred at station HM9 in December (273 individual/m^2) followed by station S8 (540) and HM7 (674) in December and then by station HM22 in August (742). There did not appear to be any consistent pattern in terms of reference or nearfield stations. However, April values were generally above December and August, reflecting maximum recruitment at this time. The predominant benthic populations at both the nearfield and reference areas are similar. They consist of detrital feeders which have an ample supply of fine substrates in this region of the bay, 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 5). In April salinity at all stations was 0 o/oo. In August salinity ranged from 1-3 o/oo with somewhat higher salinities ranging from 2-6 o/oo recorded in December. The April values were similar to the last 2 years when salinities were 1 o/oo in April 87 and 1-2 o/oo in April 88. The December values likewise fell within the same range as the previous two years. However the August values were considerably lower than those recorded in 87 and 88 when the values ranged from 6-8 o/oo. Temperature was likewise fairly comparable to the sixth and seventh year study. However, August temperature was slightly lower than the previous two years when the temperature ranged from 29-30°C in August 1988 and 27-29°C in August 1987.

Species diversity values must be interpreted carefully in analyzing benthic data from the upper Bay. Generally, high diversity values reflect a healthy, stable fauna with the number of all species in the population somewhat equally distributed, and no obvious dominance by one or two species. However, in this area of the Chesapeake, the normal condition is for one, two or three species to assume numerical dominance. This dominance is variable from year to year depending on environmental factors, in particular the amount of freshwater entering the Bay from the Susquehanna River. Because of the overwhelming numerical

TABLE 5: Salinity (in 0/00), temperature (in OC), and depth (in ft.) data for the nearfield, refer and epifaunal stations on the three collection dates during the eighth year of benthic mo ing studies at the Hart-Miller Island containment facility.

CBL STA. ID	STATE STA. #	DECEMBER 88 SAL.	DECEMBER 88 TEMP.	DECEMBER 88 DEPTH	APRIL 89 SAL.	APRIL 89 TEMP.	APRIL 89 DEPTH	AUGUST 89 SAL.	AUGUST 89 TEMP.	AUGUST 89 DEPTH
S1	XIF5710	2	8.5	6	0	9.5	6	1	26.5	6
S2	XIF5406	6	8.5	12	0	10	12	2	27	12
S3	XIF4811	3	8.5	15	0	10	13	3	27	14
S4	XIF4715	3	8.5	13	0	10	12	3	26.5	12
S5	XIF4420	3	8.5	18	0	10	18	3	27	12
S6	XIF4327	3	8.5	9	0	10	12	3	27	8
S7	XIG5405	3	8.5	11	0	10	11	2	27	11
S8	XIF4124	3	8.5	13	0	10	13	3	27	12
HM7	XIF6388	2	8.5	10	0	9.5	9	2	26.5	9
HM9	XIF5297	3	8.5	12	0	9.5	10.5	1	26.5	10
HM16	XIF3325	6	8.5	16	0	9.5	13	3	27	12
HM22	XIG7689	0	8.5	15	0	9.5	10.5	1	26.5	11
HM26	XIF5145	2	8.5	16	0	9.5	15	3	26.5	15
R2	XIF4813	4	8.5	12	NR*	NR*	NR*	NR*	NR*	NR*
R3	XIF4514	2	8.5	12	NR*	NR*	NR*	NR*	NR*	NR*
R4	XIF4518	2	8.5	10	NR*	NR*	NR*	NR*	NR*	NR*
R5	XIF3638	2	8.5	5	NR*	NR*	NR*	NR*	NR*	NR*

NR* = Not Recorded

dominance of a few species, diversity values are fairly low in this productive area of the Bay when compared to values obtained elsewhere. Diversity values for each of the quantitative benthic samples for the three different sampling dates are presented in Tables 6, 7, and 8. This year, unlike the previous few years, the overall highest species diversity (overall average seasonal value of 3.1358, as well as 7 other stations with values greater than 2.5000) was found during the winter sampling in December versus the summer sampling, in August (Table 6 and 8). Highest diversity values in the summer had been postulated in the First Interpretive Report (Pfitzenmeyer et al., 1982) and is most often the case. The lowest species diversity values occurred in April and they were indeed substantially below previous values recorded in April with only 2 stations above 2.0000 compared with 10 stations above 2.0000 in 1988. Perhaps these greatly reduced values in April were responsible for the reduction in diversity observed in the subsequent August samples.

The largest number of species recorded for any station was 17 at the Back River (HM26) reference site in December, nearfield station S7 in April and reference station HM22 in August. The lowest number of species, 7, was recorded in April and was at the nearfield sand substrate station (S1). These rankings for the highest and lowest number of species occurred at the same two stations (HM26-highest and S1-lowest) in the sixth and seventh year studies as well.

TABLE 6. Number of species and the total number of individuals collected in three grab samples (0.05m2 each) at the infaunal stations for DECEMBER 1988 Bottom substrate, species diversity (H1) and dominance factor (S.I.) are also shown. Data for the eighth 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	12	449	2.4606	0.22909
S2	Shell	15	201	3.1358	0.14943
S3	Silt/Clay	12	188	2.5704	0.22703
S4	Silt/Clay	11	235	2.7148	0.20014
S5	Silt/Clay	12	195	2.8739	0.18212
S6	Silt/Clay	10	932	1.0748	0.69142
S7	Shell	13	223	2.9134	0.18012
S8	Silt/Clay	09	081	2.8900	0.15684
REFERENCE					
HM 7	Silt/Clay	10	100	2.6231	0.21740
HM 9	Shell	07	041	2.4882	0.21356
HM16	Silt/Clay	13	375	2.7205	0.19879
HM22	Silt/Clay	09	192	2.0923	0.31538
BACK RIVER REFERENCE					
HM26	Silt/Clay	17	3066	0.7475	0.77645

TABLE 7. Number of species and the total number of individuals collected in three grab samples (0.05m2 each) at the infaunal stations for APRIL 1989. Bottom substrate, species diversity (H1) and dominance factor (S.I.) are also shown. Data for the eighth 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	07	1906	0.1183	0.97404
S2	Shell	14	1313	0.9792	0.74071
S3	Silt/Clay	11	947	1.4512	0.53441
S4	Silt/Clay	12	487	1.3835	0.59982
S5	Silt/Clay	10	315	1.8305	0.44448
S6	Silt/Clay	14	1937	1.5272	0.44666
S7	Shell	17	268	2.8563	0.19693
S8	Silt/Clay	10	187	1.4357	0.54800
REFERENCE					
HM 7	Silt/Clay	12	607	0.9938	0.72145
HM 9	Shell	11	635	1.6301	0.43535
HM16	Silt/Clay	14	772	2.0882	0.32599
HM22	Silt/Clay	12	348	1.7767	0.42411
BACK RIVER REFERENCE					
HM26	Silt/Clay	16	3182	0.8408	0.75620

TABLE 8. Number of species and the total number of individuals collected in three grab samples (0.05m2 each) at the infaunal stations for AUGUST 1989 Bottom substrate, species diversity (H1) and dominance factor (S.I.) are also shown. Data for the eighth 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	12	1943	1.3296	0.56168
S2	Shell	10	210	2.5917	0.21025
S3	Silt/Clay	13	453	2.6924	0.19716
S4	Silt/Clay	10	429	1.4959	0.51099
S5	Silt/Clay	12	361	1.6961	0.45014
S6	Silt/Clay	13	534	2.2238	0.28037
S7	Shell	13	444	2.1313	0.32339
S8	Silt/Clay	09	538	2.0638	0.29618
REFERENCE					
HM 7	Silt/Clay	13	393	2.4521	0.25210
HM 9	Shell	13	591	1.8523	0.43323
HM16	Silt/Clay	11	111	2.2200	0.31012
HM22	Silt/Clay	17	412	2.1416	0.36068
BACK RIVER REFERENCE					
HM26	Silt/Clay	16	362	2.8478	0.18376

Three species of mollusks, *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 areas for these clams (Figures 4, 5,6). The most abundant clam again this year was *R. cuneata*. In keeping with last year's observations that most of the *Rangia* collected in August 1988 ranged from 21-30 mm and that no new spring set or grow up had occurred in April, the December 1988 population was slightly lower in numbers and predominantly still in the 25-35 mm range. There was a slight decline in total numbers over the period from December 1988, when a high of about 80 individuals was recorded through April 1989 when slightly over 50 clams were collected. In August 1989, a large cohort of small sized *R. cuneata* was observed in the 0-5 mm size range. Over 180 individuals recorded at the nearfield stations and over 50 were recorded for the reference stations, compared with fewer than 5 individuals at either set of stations in December and April. In August 1988 we also continued to find large numbers (about 100-160) of the larger sized individuals (>25 mm) indicative of continued survival and growth of this cohort over the spring through summer period. There were no significant differences in the overall numbers of *Rangia* found at the nearfield or reference sites. The overall numbers of *Rangia* in both sets of samples from all three sampling periods were still lower than the August 1987 high, when 600-700 individuals

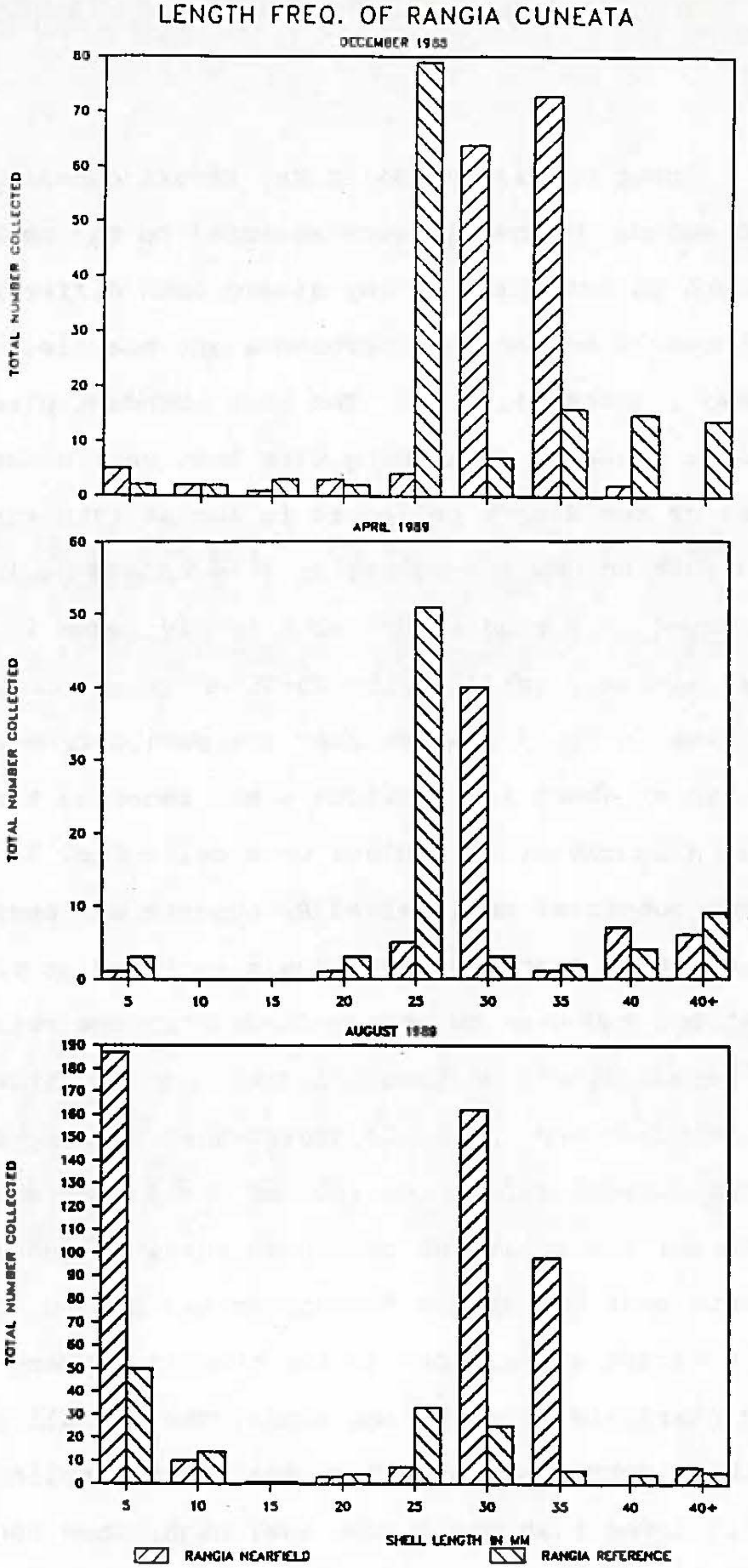

FIGURE 4: Length frequency distribution of the clam, Rangia cuneata, during the eighth year of benthic sampling at the Hart-Miller Island containment facility.

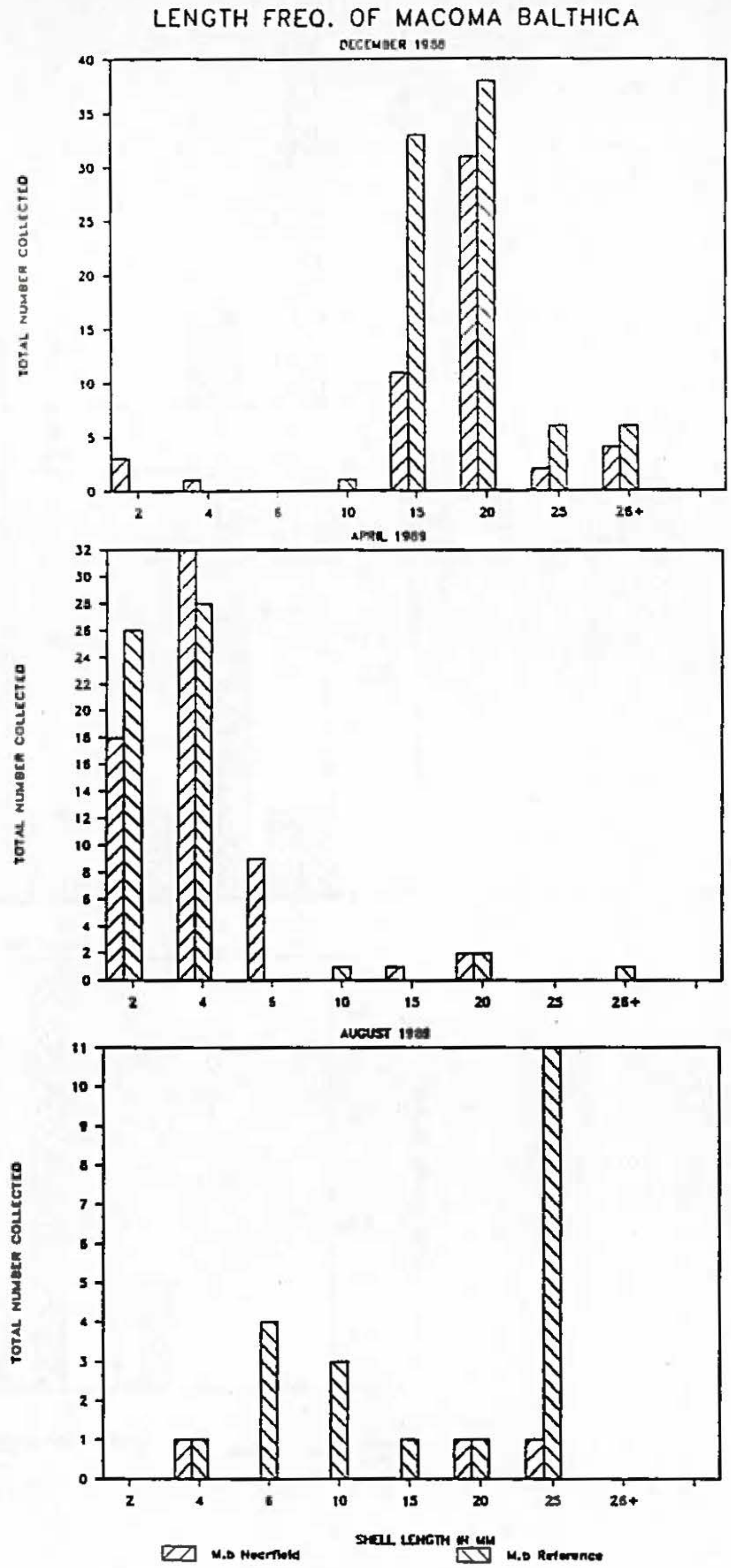

FIGURE 5: Length frequency distribution of the clam, Macoma balthica, during the eighth year of benthic monitoring at Hart-Miller Island.

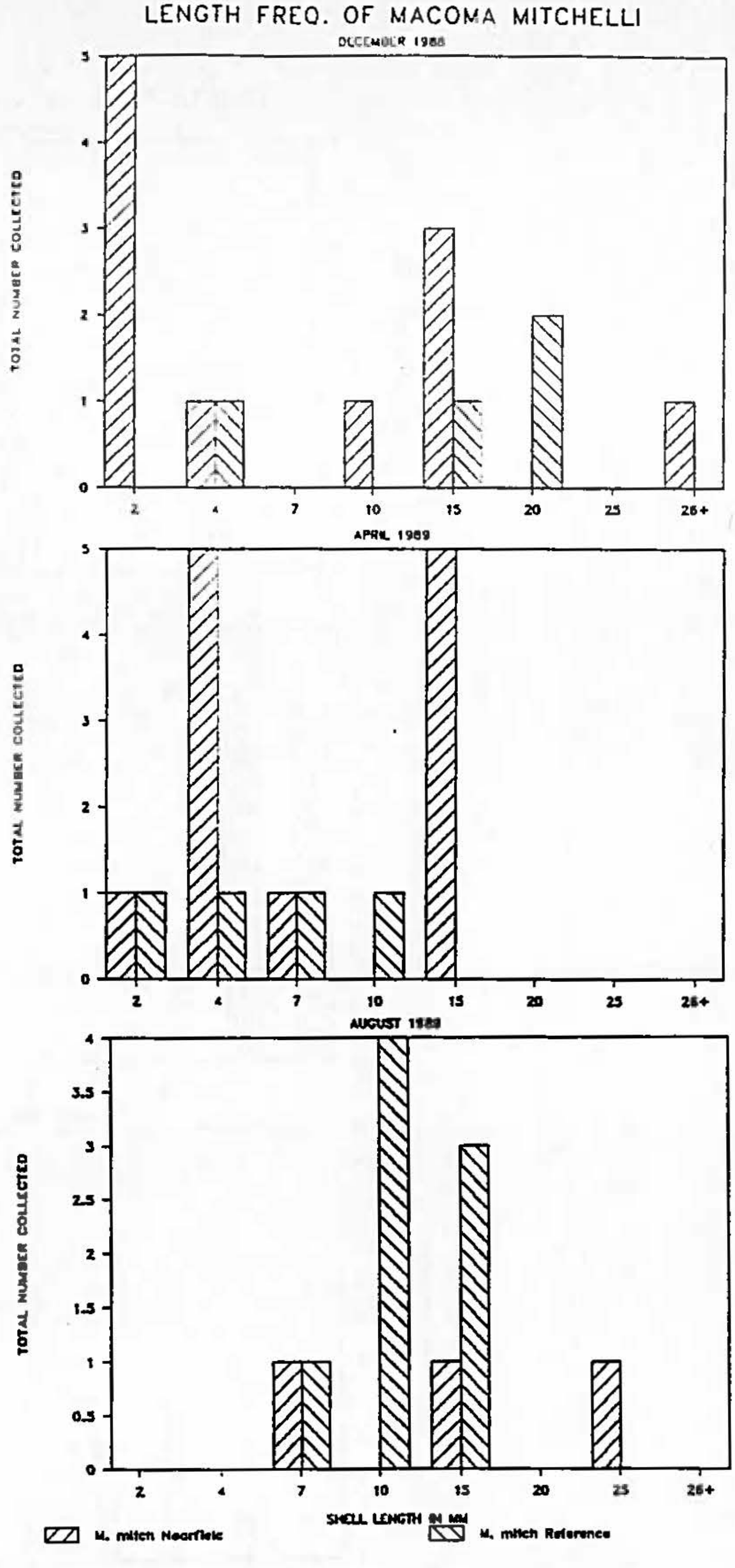

FIGURE 6: Length frequency distribtuion of the clam, Macoma mitchilii during the .eighth year of Benthic monitoring at Hart-Miller Islands.

were collected. However, the large cohort of small (0-5 mm) individuals collected in August 1989 indicated that unlike 1988, when no new spring set and grow up occurred, that the eighth 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 second most abundant clam during the eighth year of studies, as was the case for the sixth and seventh year studies, was *M. balthica*. In December the *M. balthica* population (see Figure 5) was dominated by the 11-15 and 16-20 mm size classes. Over 10-30 individuals were present at the nearfield stations and more than 30 individuals at the reference stations. These findings were in keeping with the somewhat lower number of specimens recorded at the nearfield stations (10 vs. 50) last August 1988. The organisms in the 16-20 mm size class may reflect a grow up over the fall period of the 11-15 mm August size class. This would be a slightly lower growth rate than the approximate 2.0 mm per month growth rate which we observed last year around Hart Miller Island for this species and also with the range reported by Holland et al. (1987) of 1.9 to 2.3 mm per month at their middle Potomac River stations. However, the slightly slower growth might be expected over this period of fall/winter declining temperatures. In April 1989, there was a dramatic decrease in the numbers of larger *M. balthica* at both the nearfield and reference stations (only 2 animals per size class). However, there was also a large increase in the numbers of small individuals in the range of 2-7 mm, from fewer than 5 to 10-30. The population changes suggest reproduction and subsequent die off of the large sized individuals. In August 1988, there was an overall decline in numbers of *M. balthica* at both sets of stations. The decline was somewhat more dramatic at the nearfield stations, with no organisms in the 5-15 mm size range found at this time at these stations. This overall decline in numbers of *M. balthica* in August was also observed during the seventh monitoring year,when a 77% reduction in numbers at the nearfield stations was reported versus a 16% drop at the reference station. This greater decline in numbers of *M. balthica* at the nearfield stations may reflect the very heavy barge traffic which occurs in this area during the summer months.

The length frequency and abundance pattern of the third mollusk *M. mitchelli* was somewhat similar to that observed in the previous two years. *M. mitchelli* had a lower abundance than either of the other two species. In December and April the various size classes (1-20 mm) were fairly evenly distributed (1-5 individuals), but somewhat reduced compared to previous years, when numbers ranged from 5-20 individuals. In August the larger size classes (5-15 mm) predominated. Only a few individuals were encountered in the 1-7 mm range possibly reflecting grow up over the April to August period. There was also a continued decline in the overall numbers of *M. mitchelli* found in this region of the Bay, indicating continued less favorable conditions for this particular species. Last year we reported a generally reduced number of *M. mitchelli* at the nearfield stations when compared with the reference stations. This year no particular difference between the stations was observed. However, there does seems to be a continued 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 this 8th year of sampling in 1989. The exact causes of the decline in numbers of the 2 *Macoma* species, and in particular *M. mitchelli*, are not readily apparent and bear careful monitoring. As reported in the previous 2 years, (Duguay et al., 1988 and Duguay 1989) there has been a 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 7, 8 and 9 the stations with faunal similarity (based on chi-square statistics derived from the differences between the values of the variables for 2 stations), are linked by horizontal connections in the three dendrograms. Each station was considered to be a cluster of its own. At each step (amalgamated distances) the clusters with the shortest distance between them were combined (amalgamated) and treated as one cluster. Cluster analysis in past studies at the Hart-Miller Island study site has clearly indicated a faunal response to bottom type (Pfitzenmeyer, 1985). Thus any unusual grouping of

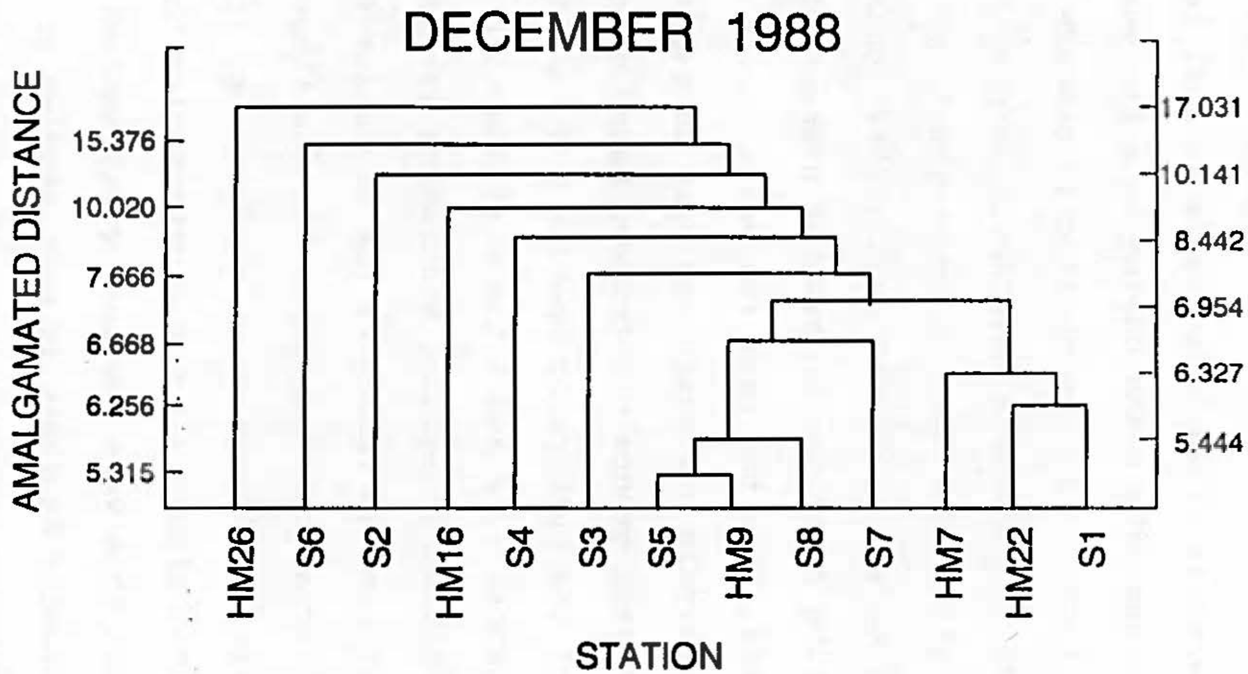

FIGURE 7: Cluster analysis for all of the Hart-Miller Island stations sampled in December 1988 during the eighth year of benthic monitoring.

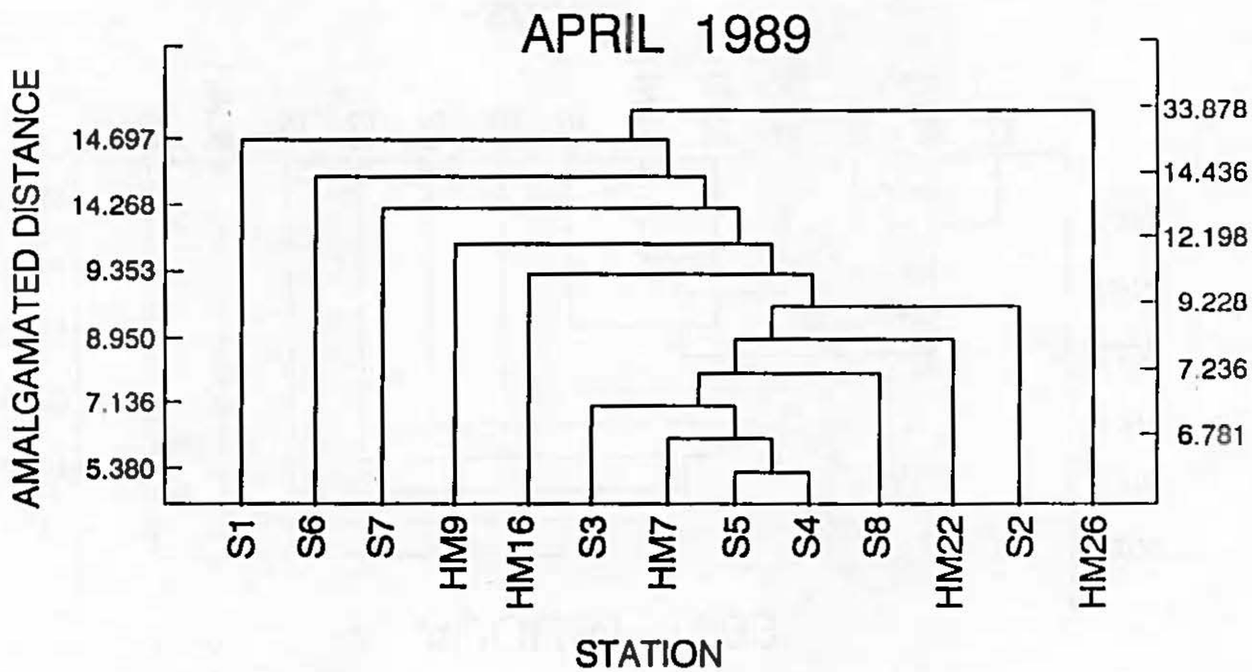

FIGURE 8: Cluster Analysis for all of the Hart-Miller Island stations sampled in April 1989 during the eighth year of benthic monitoring.

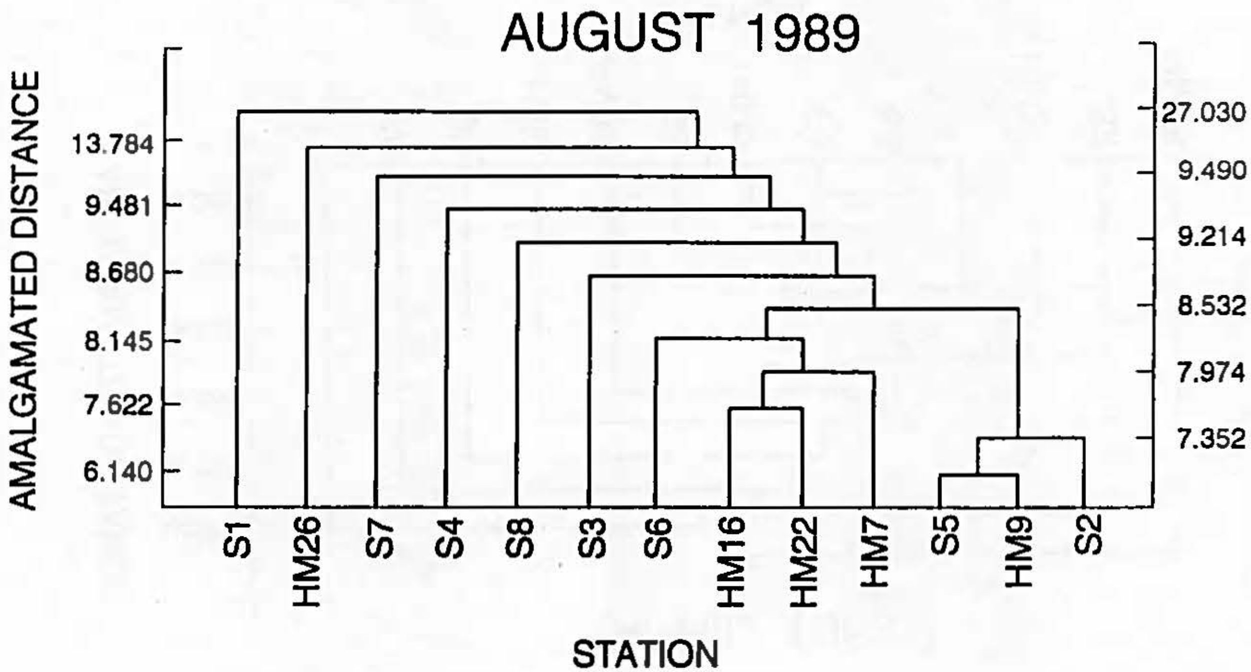

FIGURE 9: Cluster analysis for all of the Hart-Miller Island stations sampled in August 1989 during the eighth year of benthic monitoring.

stations tends to suggest changes are occurring due to factors other than bottom type, and further examination of these stations is required. Most of the time experience and familiarity with the area under study can help to explain away the differences. However, when they cannot be explained extraneous factors must be investigated further.

The basic grouping of stations for the December 1988 sampling period is presented in Figure 7. There is an initial joining of two groups of mixed nearfield and reference stations (S5, HM9, S8, S7 and S1, HM7, HM22) with intermixed bottom types. The next stations to fall in were three soft-bottom/silt-clay stations S3, S4, and HM16. The final three stations to join the dendrogram were S2, S6 and HM26. These three stations formed the outer end of the cluster in December 1988 as well. Stations S6 and HM26 are located near each other in the southwestern area of the study. HM26, the station located near Back River, is frequently one of the final stations to join the dendrogram. The clustering of stations observed for December is similar reported on previous occasions (Duguay et al., 1988 and Duguay, 1989), and an indicating no anomalous changes at the nearfield stations.

In April (Figure 8), the basic grouping was formed by a joining of two silt/clay reference (HM7 and HM22) stations and a number of silt/clay nearfield (S3,S4,S5,S8) stations. The exact set of stations making up the inner grouping differed from that in December. The next series to fall in at this juncture was a mixture of shell/sand bottom stations (S2, HM9, S7, S1) and some silt/clay stations (HM16,S6). The final station to join the dendrogram was HM26, as in December.

August 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. The four main reference sites (HM7,HM16,HM22,HM9) as in August 1988 again fell within the innermost cluster of stations and again HM9 (a shell station) formed a tight cluster with S5 (a silt/clay station) and this time also with S2 (also a shell station). The remainder of the soft bottom silt/clay stations along with shell station S7 than joined the dendrogram. The outermost members of the cluster were HM26 and S1, which was very similar to the pattern also observed in April of this year.

The clusters formed over these three sampling dates represented previously observed, normal groupings 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. If these fauna 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 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 9, 10, and 11.

In December 1988, the stations sorted themselves out into just four subsets (Table 9). Five nearfield stations, S1 through S5, formed the first subset, and the second subset was made up of two nearfield (S6, S7) and two reference (HM16, HM7) stations. The third subset dropped station S7 and added station S8 to the two reference stations. The final subset consisted of the last three reference stations (HM22, HM26, and HM9). This was more or less in keeping with the analyses made for December 86 and 87 (Duguay et al., 1988 and Duguay, 1989, respectively) as well as

TABLE 9. The Student-Neuman-Keuls test of significance for stations sampled in December 1988. Subsets show groupings of stations different at (P<0.05). Stations in a vertical column and row are significantly different from others. Eighth year of benthic monitoring studies at Hart and Miller Islands.

DECEMBER 1988

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

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F. RATIO	F. PROB.
BETWEEN GROUPS	12	61175.2	5097.9	33.4	0
WITHIN GROUPS	26	3969	152.3		
TOTAL	38	65136			

TABLE 10. The Student-Neuman-Keuls test of significance among mean number of individuals per station for stations sampled in April 1989. Subsets show groupings of different stations ($P<0.05$). Stations in a seperate vertical row and column are significantly different from others. Eighth year of benthic monitoring studies at Hart and Miller Islands.

APRIL 1989

SUBSET	STATION NUMBERS										
1	S2	S1	S3	S4							
2		S1	S3	S4	S7						
3			S3	S4	S7	S6	S5				
4								HM7	HM16	S8	HM9	H26	HM22

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F. RATIO	F. PROB.
BETWEEN GROUPS	12	168377.9	14031.4	21.4	0
WITHIN GROUPS	26	17000.7	653.8		
TOTAL	38	185378.7			

TABLE 11. 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. Eighth year of benthic monitoring studies at Hart and Miller Islands.

AUGUST 1989

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

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F. RATIO	F. PROB.
BETWEEN GROUPS	12	68891.8	5740.9	5.1715	0.0002
WITHIN GROUPS	26	28861.4	1110		
TOTAL	38	97753.2			

the fifth year (Pfitzenmeyer and Tenore, 1987), which identified two 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, again four subsets were evident (Table 10). The first subset was comprised of stations S1-S4 around the eastern end of the facility. The second subset dropped stations S2 and added S7. The third subset dropped S1 and added S6 and S5. The fourth subset was comprised of the 5 reference stations along with station S8. This final grouping, also observed during the seventh year, indicates no change in groupings over this seasonal sampling period. As in December, the reference and nearfield stations formed relatively discernible groups, and the analysis of variance for this sampling period resulted in no significant differences between or within groups.

Finally, analysis of the August 1988 data did not indicate anything unusual. Indeed, the August subsets were somewhat similar to the April findings. Again there were four subsets, as in December and April but now larger subsets were formed by bigger groupings of the stations. Subset 1 was comprised of 10 of the 13 infaunal stations, 7 nearfield and 3 reference stations. The other subsets consisted of sequentially dropping and adding one or two stations with the final subset (4) again comprised of the five reference stations and nearfield S8, although in slightly different order. This was very similar to the pattern observed last August (seventh year) and in April in the sixth sampling year.

Table 12 presents the results of Friedman's non-parametric test for differences in the means of samples (ranked abundances of 10 selected species) taken at the silt/clay nearfield and reference stations, only. Significant differences ($p<0.05$) were found at the nearfield stations surrounding the island during the December sampling period. During this period, station S6 again as it did last year in 1988 had a high number of individuals, particularly of the annelid worm, *Tubificoides sp.* which reached densities over 5000 worms/m^2 compared with less than 1000 worms/m^2 at any of the other remaining nearfield silt/clay stations. This station is located in the southwestern region of the study area, close to the Back River reference area which frequently has very high concentrations of annelid worms (Duguay et al., 1988 and Duguay, 1989). In April significant differences were observed for the three reference stations with silt/clay bottom type (HM16, HM7, and HM22). At this time all three stations had a large number of the annelid worm, *Scolecolepides viridis*. However, station HM16 also had a greater number of individuals of each of the 10 ranked species and was ranked first

TABLE 12. 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 the Hart-Miller Island containment facility. (Silt/clay stations are: NEARFIELD STAS.- S3,S4,S5,S6,S8 and REFERENCE STAS.- HM7, HM16, HM22).

	SOURCE	D.F.	CHI-SQUARED	CHI-SQUARED (0.05)
DEC 1988				
	NEARFIELD	4	29.86*	9.48
	REFERENCE	2	2.45	5.99
	NEARFIELD & REFERENCE	7	14.05	14.06
APR 1989				
	NEARFIELD	4	8.02	9.48
	REFERENCE	2	12.95*	5.99
	NEARFIELD & REFERENCE	7	24.33*	14.06
AUG 1989				
	NEARFIELD	4	6.46	9.48
	REFERENCE	2	4.05	5.99
	NEARFIELD & REFERENCE	7	3.58	14.06

*SIGNIFICANT DIFFERENCE AT THE 0.05 LEVEL.

in 9 out of 10 cases. In August, on the other hand, there was no significant difference for either the nearfield or reference stations. In April, there was also a significant difference between the reference stations and the nearfield stations when they were tested together. This is again consistent with results reported previously in the fifth, sixth, and seventh interpretive reports (Pfitzenmeyer and Tenore, 1987, Duguay et al. 1988, and Duguay, 1989).

The results for the epifaunal samples from a series of pilings surrounding the facility and one located in the Pleasure Island boat channel are presented in Table 13. Except for the December sampling period we were unable to reach station R1 due to continued shoaling up in this region. Samples this year were again limited to depths of 1.0 to 1.3 m below the surface and at 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.

A reasonably well developed fauna occurred on all three sampling dates, and 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 (R1-R4) and the reference piling (R5) are quite similar and sometimes nearly identical. Essentially, the same 10 species observed this year were the predominant species over the past three study years (Pfitzenmeyer and Tenore, 1987, Duguay et al., 1988 and Duguay, 1989). The amphipod, *Corophium lacustre*

TABLE 13. 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 Eighth Year Benthic sampling study at Hart-Miller Island.

	STATIONS R1-R4 DEPTH (M)		REFERENCE STATION R5 DEPTH (M)	
DEC 1988				
	1.0 m	2-3 m	1.0 m	2-3 m
	Corophium	Corophium	Corophium	Corophium
	Victorella	Victorella	Victorella	Victorella
	B. improvisus	Cordylophora	Polydora	Polydora
	B. subalbidus	Polydora	Cordylophora	Membranipora
	Polydora	Capitella	B. subalbidus	B. subalbidus
	Nereis	B. subalbidus	Capitella	Capitella
APR 1989				
	1.0 m	2-3 m	1.0 m	2-3 m
	Corophium	Corophium	Corophium	Corophium
	Victorella	Victorella	Nematodes	Nematodes
	Polydora	Polydora	Cordylophora	Cordylophora
	Cordylophora	Cordylophora	Capitella	Capitella
	Capitella	Capitella	Polydora	
AUG 1989				
	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
	Nereis	B. improvisus	Nematodes	Nematodes
				Polydora

again was one of the most abundant and most widespread species (Pfitzenmeyer and Tenore, 1987, Duguay et al., 1988, and Duguay, 1989). Without exception, the most abundant organism at all stations on all dates. The bryozoan, *Victorella* ranked second at all stations on all dates except for April at station R5, when it was replaced by nematodes. The third most abundant organism was more variable and consisted of either the worm, *Polydora*, the hydroid, *Cordylophora*, or the barnacle, *Balanus improvisus*. *Corophium* is a small amphipod crustacean which is extremely opportunistic. It 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, the bryozoan, *Victorella*, and the hydroid, *Cordylophora*, reached their greatest abundance in August, probably their maximal reproductive and growth season.

Table 14 lists of the types and numbers of fish collected during 5 minute otter trawls (fig. 3) on each of the sampling dates during the eighth monitoring year. A total of 9 different types of fish were collected.

TABLE 14: Total number and species of fish collected in 5 minute trawls at the stations depicted in Figure 3 during the 8th year of Benthic monitoring studies at the Hart-Miller Island containment facility.

SPECIES OF FISH	DECEMBER 1988 F1	F2	F3	F4	APRIL 1989 F1	F2	F3	F4	AUGUST 1989 F1	F2	F3	F4
ANCHOVY		13	11	250				1	1			
CATFISH					26	5			5	1		
HOGCHOKER						1	5	23	26	7	24	23
MENHADEN		2	8	382	3			3				
PUMPKINSEED									1			
ROCKFISH								2				
SPOT	10	104	4	190					80	63	35	100
WHITE PERCH	4		4	4	53	5	10	63	40			
YELLOW PERCH		16			14				2			
TOTAL # FISH	14	135	27	826	96	11	15	92	155	71	59	123

The most abundant species was menhaden in December 1988. The fish were collected primarily for analysis of tissue levels of metal and organic contaminants in yellow and white perch, the results of which are presented in Section IV of the report.

CONCLUSIONS AND RECOMMENDATIONS

During this eighth year of sampling and monitoring the benthos at Hart and Miller Island, the sampling locations, sampling techniques and analysis of the data were again maintained as close as possible to that for the previous years in order 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 last year for the qualitative epifaunal samples.

The results presented in this report are quite similar to those presented in the reports of the last three years (5th, 6th, and 7th). A total of 31 species (compared with 35, 30 and 26 for the 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 annelids, *S. viridis* ,*H. filiformis*, and *Tubificoides*, the crustaceans, *L. plumulosus* and *C. polita*, and the clam, *R. cuneata*. On the oyster shell substrates, the barnacle, *Balanus improvisus*, the worm, *N. succinea*, and the crab, *R. harrisi* were the most common inhabitants with some overlap of the 5 most abundant soft bottom species occasionally becoming dominant on this substrate as well. Salinity variations on yearly and seasonal time scales appear to determine the position of dominance of the major species.

The average number of individuals per square meter was comparable for the nearfield and the reference stations over the three sampling periods. Pfitzenmeyer and Tenore (1987) had reported a somewhat greater number of individuals at the nearfield then 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 in this eighth year was the same trend which we had observed during the sixth and seventh year monitoring study.

The highest average species diversity values this year were found in December rather than in August as had been the rule the previous two years. The lowest diversity values were in April and they were substantially lower than we had observed in previous years which may account for the persistent low values in August of this eighth sampling year.

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 2 common bivalves *M. balthica* and *M. mitchelli*. This year there appeared to be a set and grow up of these three bivalve clams over the present sampling study, but there still appears to be a general overall decline in population size of all three species from the high values reported in August 1987. The decline appeared at both the nearfield and reference stations and may be a result of less favorable salinities in the region.

Cluster analysis grouped stations of similar faunal composition in response to sediment type and general location within the Hart-Miller Island 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 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 stations S6 and HM16 located in the southwest region of the Hart and Miller Island Facility near Back River.

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

At present, there does not appear to be any discernible differences in the nearfield and reference populations resulting directly from the containment facility itself. 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 has been expanded and is in the process of being filled and capped over in the near future. It is strongly recommended that the infaunal and epifaunal populations continue to be sampled at the established locations during this continued critical period of maximal operation 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 variation and permit rapid recognition of effects resulting from the operation and existence of the containment facility. It is also recommended that some additional stations be established and monitored in order to assess any effects of effluent discharge which has occurred from the containment facility in the past and which from the Maryland Geological Survey study (section 2 of this Report) of sediment metal concentrations appears to reach areas at a greater distance from the containment facility than is currently being monitored under the present benthic study.

Project IV

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EIGHTH YEAR INTERPRETIVE REPORT

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SUMMARY

Since 1981, metals and organic chemicals have been analyzed in sediments and biota as part of the Hart-Miller Island Containment Facility Environmental Assessment 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 (Year 8; November 1988-August 1989), 99 samples of sediment and biota were collected to determine the concentrations of 43 individual trace organic contaminant compounds in fish, benthos, and sediment. Biological samples (fish, benthos) were also analyzed for concentrations of six metals: chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), and zinc (Zn).

The only organic constituents that were found above detection limits in biota were chlordane, total polychlorinated biphenyls (PCBs), bis (2-ethylhexyl) phthalate (DEHP), and di-n-butyl phthalate. PCBs in one sample of Rangia were at the FDA action level of 2.0 mg/kg, which is used in this report as a guidance level for impact assessment. No fish samples contained PCBs at or above 2.0 mg/kg. None of the benthic species contained chlordane at or above the FDA action level of 0.3 mg/kg. Three samples of white perch contained chlordane at 0.3 mg/kg.

One sample of Rangia (HM22 from August 1989) contained unusually high levels of copper (940 mg/kg), iron (12,300 mg/kg), and nickel (1830 mg/kg). A sample of Macoma (S6 from August 1989) contained an extremely high level of zinc (1290 mg/kg). The causes for these extremely high measurements are unknown and sampling or laboratory contamination cannot be ruled out. No other samples contained abnormally high metal concentrations. Contaminant concentrations in benthos collected from reference and site stations were similar as were concentrations in fish collected adjacent to and removed from the facility.

Analysis of variance was performed on ranked values as a nonparametric test to determine if inter-station or inter-year differences were statistically significant. There were no significant differences in concentrations between stations in year 7 or year 8. Analysis of trends using pooled data from all stations, indicated that for some chemicals and species there were significant differences among years. In all cases where changes were monotonic, the apparent trend was of decreasing concentrations between years 1 and 2 (or if year 1 and 2 were not available, year 6) and years 7 and 8. No significant differences between years were observed for zinc with any species. PCB and chlordane concentrations in Macoma appear to have decreased during the monitoring program. Concentrations of PCBs, chromium, copper, and nickel in Cyathura and concentrations of chromium and copper in Rangia also appear to have decreased. Concentrations of chromium and copper in white perch and concentrations of chromium in spot also appear to be decreasing but, since these are mobile species, they are more likely to be indicators of regional rather than local conditions.

The sediment samples collected during the eighth monitoring year only revealed one sample with any organic analyte (bis (2-ethylhexyl) phthalate) above the detection limits. The analysis of metals in sediment is contained in the Project II -- Sedimentary Environment Section of this report.

1. INTRODUCTION

A long-term monitoring program has been conducted since 1981 to examine possible impacts of the construction and operation of The Hart and Miller Islands Containment Facility. Studies have monitored the populations and abundance of fish and benthos, characterized the nature of the sediments and currents, measured levels of nutrients in the water column, and analyzed concentrations of contaminants in sediments and biota. The Analytical Services Project, in which contaminants are measured in sediments, fish, and benthos, has been conducted over a number of years and is intended to monitor any changes in contaminant concentrations that may result from the operation of the facility. Elevated levels of contaminants in biota would be of concern for the health of the organisms as well as for possible consumers including man.

Analyses have been performed since the inception of the program, with the first three years (1981-1983) developed to establish a baseline. No chemical analyses were performed between August 1983 and August 1984. Data from 1984 through 1987 represent a modest sampling program. An increased sampling program was reestablished in the seventh monitoring year (1987-1988) and continued in the eight monitoring year (1988-1989).

The Power Plant and Environmental Review Division of the Maryland Department of Natural Resources is responsible for overseeing the monitoring studies as well as providing the interpretation of the Analytical Services Project. This chapter summarizes and interprets the analyses of selected contaminants in samples of fish, benthos, and sediments collected from November 1988 through August 1989. Both metals and organics were measured in biota and sediments. In this chapter, all contaminant data for biota and the organic contaminant data for sediments are discussed. Metals analyses of the sediments are discussed in the Sedimentary Environment chapter. Trends in the data are analyzed by comparing data from the most recent sampling period with the previously collected data. Levels of contaminants in biota are also compared with action levels established by the U.S. Food and Drug Administration (FDA) for the protection of human health.

2. METHODS

A. Sampling and Chemical Analysis

Six benthic stations, four fish stations and eight sediment stations were sampled. Figures 2-1, 2-2, and 2-3 show the locations of the sediment, benthic, and fish sampling stations. Several stations have been designated as benthic reference stations (Stations

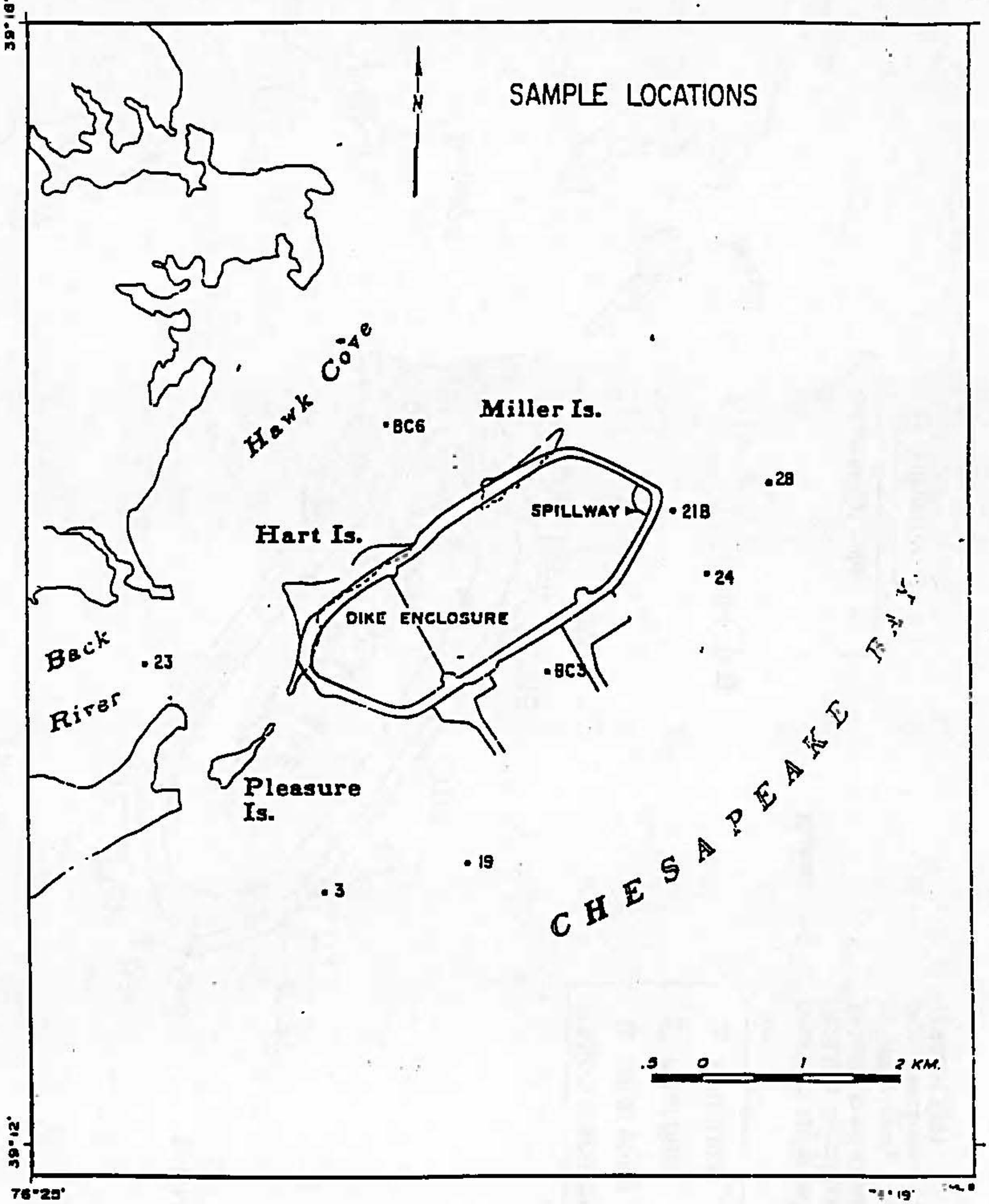


Figure 2-1: Sediment sampling stations for the Eighth Monitoring Year (1988-1989)

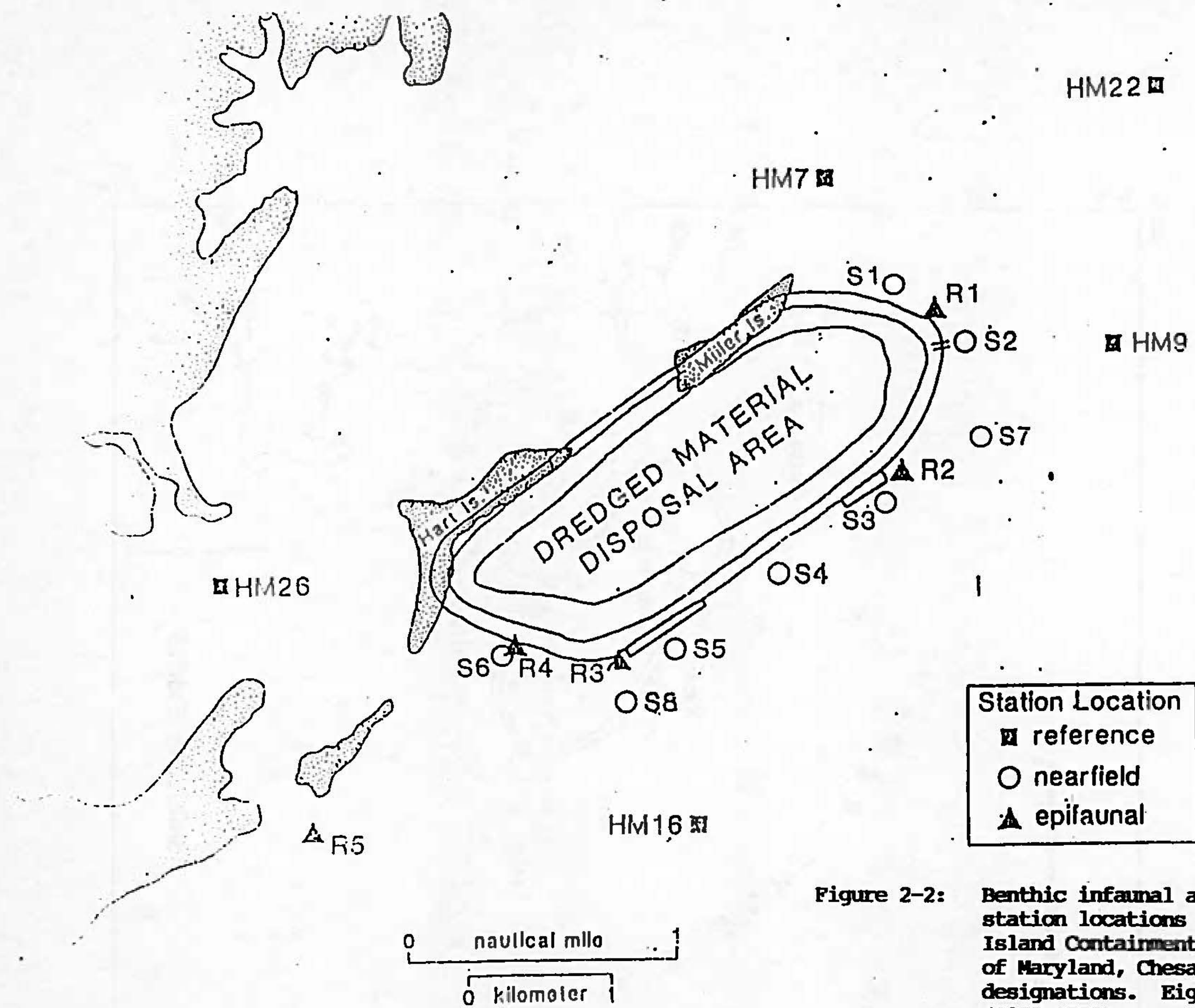


Figure 2-2: Benthic infaunal and epifaunal sampling station locations at the Hart-Miller Island Containment Facility. University of Maryland, Chesapeake Biological Lab designations. Eighth Monitoring Year (1988-1989).

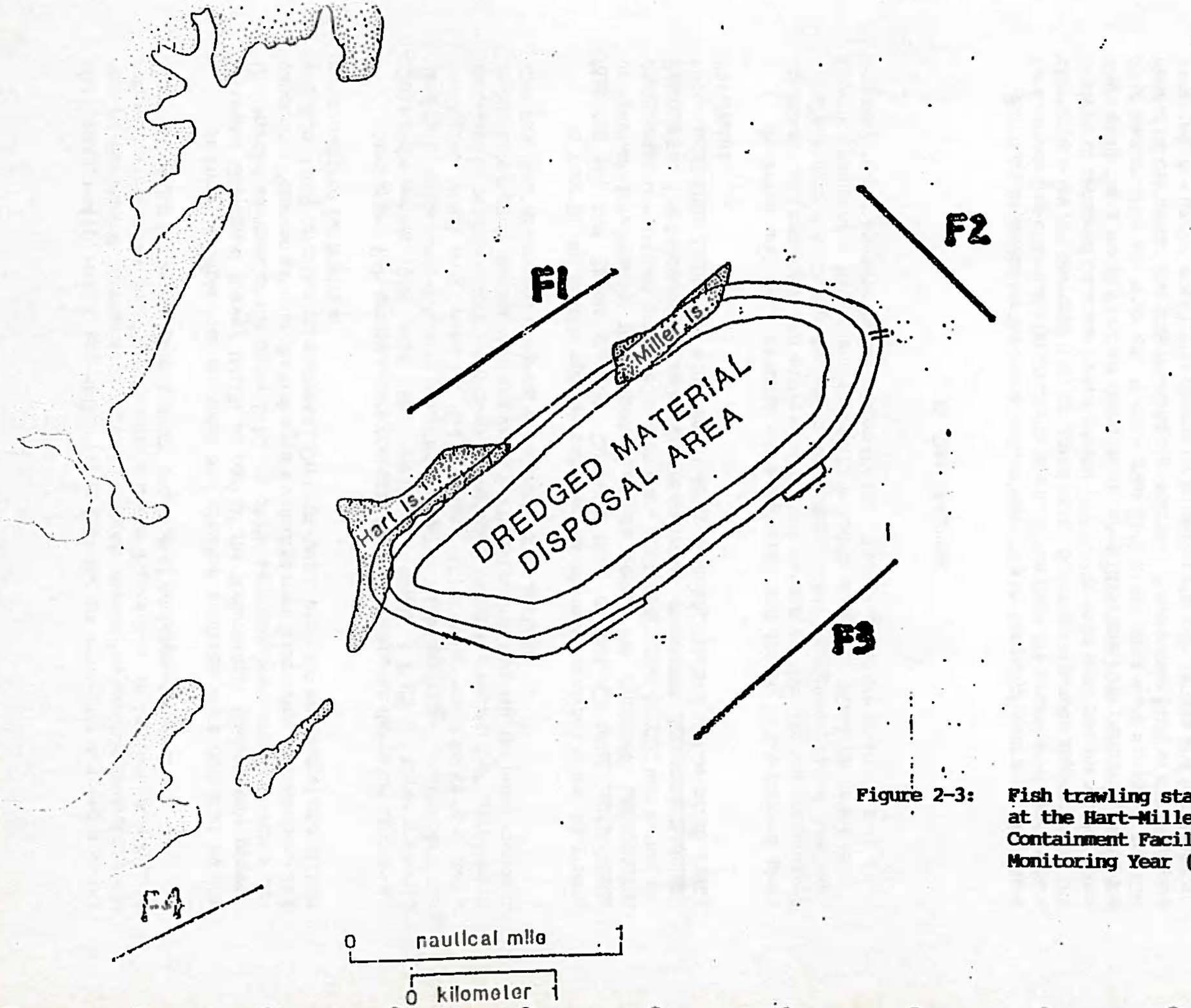


Figure 2-3: Fish trawling station locations at the Hart-Miller Island Containment Facility. Eighth Monitoring Year (1988-1989)

HM7, HM9, HM16, HM22, and HM26; Figure 2-2) and are somewhat removed from the facility. For the fish, comparisons are made between station F-4 which is several nautical miles from the facility and the three other stations (Figure 2-3). In Appendix A, sampling data including the species, date, station, and type of analyses are listed.

Sediment samples for chemical and physical analyses were collected by the Maryland Geological Survey (MGS) as part of the Sedimentary Environment project. Undisturbed samples of the upper 8-10 cm of the sediment were obtained with a dip-galvanized Peterson sampler. Samples were collected from 8 locations in November 1988 and April 1989 for chemical analyses. On both dates, triplicate samples of one station were collected for analysis.

Benthic and fish samples were collected by the Chesapeake Biological Laboratory (CBL) in December 1988, April 1989, and August 1989. A 0.05 m2 Ponar grab was used for benthos while fish were collected with a 16-18 foot otter trawl with a 1 1/2" bar mesh grab which was towed for five minutes. The benthic and fish samples were separated by species before submission for metals and organic analysis. Fish were filleted so that only muscle tissues were analyzed. For both benthos and fish, the most abundant species collected on each sampling were selected for analysis.

In Year 8, the benthic species collected for chemical analyses were the clams, Macoma sp. and Rangia cuneata; Conrad's false mussel, Congeria leucophaeta; unidentified polychaetes; the isopod, Cyathura polita; the amphipod, Leptocheirus plumulosus; unidentified amphipods; mud crab, Rhithropanopeus harrisi; and barnacles, Balanus sp. The following fish species were analyzed: menhaden, Brevoortia tyrannus; spot, Leiostomus xanthurus; white perch, Morone americana; and yellow perch, Perca flavescens.

Sediment and biota samples were collected and frozen in pre-cleaned glass containers until extraction and analysis by Martel Laboratories, Inc. The following metals were analyzed in biota tissues: chromium, copper, iron, manganese, nickel, and zinc. Organics analyzed in tissues and sediments included pesticides, PCBs, phthalate esters, and polynuclear aromatic hydrocarbons (PAHs). Test methods are given in Table 2-1.

B. Data Analysis

Summary statistics for the tissue contaminant data for the eighth year were calculated for each species-chemical-station combination. Since there are a number of cases where chemicals were not detected (i.e., censored data), summary statistics appropriate to the analysis of censored data were used (Helsel 1990). When at least two measured values were available, a median and an interquartile range (IQR; the 75th percentile minus the 25th percentile) were reported. If more than 25% of the data were censored, the IQR cannot be calculated and only medians are reported. If more than 50% of the data were censored, it was not possible to determine a median and only ranges and frequency of

Table 2-1. Analytical methods used to determine concentrations of metals and organic contaminants in sediment and biota		
Parameter	**Media**	**EPA Method Number/Reference**
Chromium (Cr)	Tissues	(EPA 218.1) (EPA 1983)
Manganese (Mg)	Tissues	(EPA 243.1) (EPA 1983)
Iron (Fe)	Tissues	(EPA 236.1) (EPA 1983)
Copper (Cu)	Tissues	(EPA 220.1) (EPA 1983)
Zinc (Zn)	Tissues	(EPA 289.1) (EPA 1983)
Nickel (Ni)	Tissues	(EPA 249.1) (EPA 1983)
Pesticides/PCBs	Tissues/Sediments	(EPA 8080) (EPA 1986)
Phthalate esters and Polynuclear Aromatic Hydrocarbons	Tissues/Sediments	(EPA 8270) (EPA 1986)

detection are reported. In addition to the median and IQR, the frequency of detection, range of detection limits, and range of detected values are reported. Summary statistics are not provided for the sediment data since only one analyte was detected in one sample.

Differences in contaminant concentrations among stations (spatial differences) and trends over the entire monitoring period (Years 1-8) were analyzed using nonparametric statistics. These techniques are recommended for hypothesis testing of censored data by Helsel (1990) because the methods avoid the need to estimate values and are free of assumptions about data distribution and variance. Spatial differences were tested only using year 7 and year 8 data because in these years station locations were standardized and there are replicates at most stations within a year. In many of the previous years there were few data or station locations were often unreported.

The following species contained the greatest number of observations during the monitoring program and were used as target species for these analyses: brackish water clam (Rangia cuneata), macoma clam (Macoma sp.), isopod (Cyathura polita), spot (Leiostomus xanthurus), and white perch (Morone americana). The following contaminants detected in tissues at the site are of greatest concern for ecological effects and were used in the statistical analysis: chlordane, PCBs, chromium, copper, nickel, and zinc. The phthalate esters, for which FDA action levels have not been established, were less frequently detected and are not included in the summary. Iron and manganese are of lesser concern for aquatic toxicity. Although these metals are measured in the National Oceanic and Atmospheric Administration (NOAA) Status and Trends Program, they are not used to characterize the contaminant status of different sites (NOAA 1989).

One way analysis of variance on ranks (equivalent to Kruskal-Wallis test) (SAS 1985), was used to test for between-station differences in concentrations of each chemical-species combination. These tests were performed for two reasons. First, they test the possibility that the stations designated as reference stations are different in tissue contaminants from the stations adjacent to the facility. The second purpose is to facilitate the analysis of trends in the data. Combining the data within a year expands the number of species-chemical combinations that can be examined and increases the power of the test to detect trends.

Since the analysis found no significant differences among stations for any of the year-target species-chemical combinations, all stations were combined for each year. Trends were analyzed according to procedures used by the NOAA Status and Trends Program (NOAA 1989). One way analysis of variance on ranks was used to test for between year differences. If significant differences were found, the direction of the ranks was tracked over time to determine if there is a monotonic change (i.e., increasing or decreasing concentrations). Tukey's multiple comparison test (SAS 1985) was used to determine the groupings of the years. A p value of 0.05 was used for all significance tests. Cases where both criteria (significant differences and monotonic change) were met are considered to show evidence of a trend.

In this report, all chemicals are reported as wet weight concentrations. Chemicals were reported in terms of mg/kg or µg/kg wet weight tissue in years 5-8 and as dry weight in years 1 and 2. In years where data were reported as dry weight, data were converted to wet weights using wet:dry ratios reported in the fifth annual Hart-Miller Island data report (DNR 1987).

Chlordane and PCB levels were also compared to Food and Drug Administration (FDA) action levels for human consumption of fish and shellfish. Although some of the target species are inedible, these action levels are useful as indicators of concern for human health effects. In the analysis of trends, information is provided on the frequency that contaminant concentrations exceeded FDA limits (2.0 mg/kg for PCBs, 0.3 mg/kg for chlordane).

3. RESULTS AND DISCUSSION

A. Summary of the Eighth Monitoring Year Data

Summary statistics, including the frequency of detection, range of detection limits, median, maximum, and interquartile range, are provided in Table 3-1. Individual sample results for the seventh and eighth year data are given in Appendix B. In the following sections, a synopsis of the eighth year data for each species is provided. For the benthic species, comparisons are made between concentrations in samples collected from the stations adjacent to the facility with concentrations at the designated reference stations. For the fish, comparisons are made between the trawls made closer to the facility (F-1, F-2, and F-3) and one several nautical miles away (F-4) (Figure 2-3). It is recognized that the mobility of the fish species makes them poor indicators of local sources of contamination.

Benthic Species

Polychaetes (Unspecified)

One polychaete sample was collected in December 1988 (Station S1) and two in August 1989 (S1 and HM16). Although no organic chemicals were detected in any of the three samples, detection limits were unusually high. For example, the detection limit for most of the PAHs and total PCBs were 1000 and 100 µg/kg, respectively, whereas for many of the clam samples detection limits for both analytes were 1 µg/kg.

Table 3-1. Summary statistics for Year 8

	BIS (2-ETHYLHEXYL) PHTHALATE							
Species	**Station**	**N**	**% Detects**	**Min Det Lt**	**Max Det Lt**	**Maximum**	**Median**	**Quart. Range**
Clam (Macoma)	HM16	4	25	10	10000	290		
Clam (Macoma)	S4	1	0	50	50			
Clam (Macoma)	S6	3	0	20	10000			
Clam (Macoma)	All Stns	8	13	10	10000	290		
Clam (Rangia)	HM16	3	0	10	10			
Clam (Rangia)	HM22	6	17	10	10	20000		
Clam (Rangia)	S1	5	20	10	10	490		
Clam (Rangia)	S2	3	0	10	10			
Clam (Rangia)	S4	4	25	10	50	350		
Clam (Rangia)	S6	3	0	10	50			
Clam (Rangia)	S7	1	0	1	1			
Clam (Rangia)	All Stns	25	12	1	50	20000		
Conrad's False Mussel	S2	1	0	10000	10000			
Conrad's False Mussel	All Stns	1	0	10000	10000			
Amphipod (Leptocheirus)	S4	1	0	10000	10000			

Table 3-1. Continued

	BIS (2-ETHYLHEXYL) PHTHALATE (Continued)							
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Amphipod (Leptocheirus)	All Stns	1	0	10000	10000			
Barnacle	S2	1	0	10	10			
Barnacle	All Stns	1	0	10	10			
Isopod (Cyathura)	HM16	3	0	1000	10000			
Isopod (Cyathura)	S1	2	0	10000	10000			
Isopod (Cyathura)	S4	2	0	1000	10000			
Isopod (Cyathura)	S6	3	0	1000	10000			
Isopod (Cyathura)	All Stns	10	0	1000	10000			
Mud Crab	S2	1	0	5000	5000			
Mud Crab	All Stns	1	0	5000	5000			
Polychaete (Unspecified)	HM16	1	0	10000	10000			
Polychaete (Unspecified)	S1	2	0	10000	10000			
Polychaete (Unspecified)	All Stns	3	0	10000	10000			
Menhaden	F3	1	0	10	10			
Menhaden	F4	1	0	10000	10000			

Table 3-1. Continued								
	BIS (2-ETHYLHEXYL) PHTHALATE (Continued)							
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Menhaden	All Stns	2	0	10	10000			
Spot	F1	1	100			1300		
Spot	F2	3	0	10	10			
Spot	F3	3	0	10	10			
Spot	F4	2	0	10	10			
Spot	All Stns	9	11	10	10	1300		
White Perch	F1	5	40	10	10	4200		
White Perch	F2	3	0	1	10			
White Perch	F3	3	0	10	100			
White Perch	F4	4	0	10	100			
White Perch	All Stns	15	13	1	100	4200		
Yellow Perch	F1	2	50	10	10	900	445	910
Yellow Perch	F2	1	100			720		
Yellow Perch	All Stns	3	67	10	10	900	720	910

Table 3-1. Continued

CHLORDANE								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Clam (Macoma)	HM16	4	25	10	1000	236		
Clam (Macoma)	S4	1	0	5	5			
Clam (Macoma)	S6	3	0	2	10000			
Clam (Macoma)	All Stns	8	13	2	10000	236		
Clam (Rangia)	HM16	3	0	1	10			
Clam (Rangia)	HM22	6	0	1	10			
Clam (Rangia)	S1	5	0	1	10			
Clam (Rangia)	S2	3	0	1	10			
Clam (Rangia)	S4	4	0	1	20			
Clam (Rangia)	S6	3	0	1	100			
Clam (Rangia)	S7	1	0	10	10			
Clam (Rangia)	All Stns	25	0	1	100			
Conrad's False Mussel	S2	1	0	1000	1000			
Conrad's False Mussel	All Stns	1	0	1000	1000			
Amphipod (Leptocheirus)	S4	1	0	10000	10000			
Amphipod (Leptocheirus)	All Stns	1	0	10000	10000			

Table 3-1. Continued

CHLORDANE (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Barnacle	S2	1	0	1	1			
Barnacle	All Stns	1	0	1	1			
Isopod (Cyathura)	HM16	3	0	100	2000			
Isopod (Cyathura)	S1	2	0	100	1000			
Isopod (Cyathura)	S4	2	0	100	100			
Isopod (Cyathura)	S6	3	0	100	10000			
Isopod (Cyathura)	All Stns	10	0	100	10000			
Mud Crab	S2	1	0	500	500			
Mud Crab	All Stns	1	0	500	500			
Polychaete (Unspecified)	HM16	1	0	100	100			
Polychaete (Unspecified)	S1	2	0	100	1000			
Polychaete (Unspecified)	All Stns	3	0	100	1000			
Menhaden	F3	1	100			200		
Menhaden	F4	1	0	1	1			
Menhaden	All Stns	2	50	1	1	200	100	201

Table 3-1. Continued

CHLORDANE (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Spot	F1	1	0	1	1			
Spot	F2	3	0	1	10			
Spot	F3	3	0	1	10			
Spot	F4	2	0	10	10			
Spot	All Stns	9	0	1	10			
White Perch	F1	5	60	1	10	300	300	306
White Perch	F2	3	67	1	1	200	130	201
White Perch	F3	3	100			200	110	170
White Perch	F4	4	50	1	1	200	100	201
White Perch	All Stns	15	67	1	10	300	130	201
Yellow Perch	F1	2	0	10	10			
Yellow Perch	F2	1	0	1	1			
Yellow Perch	All Stns	3	0	1	10			

Table 3-1. Continued

CHROMIUM								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Clam (Macoma)	HM16	4	25	2	8	3		
Clam (Macoma)	S4	1	100			5		
Clam (Macoma)	S6	3	33	2	5	5		
Clam (Macoma)	All Stns	8	38	2	8	5		
Clam (Rangia)	HM16	3	0	2	2			
Clam (Rangia)	HM22	6	17	2	2	9		
Clam (Rangia)	S1	5	40	2	2	3		
Clam (Rangia)	S2	3	0	2	2			
Clam (Rangia)	S4	4	25	2	2	7		
Clam (Rangia)	S6	3	0	2	2			
Clam (Rangia)	S7	1	0	2	2			
Clam (Rangia)	All Stns	25	16	2	2	9		
Conrad's False Mussel	S2	1	100			9		
Conrad's False Mussel	All Stns	1	100			9		
Amphipod (Leptocheirus)	S4	1	0	60	60			
Amphipod (Leptocheirus)	All Stns	1	0	60	60			

Table 3-1. Continued

CHROMIUM (Continued)								
Species	**Station**	**N**	**% Detects**	**Min Det Lt**	**Max Det Lt**	**Maximum**	**Median**	**Quart. Range**
Barnacle	S2	1	100			12		
Barnacle	All Stns	1	100			12		
Isopod (Cyathura)	HM16	3	0	4	6			
Isopod (Cyathura)	S1	2	50	20	20	30	5	50
Isopod (Cyathura)	S4	2	0	20	20			
Isopod (Cyathura)	S6	3	0	8	20			
Isopod (Cyathura)	All Stns	10	10	4	20	30		
Mud Crab	S2	1	100			6		
Mud Crab	All Stns	1	100			6		
Polychaete (Unspecified)	HM16	1	0	20	20			
Polychaete (Unspecified)	S1	2	50	8	8	12	2	20
Polychaete (Unspecified)	All Stns	3	33	8	20	12		
Menhaden	F3	1	100			3		
Menhaden	F4	1	100			3		
Menhaden	All Stns	2	100			3	3	0

Table 3-1. Continued

CHROMIUM (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Spot	F1	1	0	2	2			
Spot	F2	3	33	2	2	6		
Spot	F3	3	0	2	2			
Spot	F4	2	0	2	2			
Spot	All Stns	9	11	2	2	6		
White Perch	F1	5	0	2	2			
White Perch	F2	3	0	2	2			
White Perch	F3	3	0	2	2			
White Perch	F4	4	0	2	2			
White Perch	All Stns	15	0	2	2			
Yellow Perch	F1	2	0	2	2			
Yellow Perch	F2	1	0	2	2			
Yellow Perch	All Stns	3	0	2	2			

Table 3-1. Continued								
COPPER								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Clam (Macoma)	HM16	4	100			20	12	10
Clam (Macoma)	S4	1	100			15		
Clam (Macoma)	S6	3	100			27	20	17
Clam (Macoma)	All Stns	8	100			27	15	11
Clam (Rangia)	HM16	3	100			3	3	0
Clam (Rangia)	HM22	6	83	2	2	940	3	236
Clam (Rangia)	S1	5	80	2	2	3	3	3
Clam (Rangia)	S2	3	100			4	3	1
Clam (Rangia)	S4	4	100			6	5	2
Clam (Rangia)	S6	3	67	2	2	3	2	5
Clam (Rangia)	S7	1	0	2	2			
Clam (Rangia)	All Stns	25	84	2	2	940	3	2
Conrad's False Mussel	S2	1	100			7		
Conrad's False Mussel	All Stns	1	100			7		
Amphipod (Leptocheirus)	S4	1	0	60	60			
Amphipod (Leptocheirus)	All Stns	1	0	60	60			

Table 3-1. Continued

COPPER (Continued)								
Species	**Station**	**N**	**% Detects**	**Min Det Lt**	**Max Det Lt**	**Maximum**	**Median**	**Quart. Range**
Barnacle	S2	1	100			8		
Barnacle	All Stns	1	100			8		
Isopod (Cyathura)	HM16	3	100			21	20	8
Isopod (Cyathura)	S1	2	100			30	25	10
Isopod (Cyathura)	S4	2	0	10	20			
Isopod (Cyathura)	S6	3	67	20	20	30	30	50
Isopod (Cyathura)	All Stns	10	70	10	20	30	20	43
Mud Crab	S2	1	100			29		
Mud Crab	All Stns	1	100			29		
Polychaete (Unspecified)	HM16	1	0	10	10			
Polychaete (Unspecified)	S1	2	100			10	9	2
Polychaete (Unspecified)	All Stns	3	67	10	10	10	8	20
Menhaden	F3	1	100			2		
Menhaden	F4	1	100			3		
Menhaden	All Stns	2	100			3	3	1

Table 3-1. Continued

COPPER (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Spot	F1	1	100			2		
Spot	F2	3	33	1	2	3		
Spot	F3	3	33	1	2	2		
Spot	F4	2	50	1	1	2	1	3
Spot	All Stns	9	44	1	2	3		
White Perch	F1	5	60	2	2	4	2	6
White Perch	F2	3	33	2	2	2		
White Perch	F3	3	33	2	2	2		
White Perch	F4	4	50	2	2	4	1	6
White Perch	All Stns	15	47	2	2	4		
Yellow Perch	F1	2	0	1	2			
Yellow Perch	F2	1	100			2		
Yellow Perch	All Stns	3	33	1	2	2		

Table 3-1. Continued

DI-N-BUTYL PHTHALATE								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Clam (Macoma)	HM16	4	0	1	1000			
Clam (Macoma)	S4	1	0	5	5			
Clam (Macoma)	S6	3	0	2	1000			
Clam (Macoma)	All Stns	8	0	1	1000			
Clam (Rangia)	HM16	3	0	1	1			
Clam (Rangia)	HM22	6	0	1	1			
Clam (Rangia)	S1	5	0	1	1			
Clam (Rangia)	S2	3	0	1	1			
Clam (Rangia)	S4	4	0	1	5			
Clam (Rangia)	S6	3	0	1	5			
Clam (Rangia)	S7	1	0	1	1			
Clam (Rangia)	All Stns	25	0	1	5			
Conrad's False Mussel	S2	1	0	1000	1000			
Conrad's False Mussel	All Stns	1	0	1000	1000			
Amphipod (Leptocheirus)	S4	1	0	1000	1000			
Amphipod (Leptocheirus)	All Stns	1	0	1000	1000			

Table 3-1. Continued

DI-N-BUTYL PHTHALATE (Continued)								
Species	**Station**	**N**	**% Detects**	**Min Det Lt**	**Max Det Lt**	**Maximum**	**Median**	**Quart. Range**
Barnacle	S2	1	0	1	1			
Barnacle	All Stns	1	0	1	1			
Isopod (Cyathura)	HM16	3	0	100	1000			
Isopod (Cyathura)	S1	2	0	1000	1000			
Isopod (Cyathura)	S4	2	0	100	1000			
Isopod (Cyathura)	S6	3	33	100	1000	200		
Isopod (Cyathura)	All Stns	10	10	100	1000	200		
Mud Crab	S2	1	0	500	500			
Mud Crab	All Stns	1	0	500	500			
Polychaete (Unspecified)	HM16	1	0	1000	1000			
Polychaete (Unspecified)	S1	2	0	1000	1000			
Polychaete (Unspecified)	All Stns	3	0	1000	1000			
Menhaden	F3	1	0	1	1			
Menhaden	F4	1	0	1000	1000			
Menhaden	All Stns	2	0	1	1000			

Table 3-1. Continued

DI-N-BUTYL PHTHALATE (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Spot	F1	1	0	1	1			
Spot	F2	3	0	1	1			
Spot	F3	3	0	1	1			
Spot	F4	2	0	1	1			
Spot	All Stns	9	0	1	1			
White Perch	F1	5	20	1	1	300		
White Perch	F2	3	33	1	10	450		
White Perch	F3	3	0	1	100			
White Perch	F4	4	0	1	100			
White Perch	All Stns	15	13	1	100	450		
Yellow Perch	F1	2	0	1	1			
Yellow Perch	F2	1	0	1	1			
Yellow Perch	All Stns	3	0	1	1			

Table 3-1. Continued

IRON								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Clam (Macoma)	HM16	4	100			860	575	489
Clam (Macoma)	S4	1	100			830		
Clam (Macoma)	S6	3	100			920	540	605
Clam (Macoma)	All Stns	8	100			920	585	487
Clam (Rangia)	HM16	3	100			272	240	69
Clam (Rangia)	HM22	6	100			12300	295	3299
Clam (Rangia)	S1	5	100			371	214	164
Clam (Rangia)	S2	3	100			229	199	153
Clam (Rangia)	S4	4	100			500	345	172
Clam (Rangia)	S6	3	100			174	170	101
Clam (Rangia)	S7	1	100			27		
Clam (Rangia)	All Stns	25	100			12300	224	161
Conrad's False Mussel	S2	1	100			308		
Conrad's False Mussel	All Stns	1	100			308		
Amphipod (Leptocheirus)	S4	1	100			870		
Amphipod (Leptocheirus)	All Stns	1	100			870		

Table 3-1. Continued

IRON (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Barnacle	S2	1	100			184		
Barnacle	All Stns	1	100			184		
Isopod (Cyathura)	HM16	3	100			250	140	121
Isopod (Cyathura)	S1	2	100			360	320	80
Isopod (Cyathura)	S4	2	100			440	290	300
Isopod (Cyathura)	S6	3	100			310	240	120
Isopod (Cyathura)	All Stns	10	100			440	245	183
Mud Crab	S2	1	100			300		
Mud Crab	All Stns	1	100			300		
Polychaete (Unspecified)	HM16	1	100			250		
Polychaete (Unspecified)	S1	2	100			1430	1230	400
Polychaete (Unspecified)	All Stns	3	100			1430	1030	1180
Menhaden	F3	1	100			50		
Menhaden	F4	1	100			24		
Menhaden	All Stns	2	100			50	37	26

Table 3-1. Continued								
IRON (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Spot	F1	1	100			28		
Spot	F2	3	100			33	10	24
Spot	F3	3	100			27	16	23
Spot	F4	2	100			13	10	7
Spot	All Stns	9	100			33	13	20
White Perch	F1	5	100			84	38	55
White Perch	F2	3	100			37	15	23
White Perch	F3	3	100			25	13	13
White Perch	F4	4	100			31	21	20
White Perch	All Stns	15	100			84	22	24
Yellow Perch	F1	2	100			13	12	3
Yellow Perch	F2	1	100			36		
Yellow Perch	All Stns	3	100			36	13	26

Table 3-1. Continued

MANGANESE								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Clam (Macoma)	HM16	4	100			180	164	78
Clam (Macoma)	S4	1	100			195		
Clam (Macoma)	S6	3	100			177	168	77
Clam (Macoma)	All Stns	8	100			195	167	64
Clam (Rangia)	HM16	3	100			54	51	19
Clam (Rangia)	HM22	6	100			1020	42	269
Clam (Rangia)	S1	5	100			46	19	20
Clam (Rangia)	S2	3	100			38	28	27
Clam (Rangia)	S4	4	100			70	66	24
Clam (Rangia)	S6	3	100			28	18	22
Clam (Rangia)	S7	1	0	2	2			
Clam (Rangia)	All Stns	25	96	2	2	1020	35	34
Conrad's False Mussel	S2	1	100			447		
Conrad's False Mussel	All Stns	1	100			447		
Amphipod (Leptocheirus)	S4	1	0	60	60			
Amphipod (Leptocheirus)	All Stns	1	0	60	60			

Table 3-1. Continued

MANGANESE (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Barnacle	S2	1	100			1410		
Barnacle	All Stns	1	100			1410		
Isopod (Cyathura)	HM16	3	100			245	180	158
Isopod (Cyathura)	S1	2	100			210	190	40
Isopod (Cyathura)	S4	2	100			230	150	160
Isopod (Cyathura)	S6	3	100			180	120	140
Isopod (Cyathura)	All Stns	10	100			245	175	132
Mud Crab	S2	1	100			696		
Mud Crab	All Stns	1	100			696		
Polychaete (Unspecified)	HM16	1	100			40		
Polychaete (Unspecified)	S1	2	100			180	120	120
Polychaete (Unspecified)	All Stns	3	100			180	60	140
Menhaden	F3	1	100			16		
Menhaden	F4	1	100			23		
Menhaden	All Stns	2	100			23	20	7

Table 3-1. Continued

MANGANESE (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Spot	F1	1	100			74		
Spot	F2	3	100			14	8	10
Spot	F3	3	67	2	2	25	5	27
Spot	F4	2	100			5	4	2
Spot	All Stns	9	89	2	2	74	5	16
White Perch	F1	5	100			27	12	17
White Perch	F2	3	67	2	2	5	4	7
White Perch	F3	3	100			14	6	9
White Perch	F4	4	75	2	2	15	4	13
White Perch	All Stns	15	87	2	2	27	5	9
Yellow Perch	F1	2	100			13	8	11
Yellow Perch	F2	1	100			7		
Yellow Perch	All Stns	3	100			13	7	11

Table 3-1. Continued

NICKEL								
Species	**Station**	**N**	**% Detects**	**Min Det Lt**	**Max Det Lt**	**Maximum**	**Median**	**Quart. Range**
Clam (Macoma)	HM16	4	25	2	8	9		
Clam (Macoma)	S4	1	0	2	2			
Clam (Macoma)	S6	3	0	2	5			
Clam (Macoma)	All Stns	8	13	2	8	9		
Clam (Rangia)	HM16	3	67	2	2	20	5	22
Clam (Rangia)	HM22	6	100			1830	9	469
Clam (Rangia)	S1	5	60	2	2	12	7	12
Clam (Rangia)	S2	3	100			12	7	9
Clam (Rangia)	S4	4	50	2	2	10	2	11
Clam (Rangia)	S6	3	100			17	8	11
Clam (Rangia)	S7	1	100			5		
Clam (Rangia)	All Stns	25	80	2	2	1830	7	7
Conrad's False Mussel	S2	1	100			3		
Conrad's False Mussel	All Stns	1	100			3		
Amphipod (Leptocheirus)	S4	1	0	60	60			
Amphipod (Leptocheirus)	All Stns	1	0	60	60			

Table 3-1. Continued

NICKEL (Continued)								
Species	**Station**	**N**	**% Detects**	**Min Det Lt**	**Max Det Lt**	**Maximum**	**Median**	**Quart. Range**
Barnacle	S2	1	100			7		
Barnacle	All Stns	1	100			7		
Isopod (Cyathura)	HM16	3	33	5	6	4		
Isopod (Cyathura)	S1	2	0	20	20			
Isopod (Cyathura)	S4	2	0	20	20			
Isopod (Cyathura)	S6	3	0	8	20			
Isopod (Cyathura)	All Stns	10	10	5	20	4		
Mud Crab	S2	1	100			8		
Mud Crab	All Stns	1	100			8		
Polychaete (Unspecified)	HM16	1	0	20	20			
Polychaete (Unspecified)	S1	2	0	8	8			
Polychaete (Unspecified)	All Stns	3	0	8	20			
Menhaden	F3	1	100			3		
Menhaden	F4	1	100			3		
Menhaden	All Stns	2	100			3	3	0

Table 3-1. Continued								
NICKEL (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Spot	F1	1	0	2	2			
Spot	F2	3	33	2	2	19		
Spot	F3	3	67	2	2	46	24	48
Spot	F4	2	100			14	12	4
Spot	All Stns	9	56	2	2	46	10	24
White Perch	F1	5	60	2	2	6	3	8
White Perch	F2	3	0	2	2			
White Perch	F3	3	0	2	2			
White Perch	F4	4	25	2	2	3		
White Perch	All Stns	15	27	2	2	6		
Yellow Perch	F1	2	0	2	2			
Yellow Perch	F2	1	0	2	2			
Yellow Perch	All Stns	3	0	2	2			

Table 3-1. Continued

PCB								
Species	**Station**	**N**	**% Detects**	**Min Det Lt**	**Max Det Lt**	**Maximum**	**Median**	**Quart. Range**
Clam (Macoma)	HM16	4	0	1	100			
Clam (Macoma)	S4	1	0	5	5			
Clam (Macoma)	S6	3	33	100	10000	100		
Clam (Macoma)	All Stns	8	13	1	10000	100		
Clam (Rangia)	HM16	3	0	1	100			
Clam (Rangia)	HM22	6	33	1	100	1000		
Clam (Rangia)	S1	5	40	1	100	1000		
Clam (Rangia)	S2	3	33	1	1	2000		
Clam (Rangia)	S4	4	25	1	200	100		
Clam (Rangia)	S6	3	0	1	200			
Clam (Rangia)	S7	1	0	100	100			
Clam (Rangia)	All Stns	25	24	1	200	2000		
Conrad's False Mussel	S2	1	0	1000	1000			
Conrad's False Mussel	All Stns	1	0	1000	1000			
Amphipod (Leptocheirus)	S4	1	0	10000	10000			
Amphipod (Leptocheirus)	All Stns	1	0	10000	10000			

Table 3-1. Continued

PCB (Continued)								
Species	**Station**	**N**	**% Detects**	**Min Det Lt**	**Max Det Lt**	**Maximum**	**Median**	**Quart. Range**
Barnacle	S2	1	0	1	1			
Barnacle	All Stns	1	0	1	1			
Isopod (Cyathura)	HM16	3	0	100	20000			
Isopod (Cyathura)	S1	2	0	100	1000			
Isopod (Cyathura)	S4	2	0	100	100			
Isopod (Cyathura)	S6	3	0	100	10000			
Isopod (Cyathura)	All Stns	10	0	100	20000			
Mud Crab	S2	1	0	500	500			
Mud Crab	All Stns	1	0	500	500			
Polychaete (Unspecified)	HM16	1	0	100	100			
Polychaete (Unspecified)	S1	2	0	100	1000			
Polychaete (Unspecified)	All Stns	3	0	100	1000			
Menhaden	F3	1	100			200		
Menhaden	F4	1	100			300		
Menhaden	All Stns	2	100			300	250	100

Table 3-1. Continued

Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
PCB (Continued)								
Spot	F1	1	0	1	1			
Spot	F2	3	33	1	1	50		
Spot	F3	3	0	1	1			
Spot	F4	2	0	1	1			
Spot	All Stns	9	11	1	1	50		
White Perch	F1	5	60	1	1	1300	750	1051
White Perch	F2	3	100			1000	1000	700
White Perch	F3	3	100			400	200	320
White Perch	F4	4	100			1300	835	758
White Perch	All Stns	15	87	1	1	1300	750	800
Yellow Perch	F1	2	0	1	100			
Yellow Perch	F2	1	0	1	1			
Yellow Perch	All Stns	3	0	1	100			

Table 3-1. Continued

ZINC									
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Clam (Macoma)	HM16	4	100			116	65	60
Clam (Macoma)	S4	1	100			50		
Clam (Macoma)	S6	3	100			1290	65	1240
Clam (Macoma)	All Stns	8	100			1290	58	57
Clam (Rangia)	HM16	3	100			21	19	3
Clam (Rangia)	HM22	6	100			67	21	17
Clam (Rangia)	S1	5	100			24	23	8
Clam (Rangia)	S2	3	100			34	20	14
Clam (Rangia)	S4	4	100			47	23	32
Clam (Rangia)	S6	3	100			30	29	17
Clam (Rangia)	S7	1	100			14		
Clam (Rangia)	All Stns	25	100			67	21	6
Conrad's False Mussel	S2	1	100			13		
Conrad's False Mussel	All Stns	1	100			13		
Amphipod (Leptocheirus)	S4	1	100			70		
Amphipod (Leptocheirus)	All Stns	1	100			70		

Table 3-1. Continued

ZINC (Continued)								
Species	Station	N	% Detects	Min Det Lt	Max Det Lt	Maximum	Median	Quart. Range
Barnacle	S2	1	100			88		
Barnacle	All Stns	1	100			88		
Isopod (Cyathura)	HM16	3	100			85	74	32
Isopod (Cyathura)	S1	2	100			110	95	30
Isopod (Cyathura)	S4	2	100			100	85	30
Isopod (Cyathura)	S6	3	100			110	71	50
Isopod (Cyathura)	All Stns	10	100			110	77	35
Mud Crab	S2	1	100			25		
Mud Crab	All Stns	1	100			25		
Polychaete (Unspecified)	HM16	1	100			60		
Polychaete (Unspecified)	S1	2	100			50	39	22
Polychaete (Unspecified)	All Stns	3	100			60	50	32
Menhaden	F3	1	100			27		
Menhaden	F4	1	100			32		
Menhaden	All Stns	2	100			32	30	5

Table 3-1. Continued

ZINC (Continued)								
Species	**Station**	**N**	**% Detects**	**Min Det Lt**	**Max Det Lt**	**Maximum**	**Median**	**Quart. Range**
Spot	F1	1	100			16		
Spot	F2	3	100			23	12	13
Spot	F3	3	100			10	10	4
Spot	F4	2	100			9	8	3
Spot	All Stns	9	100			23	10	7
White Perch	F1	5	100			23	17	10
White Perch	F2	3	100			19	18	3
White Perch	F3	3	100			33	26	20
White Perch	F4	4	100			26	15	11
White Perch	All Stns	15	100			33	17	10
Yellow Perch	F1	2	100			13	13	1
Yellow Perch	F2	1	100			14		
Yellow Perch	All Stns	3	100			14	13	2

Concentrations of the four metals of concern (chromium, copper, nickel, and zinc) were similar at the HM16 reference station with the S1 station adjacent to the facility. The zinc concentration at HM16 (60 mg/kg) was greater than either measurement at S1 (28 and 50 mg/kg).

Conrad's False Mussel (*Congeria leucophaeta*)

One sample of Conrad's false mussel was collected at station S2 in December 1988 and analyzed for both metals and organics. Again, no organics were detected but detection limits were high 1000 µg/kg for chlordane, PCBs and di-n-butyl phthalate. The four metals of concern were found at concentrations less than or equal to 13 mg/kg.

Brackish-Water Clam (*Rangia cuneata*)

Twenty five samples were collected from seven stations. A total of five samples had detectable concentrations of PCBs. These were collected at stations HM22, S2, and S1. One sample at station S2 was at the FDA action level of 2000 µg/kg. All of the other samples were between 100 and 1000 µg/kg. None of the samples collected during the eighth monitoring year contained chlordane concentrations greater than the detection limit, which ranged from 1 to 100 µg/kg. Two samples collected in December, 1988 revealed concentrations of DEHP above the detection limits. These samples were collected at stations HM22 and S1. One of two samples collected at station HM22 in April revealed a concentration of 20,000 µg/kg of DEHP while the compound was not detected in the second sample. Since none of the eighth year samples at this location contained detectable concentrations of the compound and phthalates are common laboratory contaminants, it is likely that this extremely high value resulted from laboratory contamination. Di-n-butyl phthalate was not detected in any samples.

Concentrations of chromium, copper, and nickel were generally less than 20 mg/kg, while concentrations of zinc were generally less than 50 mg/kg. Chromium was detected in only four of the 25 samples with a maximum concentration of 9 mg/kg. Copper was detected in 21 of 25 samples; median concentrations were similar at the reference (3 mg/kg) and Hart-Miller stations (2-5 mg/kg). One sample contained 940 mg/kg (HM22 collected in April 1989), whereas all other copper concentrations were less than 6 mg/kg. It is likely that this sample reflects contamination occurring either during collection or analysis. The same sample contained nickel at a concentration of 1830 mg/kg while all other nickel concentrations were less than or equal to 20 mg/kg. Median nickel concentrations were similar at the reference (5 and 9 mg/kg) and site (2-8 mg/kg) stations. Zinc was detected in all samples. The same April 1989 HM22 sample with the high copper concentration contained the maximum zinc concentration (67 mg/kg) while all other samples were less than or equal to 47 mg/kg. Median zinc concentrations were similar at all stations (19 and 21 mg/kg -- reference; 20-29 mg/kg -- site).

Macoma Clam (Macoma sp.)

Organic chemicals were detected in two of the eight samples collected during the eighth monitoring year. However, for several samples, detection limits were unusually high (e.g., chlordane at 1000 and 10000 µg/kg; PCBs at 10000 µg/kg). One sample, collected at station HM16 from December 1988, contained chlordane at 236 µg/kg and DEHP at 290 µg/kg. The other sample, collected from S6 in December 1988, contained 100 µg/kg PCBs. The PCB level was far below the FDA action level for fish and shellfish of 2000 µg/kg, whereas the chlordane concentration approached the FDA limit of 300 µg/kg.

Chromium was detected in three of eight samples with concentrations less than or equal to 5 mg/kg. Copper was detected in all samples with a maximum concentration of 27 mg/kg and most concentrations in the 8-20 mg/kg range. Median concentrations were similar at the reference (12 mg/kg) and site (20 mg/kg) stations. Nickel was detected in a single sample at station HM16 at a concentration of 5 mg/kg. Zinc was detected at all stations; a maximum concentration of 1290 mg/kg was measured in a sample collected at station S6 in August 1989. All other samples were in the 50-116 mg/kg range; with median values of 65 mg/kg at both the reference and site stations. Since none of the other metals were elevated in this sample, it is unlikely (but not impossible) that contamination during sampling or analysis is responsible for the one extremely high measurement.

Barnacle (Balanus sp.)

Only one sample of Balanus was collected at station S2, in December 1988. All organics were below the detection limits which were in the usual range of 1-10 µg/kg. Chromium, copper, and nickel were detected at concentrations $\leq$ 12 mg/kg. Zinc was found at 88 mg/kg.

Isopod (Cyathura polita)

Eleven samples of Cyathura were collected with samples taken from stations HM16 and S6 on all three trips and from S4 and S1 in the fall and summer. Only a single organic analyte -- di-n-butyl phthalate -- was detected (200 µg/kg in one sample from S6). Detection limits for the organic chemicals of concern were frequently higher than what was achieved for clam samples. For example PCB detection limits ranged from 100 to 20000 µg/kg in Cyathura as opposed to 1 to 100 in Rangia.

Chromium was detected in only one sample (30 mg/kg at S1). Copper was detected in 7/10 samples with similar concentrations (up to 30 mg/kg) measured at all stations. Median concentrations were similar at the reference (20 mg/kg) and site (25 and 30 mg/kg) stations. Nickel was only detected in one sample at HM16 and the concentration (4 mg/kg) was less than the detection limit of the other samples. Zinc was detected in all samples at concentrations ranging from 53 to 110 mg/kg. Median concentrations were similar among reference (74 mg/kg) and site (71-95 mg/kg) stations.

Amphipod (Leptocheirus plumulosus)

One sample of Leptocheirus was collected from station S-4 in April 1989. No organics were detected but detection limits were unusually high (1000-10000 µg/kg). Nickel, copper, and chromium were not detected but the detection limit for each metal was unusually high (60 mg/kg). Zinc was detected at 70 mg/kg.

Mud Crab (Rhithropanopeus harrisii)

One sample of R. harrisii from sampled from station S-2 was sampled in December 1988. No organic concentrations were above the detection limits, which were unusually high (500-5000 µg/kg). Concentrations of chromium, copper, nickel, and zinc were 6, 29, 8, and 25 mg/kg, respectively.

Fish Species

Menhaden (Brevoortia tyrannus)

Samples of menhaden were collected in December 1988, from stations F-4 and F-3. PCBs were detected at 200 µg/kg (F-3) and 300 µg/kg (F-4), which are well below the FDA action limit of 2000 µg/kg. The sample collected at station F-3 contained a chlordane concentration of 200 µg/kg. This approaches but does not exceed the FDA action level of 300 µg/kg.

Concentrations of copper, chromium, nickel and zinc were similar at the F-3 and F-4 stations. Copper, chromium, and nickel were detected at concentrations less than 10 mg/kg, while zinc was detected at about 30 mg/kg.

Spot (Leiostomus xanthurus)

Nine samples of spot were collected in the eighth monitoring year. PCBs were detected in a single sample (50 µg/kg from station F-2 in December 1988). The concentration was well below the FDA action level of 2000 µg/kg. One sample from station F-1 in December 1988 contained DEHP at 1300 μg/kg. No other organic chemicals were detected.

Chromium was detected in one of the nine samples (F-2 at 6 mg/kg). Copper was detected in four samples at concentrations of 3 mg/kg or less. Nickel was detected in five samples with somewhat higher values at station F-3 (24 and 46 mg/kg) vs. station F-4 (10 and 14 mg/kg). Median zinc concentrations were similar at F-4 (8 mg/kg) and the other stations (10 and 12 mg/kg).

White Perch (Morone americana)

Fifteen samples of white perch were collected from the four trawling stations. PCBs were detected in 13 samples with values ranging from 80 to 1300 μg/kg. Two samples -- one at F-4 and one at F-1 -- contained 1300 μg/kg PCBs which approaches the FDA action limit of 2000 μg/kg. Median concentrations were 200 μg/kg at F-3, 750 μg/kg at F-1, 835 μg/kg at F-4, and 1000 μg/kg at F-2. Chlordane was also detected in 13 samples with values ranging from 30 to 300 μg/kg. Three samples at station F-1 were at the FDA action level of 300 μg/kg. Median concentrations were 100 μg/kg for F-4, 110 μg/kg for F-2, 130 μg/kg for F-3, and 300 μg/kg for F-1. DEHP was detected in two samples at F-1 (at 560 and 4200 μg/kg) and one sample at F-2 (450 μg/kg). One sample at F-1 and one at F-2 contained detectable levels of di-n-butyl phthalate.

There was no general pattern of organic contamination evident. Samples that were high in one analyte (e.g., PCBs) often contained non-detectable levels of the other analytes. Median concentrations of PCBs and chlordane were not consistently higher at stations F-1 through F-3 vs. F-4.

Chromium was not detected in any of the samples. Copper was detected in seven samples with a maximum concentration of 4 mg/kg. Nickel was detected in four samples -- three at F-1 and one at F-4 -- with a maximum concentration of 6 mg/kg. Zinc was detected in all 15 samples with a maximum level of 33 mg/kg at F-3. Median concentrations were similar at all stations, ranging from 15 mg/kg at F-4 to 26 mg/kg at F-3.

Yellow perch (Perca flavescens)

Three samples of yellow perch were collected during the eighth monitoring year. Two samples were collected from station F-1 and one from station F-2. The only organic analyte detected was DEHP which was found in the F-2 sample (720 μg/kg) and in one of the F-1 samples (900 μg/kg). Detection limits were within the usual range (1-10 μg/kg for chlordane; 1-100 μg/kg for PCBs).

Chromium and nickel were not detected in any of the samples. Copper was detected in a single sample (F-2) at 2 mg/kg, which was the detection limit for several other samples. Zinc was detected in all three samples at concentrations of 12-14 mg/kg.

Sediment Organics Data

Only one organic analyte was detected in the sediment samples. The sample from station 24 (Figure 2-1) contained 66 µg/kg of DEHP. This station had triplicate samples tested; the other two samples contained no organics above the detection limits.

B. Analysis of Trends in the Hart-Miller Data Base

One way ANOVA on ranks were performed on a total of 30 species-chemical combinations. Statistically significant differences between years occurred in 18 of the comparisons. In 10 of these cases, there was a trend in which concentrations decreased between years 1 and 2 and years 7 and 8. In three cases in which comparisons were made between years 6, 7, and 8 year 6 was significantly greater than both of the later years. In the remaining five comparisons, there was either no clear direction in the change or only a single analysis was performed in one of the years. In no cases was there a steady increase from year 1 or 2 to year 8. The chemical-species combinations that show evidence of decreasing trends are graphed in Figures 3-1 through 3-5.

Chlordane concentrations (Figure 3-1) in Macoma were greatest in year 2 and decreased in years 7 and 8. The median concentration (across all stations) for years 2, 7, and 8 were 2491 µg/kg, less than the detection limit (ND), and ND, respectively.

PCB concentrations in Macoma decreased from year 2 (median = 2105 µg/kg) to non-detectable in years 7 and 8. Concentrations in Cyathura decreased from year 2 (median = 2730 µg/kg) to non-detectable in years 7 and 8.

Trends in the frequency that PCBs or chlordane levels in the target species exceeded FDA action limits can be observed in Table 3-2. Tissue concentrations were frequently higher than these limits in year 2; 60% of benthic samples exceeded the PCB limit while 100% of the benthic samples exceeded the chlordane limit. In years 7 and 8, benthic sample concentrations were rarely above the FDA limits (Table 3-2).

Median chromium concentrations in Rangia decreased from 12.0 mg/kg in year 6 to non-detectable in years 7 and 8. In Cyathura, median concentrations decreased from 5.22 mg/kg in year 2 to non-detectable in years 7 and 8. In spot, median concentrations were 0.39 mg/kg in year 1, 0.53 mg/kg in year 2, and non-detectable in years 7 and 8.

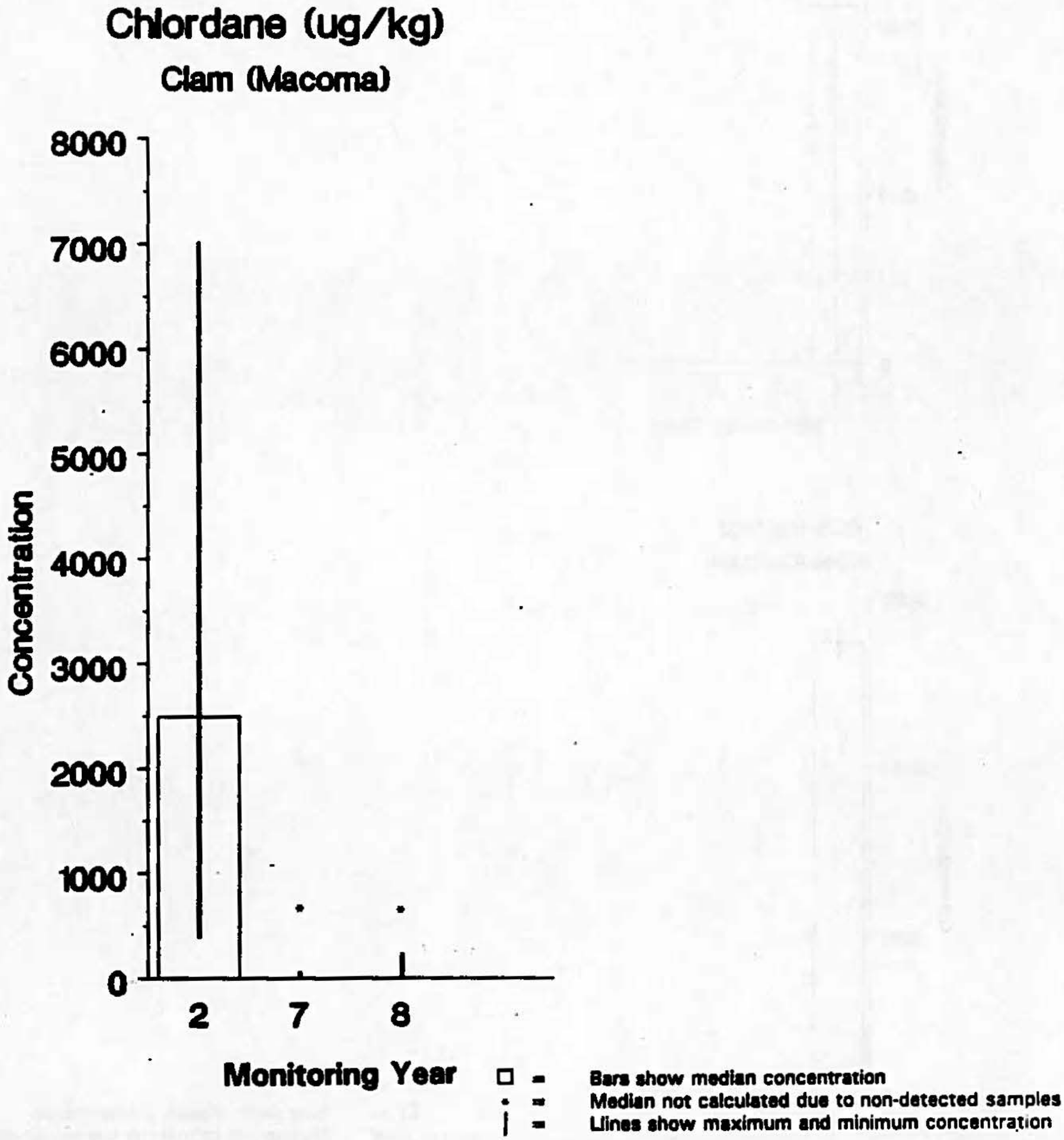


Figure 3-1. Trends in Hart-Miller Island chlordane data

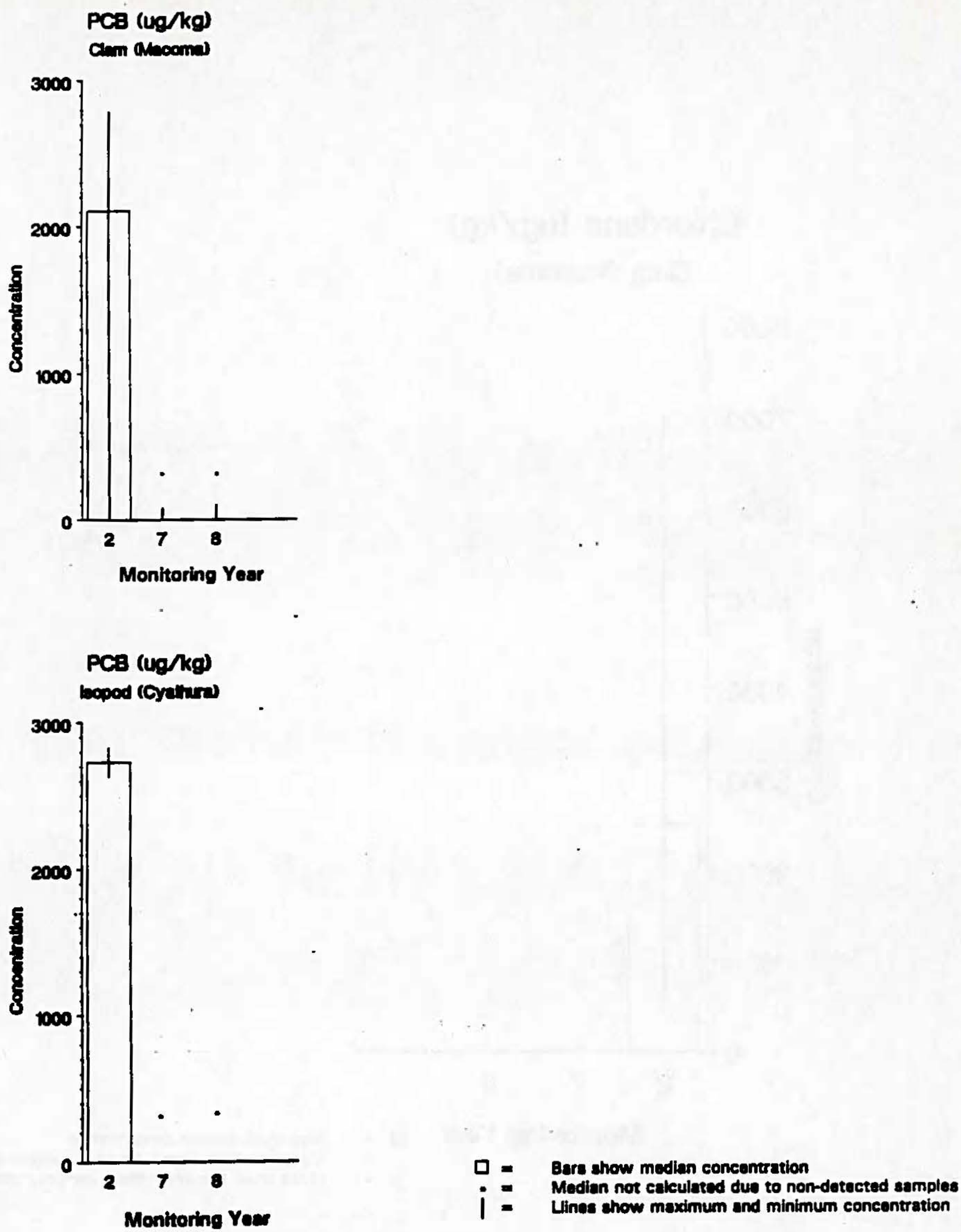


Figure 3-2. Trends in Hart-Miller Island PCB data

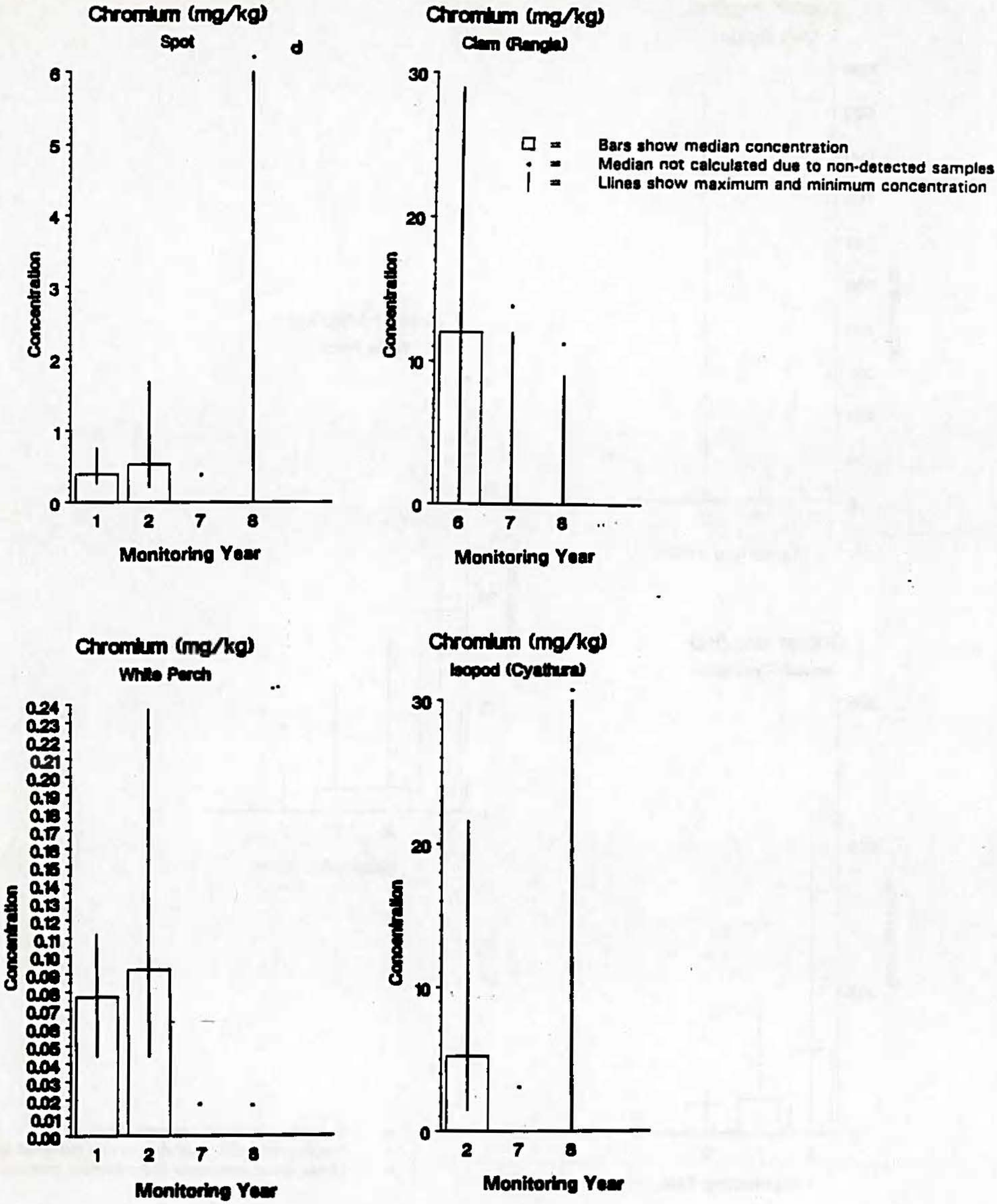


Figure 3-3. Trends in Hart-Miller Island chromium data

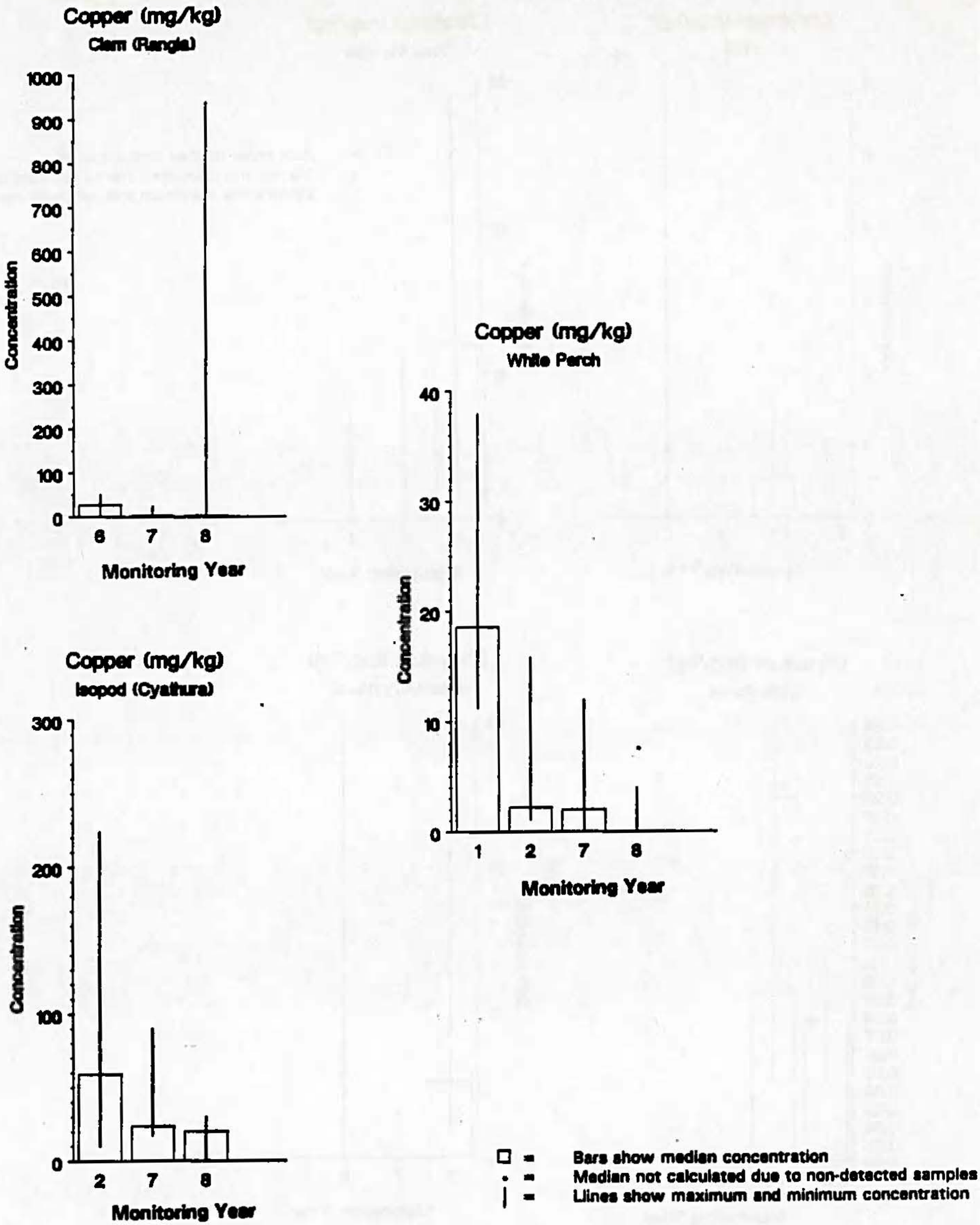
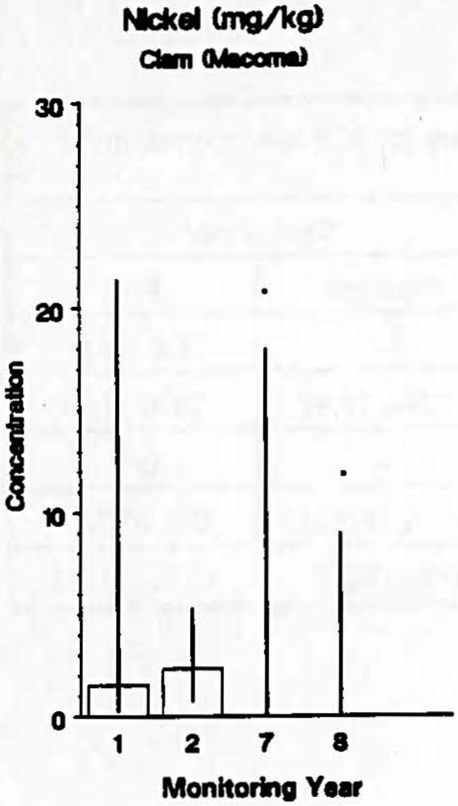


Figure 3-4. Trends in Hart-Miller Island copper data



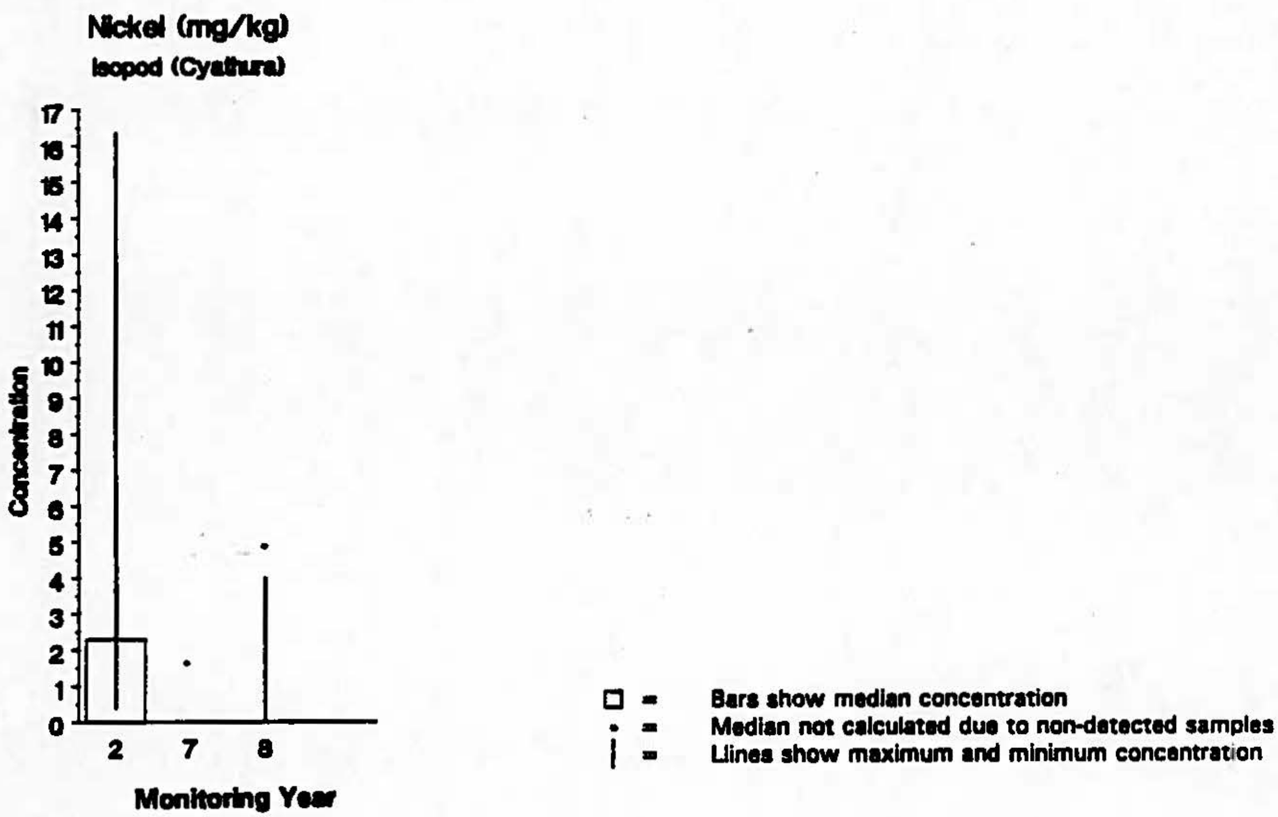


Figure 3-5. Trends in Hart-Miller Island nickel data

Table 3-2. Frequency of target species with chlordane or PCB levels equal to or greater than FDA limits				
	PCBs[a]		Chlordane[b]	
Year	Benthos[c]	Fish[d]	Benthos	Fish
1	--	0% (0/1)	--	0% (0/1)
2	60% (6/10)	0% (0/3)	100% (8/8)	33% (1/3)
6	--	0% (0/1)	--	0/1
7	0% (0/33)	0% (0/18)	11% (5/46)	0% (0/15)
8	2% (1/40)	0% (0/24)	0% (0/37)	12% (3/24)

[a] FDA limit = 2.0 mg/kg
[b] FDA limit = 0.3 mg/kg
[c] Benthos = *Rangia, Macoma, Cyathura*
[d] Fish = White perch, spot

In white perch, median concentrations were 0.08 mg/kg in year 1, 0.09 mg/kg in year 2, and non-detectable in years 7 and 8 (Figure 3-3).

Copper concentrations in Rangia decreased from a median of 27.0 mg/kg in year 6 to 3.0 mg/kg in years 7 and 8. Median concentrations in Cyathura decreased from 58.8 in year 2 to 23.5 in year 7 and 20.0 in year 8. Concentrations in white perch decreased from a median of 18.57 in year 1, to 2.21 in year 2, to 2.00 in year 7, and non-detectable in year 8 (Figure 3-4).

Median nickel concentrations in Macoma were 1.52 mg/kg in year 1, 2.35 in year 2, and non-detectable in years 7 and 8. Median concentrations in Cyathura were 2.30 mg/kg in year 2 to non-detectable in years 7 and 8 (Figure 3-5).

In summary, a number of analytes have shown evidence of decreasing concentrations between years 1 and 2 and years 7 and 8. Others do not show evidence of any trends. No analytes seem to be increasing. While the pooling of seasons and stations are possible confounding factors, the available evidence does not suggest that operation of the facility has resulted in increased contaminant concentrations over the baseline levels measured in the first and second monitoring years.

C. Comparisons of the Hart-Miller Data with Other Data

In order to compare the Hart-Miller Island data with other Chesapeake Bay data, literature was searched for multi-year monitoring programs which analyzed contaminants in the target species. The only data set located for the target species is the Fish Tissue Network monitoring program conducted by the Maryland Department of the Environment (MDE).

Murphy (1988) summarized the Fish Tissue Network data from the 1977-1985 collections and these data are used to place the fish contaminant levels measured at Hart-Miller Islands in context. Data are available for several chemicals that have been monitored in both programs: chromium, copper, zinc, and chlordane. There are several major differences in the programs in addition to the differences in the years. The MDE program samples once a year in the fall whereas the Hart-Miller program collects on three occasions. Thus, seasonal differences may confound the comparisons. Tissues analyzed in the MDE program are whole fish whereas the Hart-Miller program analyzes fillets.

Data were summarized for the 1978-1985 period for station XJH6680 which is located in the Upper Chesapeake Bay between Turkey and Sandy Points (about 20 nautical miles from Hart-Miller Island). The individual year results and median concentrations are listed in Table 3-3 along with the median values from the Hart-Miller program.

Table 3-3. Comparison of MDE Fish Tissue Network Station XJH 6680 data with Hart-Miller data									
		MDE Station XJH 6680							
		Chlordane (µg/kg)		Chromium (mg/kg)		Copper (mg/kg)		Zinc (mg/kg)	
Study	Year	White Perch	Spot	White Perch	Spot	White Perch	Spot	White Perch	Spot
MDE	1978	120	50	0.2	0.4	11.30	1.41	27.70	12.40
MDE	1979	150	50	0.1	<0.1	5.94	0.74	20.80	14.60
MDE	1980	140	100	<0.1	<0.1	10.60	0.73	14.40	12.50
MDE	1981 (sample 1)	30	<100	0.2	<0.1	0.58	0.40	13.40	12.60
MDE	1981 (sample 2)	30	<100	0.1	0.3	13.00	0.96	18.20	11.70
MDE	1982	30	50	<0.5	0.5	19.80	1.10	34.30	21.50
MDE	1984	100	60	0.8	--	2.54	--	16.80	--
MDE	Median (1978-84)	100	50	0.15	0.1-0.3	10.60	0.85	18.20	12.55
MDE	Range (1978-89)	30-150	ND[a]	ND-0.8	ND-0.5	0.58-19.80	0.40-1.41	13.40-27.70	11.70-21.50
		Hart-Miller Stations							
Hart-Miller	Median (Yr 8)[c]	130	ND[a]	ND[a]	NC[b]	NC[b]	NC[b]	17	10
Hart-Miller	Range (Yr 8)	ND-300	ND[a]	ND[a]	ND[a]-6	ND[a]-4	ND[a]-3	10-33	6-23
Hart-Miller	Median (Yr 1-8)[d]	36	NC[b]	NC[b]	0.4	2	1.5	19.1	16.0
Hart-Miller	Range (Yr 1-8)	ND-311	ND-61	ND-0.2	ND-6	ND-38	ND-5	6-220	6-30

[a] ND = Not detected
[b] NC = Median could not be calculated due to non-detected samples
[c] Yr 8 = 1988-1989
[d] Yr 1-8 = 1981-1989

Although the data sets were not compared statistically (due to the above-mentioned differences and their small size), the ranges and medians measured in the two programs are similar. These data, and the knowledge that spot and white perch are mobile species, suggest that concentrations measured in fish at Hart-Miller reflect regional rather than local inputs.

4. CONCLUSIONS AND RECOMMENDATIONS

Metal and organic contaminants were analyzed in sediments and biota as part of the Hart-Miller Island Containment Facility Environmental Assessment Monitoring Program. In the present monitoring year (Year 8; November 1988-August 1989), 99 samples of sediment and biota were analyzed.

The only organic constituents that were found above detection limits in biota were chlordane, PCBs, DEHP, and di-n-butyl phthalate. PCBs in one sample of Rangia were at the FDA action level of 2.0 mg/kg. No fish samples contained PCBs at or above 2.0 mg/kg. None of the benthic species contained chlordane at or above the FDA action level of 0.3 mg/kg. Three samples of white perch contained chlordane at 0.3 mg/kg.

One sample of Rangia (HM22 from August 1989) contained unusually high levels of copper (940 mg/kg), iron (12,300 mg/kg), and nickel (1830 mg/kg). A sample of Macoma (S6 from August 1989) contained an extremely high level of zinc (1290 mg/kg). The causes for these extremely high measurements are unknown and sampling or laboratory contamination cannot be ruled out. No other samples contained abnormally high metal concentrations. In general, concentrations of contaminants in reference and site benthic stations and in fish stations adjacent to and removed from the facility were similar.

Analysis of variance was performed on ranked values as a nonparametric test to determine if inter-station or inter-year differences were statistically significant. There were no significant differences in concentrations between stations in year 7 or year 8. Analysis of trends using pooled data from all stations, indicated that for some chemicals and species there were significant differences among years. In all cases where changes were monotonic, the apparent trend was of decreasing concentrations between years 1 and 2 (or if year 1 and 2 were not available, year 6) and years 7 and 8. No significant differences between years were observed for zinc with any species. PCB and chlordane concentrations in Macoma appear to have decreased during the monitoring program. Concentrations of PCBs, chromium, copper, and nickel in Cyathura and concentrations of chromium and copper in Rangia also appear to have decreased. Concentrations of chromium and copper in white perch and concentrations of copper in and spot also appear to be decreasing but, since these are mobile species, they are more likely to be indicators of regional rather than local conditions.

The sediment samples collected during the eighth monitoring year only revealed one sample with any organic analyte (bis (2-ethylhexyl) phthalate) above the detection limits. The analysis of metals in sediment is contained in the Project II - Sedimentary Environment Section of this report.

Years 7 and 8 have produced larger data sets with more standardized protocols for sample handling, station designations, and analytical methods than was the case in years 3-6. For the most part, analytical methods have been acceptable although occasionally detection limits for some of the organic analytes were far too high.

The following recommendations are suggested as possible ways to improve the program:

- Identify possible problems with organic detection limits and determine if adequate sample sizes are being provided.

- Reevaluate the sampling locations. Since statistical analysis of years 7 and 8, indicated no significant differences between stations, it may be useful to sample a fewer number of stations more intensively. Establishment of additional benthic stations farther removed from the facility should be considered in order to guarantee that at least one reference station is well-removed from possible influences of the facility.

- Reevaluate the metals chosen for tissue analysis. It may be useful to replace iron and manganese with cadmium, lead, and mercury, which are included on the Chesapeake Bay Program's list of toxics of concern (Alliance for the Chesapeake Bay 1991).

- Consider selecting a smaller number of species as targets for analysis. Analyzing a single mud crab every few years will provide little useful information. Analytical funds would be better spent on sampling fewer species more intensively.

- Reevaluate the purpose of the fish monitoring data. If a non-mobile species (e.g., mummichog) cannot be collected, then it may be more useful to terminate the fish monitoring program and spend the resources on further benthic analyses. If the fish monitoring is continued, it would be useful to coordinate procedures with the MDE Fish Tissue Network to make data comparable.

APPENDIX A

HART-MILLER ISLAND EXTERIOR MONITORING PROGRAM SAMPLES COLLECTED FOR 1988-89

Appendix B: Summary of Laboratory Analysis of Biota Samples Collected for Hart-Miller Island Exterior Monitoring program August 1987-August 1989 (Years 7 and 8)

Polychaete (04801001)

station: HM16 (XIF3325)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<20	250	40	<10	60	<20	<100	<100	<10000	<1000	890807

station: S2 (XIF5406)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<4	128	52	6	15	<10	<50	<10	<500	<100	880411

station: S1 (XIF5710)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
12	1030	60	8	28	<8	<1000	<1000	<10000	<1000	881201
<8	1430	180	10	50	<8	<100	<100	<10000	<1000	890807

Congeria leucophaeta (04905007)

station: S2 (XIF5406)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
9	308	447	7	13	3	<1000	<1000	<10000	:1000	881201

Rangia cuneata (04905008)

station: HM16 (XIF3325)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	81	17	<1	6	<5	<50	38	<500	<100	871207
<5	172	21	2	12	<5	<50	<10	<500	<100	871207
4	48	19	5	20	<5	<50	<10	<500	<100	880411
<2	389	59	6	18	<2	<10	<10	<10	<1	880801
<2	272	54	3	18	5	<1	<1	<10	<1	881201
<2	203	35	3	19	20	<10	<100	<10	<1	890410
<2	240	51	3	21	<2	<10	<1	<10	<1	890807

station: S6 (XIF4327)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	33	3	1	8	5	<50	76	<500	<100	871207
<5	36	5	<1	5	9	<50	100	<500	<100	871207
8	82	44	6	8	<5	50	<10	<500	<100	880411
<2	328	29	4	19	<2	<10	<10	<10	<1	880801
<2	174	18	3	29	6	<1	<1	<10	<1	881201
<2	73	6	<2	13	17	<20	<200	<20	<2	890410
<2	170*	28	2	30	8	<100	<100	<50	<5	890807

station: S4 (XIF4715)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	114	7	3	6	<5	<50	<10	<500	<100	871207
<5	290	17	1	10	<5	<50	<10	<500	<100	871207
3	81	43	4	2	<5	<50	<10	<500	<100	880411
<2	122	16	3	16	<2	<10	<10	<10	<1	880411
<2	370	39	4	22	<2	<1	100	<10	<1	881201
7	320	70	6	5	<2	<20	<200	350	<5	890410
<2	287	67	5	24	6	<10	<1	<50	<5	890807
<2	500	64	4	47	10	<10	<1	<10	<1	890807

Appendix 8: Summary of Laboratory Analysis of Biota Samples Collected for Hart-Miller Island Exterior Monitoring program August 1987-August 1989 (Years 7 and 8)

Polychaete (04801001)

station: HM16 (XIF3325)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<20	250	40	<10	60	<20	<100	<100	<10000	<1000	890807

station: S2 (XIF5406)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<4	128	52	6	15	<10	<50	<10	<500	<100	880411

station: S1 (XIF5710)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
12	1030	60	8	28	<8	<1000	<1000	<10000	<1000	881201
<8	1430	180	10	50	<8	<100	<100	<10000	<1000	890807

Congeria leucophaeta (04905007)

station: S2 (XIF5406)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
9	308	447	7	13	3	<1000	<1000	<10000	:1000	881201

Rangia cuneata (04905008)

station: HM16 (XIF3325)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	81	17	<1	6	<5	<50	38	<500	<100	871207
<5	172	21	2	12	<5	<50	<10	<500	<100	871207
4	48	19	5	20	<5	<50	<10	<500	<100	880411
<2	389	59	6	18	<2	<10	<10	<10	<1	880801
<2	272	54	3	18	5	<1	<1	<10	<1	881201
<2	203	35	3	19	20	<10	<100	<10	<1	890410
<2	240	51	3	21	<2	<10	<1	<10	<1	890807

station: S6 (XIF4327)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	33	3	1	8	5	<50	76	<500	<100	871207
<5	36	5	<1	5	9	<50	100	<500	<100	871207
8	82	44	6	8	<5	50	<10	<500	<100	880411
<2	328	29	4	19	<2	<10	<10	<10	<1	880801
<2	174	18	3	29	6	<1	<1	<10	<1	881201
<2	73	6	<2	13	17	<20	<200	<20	<2	890410
<2	170*	28	2	30	8	<100	<100	<50	<5	890807

station: S4 (XIF4715)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	114	7	3	6	<5	<50	<10	<500	<100	871207
<5	290	17	1	10	<5	<50	<10	<500	<100	871207
3	81	43	4	2	<5	<50	<10	<500	<100	880411
<2	122	16	3	16	<2	<10	<10	<10	<1	880411
<2	370	39	4	22	<2	<1	100	<10	<1	881201
7	320	70	6	5	<2	<20	<200	350	<5	890410
<2	287	67	5	24	6	<10	<1	<50	<5	890807
<2	500	64	4	47	10	<10	<1	<10	<1	890807

Appendix B:(cont.)

(continue)

Rangia cuneata (04905008)

station: S2 (XIF5406)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
3	131	42	5	12	6	<50	<10	<500	<100	880411
8	88	60	9	6	5	50	<10	<500	<100	880411
<2	351	21	3	21	<2	<10	<10	<10	<1	880801
<2	229	28	3	20	3	<1	2000	<10	<1	881201
<2	199	38	4	34	12	<10	<1	<10	<1	890807
<2	76	11	3	20	7	<10	<1	<10	<1	890807

station: S1 (XIF5710)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	134	17	1	16	<5	<50	<10	<500	<100	871207
6	33	17	2	12	<5	<50	<10	<500	<100	871207
2	49	25	6	17	5	<50	<10	<500	<100	880411
<2	48	10	2	20	<2	15	<10	<10	<1	880801
3	210	19	3	18	<2	<1	200	<10	<1	881201
3	224	19	3	23	7	<1	1000	490	<1	881201
<2	57	18	<2	14	12	<10	<100	<10	<1	890410
<2	214	30	3	24	7	<10	<1	<10	<1	890807
<2	371	46	3	24	<2	<10	<1	<10	<1	890807

station: HM22 (XIG7689)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
25	203	59	3	11	<5	<50	<10	<500	<100	871207
12	107	123	5	4	5	<50	<10	<500	<100	871207
<2	132	42	3	11	10	<50	<10	<500	<100	880411
3	78	62	4	6	<5	<500	<10	<500	<100	880411
<2	130	8	3	15	11	2000	<10	<10	<1	880801
<2	400	49	2	25	5	<10	<10	<10	<1	880801
<2	259	37	3	18	5	<1	1000	<10	<1	881201
<2	99	20	2	18	6	<1	1000	<10	<1	881201
9	12300	1020	940	67	1830	<10	<100	<10	<1	890410
<2	159	35	<2	20	9	<10	<100	20000	<1	890410
<2	490	60	3	24	23	<10	<1	<10	<1	890807
<2	330	46	2	22	9	<10	<1	<10	<1	890807

station: S7 (XI65405)

Cr.	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
8	73	35	3	6	<5	<50	<10	<500	<100	871207
5	155	27	1	10	<5	<50	<10	<500	<100	871207
<2	27	<2	<2	14	5	<10	<100	<10	<1	890410

Appendix B:(cont.)

Macoma sp. (04905012)

station: HH16 (XIF3325)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
3	790	152	8	70	18	<50	<10	<500	<100	880411
<2	483	208	8	59	<2	28	<10	<10	<1	880801
<2	860	162	14	116	<2	236	<1	290	<1	881201
3	630	165	9	50	5	<1000	<100	<50	<5	890410
<2	245	77	8	80	<2	<10	<1	<10	<1	890807
<8	519	180	20	46	<8	<100	<100	<10000	<1000	890807

station: S6 (XIF4327)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	681	133	6	38	<5	<50	81	<500	<100	871207
3	466	101	8	46	<5	<50	<10	<500	<100	880411
<2	560	145	6	29	<2	23	<10	<10	<1	880801
5	920	177	10	65	<2	<2	100	<20	<2	881201
<5	315	100	20	50	<5	<10000	<10000	<10000	<1000	890410
<2	540	168	27	1290	<2	<100	<100	<10000	<1000	890807

station: S4 (XIF4715)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
6	1370	121	7	27	<5	<50	<10	<500	<100	871207
3	990	119	8	40	<5	62	<10	<500	<100	880411
6	122	116	25	20	6	<50	<10	<500	<100	880411
5	830	195	15	50	<2	<5	<5	<50	<5	881201

Appendix B:(cont.)

Balanus sp. (05307002)

station: S2 (XIF5406)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
12	184	1410	8	88	7	<1	<1	<10	<1	881201

Cyathura polita (05316012)

station: HM16 (XIF3325)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	133	28	18	23	<5	<50	<10	<500	<100	871207
<2	252	143	25	42	<5	110	<10	<500	<100	880411
<10	582	759	35	59	<10	533	<10	<10	<1	880801
<4	129	87	13	53	4	<1000	<1000	<10000	<1000	881201
<6	250	180	20	85	<6	<2000	<20000	<1000	<100	890410
<5	140	245	21	74	<5	<100	<100	<10000	<1000	890807

station: S6 (XIF4327)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	96	47	19	26	<5	<50	<10	<500	<100	871207
<2	364	126	34	54	<5	95	<10	<500	<100	880411
<4	320	148	17	46	<10	80	<10	<500	<100	880411
<10	556	424	44	76	<10	83000	<10	<10	<1	880801
<20	310	40	30	110	<20	<100	<100	<1000	<100	881201
<2	240	120	<20	60	<20	<10000	<10000	<1000	200	890410
<8	190	180	30	71	<8	<100	<100	<10000	<1000	890807

station: S4 (XIF4715)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<20	340	280	20	60	<20	1400	<10	<10	<1	880801
<20	310	40	30	110	<20	<100	<100	<1000	<100	881201
<20	140	70	<20	70	<20	<100	<100	<1000	<100	881201
<20	440	230	<10	100	<20	<100	<100	<10000	<1000	890807

station: S2 (XIF5406)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<4	67	25	19	22	<10	<50	<10	<500	<100	880411
<20	720	920	20	140	<20	1700	<10	<10	<1	880801

station: S1 (XIF5710)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<20	380	380	90	140	<50	<50	<10	<500	<100	880411
<10	306	222	22	111	<10	<10	<10	<10	<1	880801
30	360	210	20	80	<20	<1000	<1000	<10000	<1000	881201
<20	280	170	30	110	<20	<100	<100	<10000	<1000	890807

station: HM22 (XIG7689)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<14	142	104	26	52	<10	<1000	<10	<500	<100	880411
<20	440	340	40	120	<20	<10	<10	<10	<1	880801

Amphipod-unidentified (05317004)

station: S1 (XIF5710)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<4	146	14	9	9	<10	<50	<10	<500	<100	880411

Appendix B:(cont.)

Leptocheirus plumulosus (05317016)

station: S4 (XIF4715)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<60	870	<60	<60	70	<60	<10000	<10000	<10000	<1000	890410

Mud crab (05319014)

station: S2 (XIF5406)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	715	2000	33	49	<5	<10	<10	<10	<1	880801
6	300	696	29	25	8	<500	<500	<5000	<500	881201

Menhaden (07904010)

station: F4 (XIF2743)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	11	<2	<1	5	<5	400	680	<500	<100	871208
3	24	23	3	32	3	<1	300	<10000	<1000	881202

station: F3 (XIF4516)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	11	4	<1	6	<5	46	94	<500	<100	871208
<5	9	<2	<1	4	<5	72	98	<500	<100	871208
3	50	16	2	27	3	200	200	<10	<1	881202

catfish (07918000)

station: F1 (XIF5727)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	8	<2	<1	11	<5	<200	1100	<500	<100	880411

station: F2 (XIG5704)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	8	<2	2	12	<5	<200	240	<500	<100	880411

Appendix 8:(cont.)

spot (07938007)

station: F4 (XIF2743)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	15	12	5	15	<2	<10	217	<10	<1	880801
<2	13	5	2	9	14	<10	<1	<10	<1	890807
<2	6	3	<1	6	10	<10	<1	<10	<1	890807

station: F3 (XIF4516)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	13	12	<1	13	<2	<10	82	<10	<1	880801
<2	27	25	<2	10	<2	<1	<1	<10	<1	881202
<2	16	5	2	10	46	<10	<1	<10	<1	890807
<2	4	<2	<1	6	24	<10	<1	<10	<1	890807

station: F1 (XIF5727)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	28	74	2	16	<2	<1	<1	1300	<1	881201

station: F2 (XIG5704)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	22	15	<1	9	<2	<10	<100	<10	<1	880801
<2	33	14	<2	23	<2	<1	50	<10	<1	881201
<2	9	4.	3	10	<2	<10	<1	<10	<1	890807
6	10	8	<1	12	19	<10	<1	<10	<1	890807

Appendix B:(cont.)

White perch (07938008)

station: F4 (XIF2743)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	27	4	4	18	<5	<500	790	<500	<100	880411
<2	24	15	12	27	6	<500	720	<500	<100	880411
<2	30	4	<2	12	<2	<1	820	<10	<1	881201
<2	31	4	4	15	3	<1	650	<10	<1	881202
<2	12	15	<2	26	<2	200	300	<100	<10	890410
<2	11	<2	3	14	<2	200	1300	<100	<10	890410

station: F3 (XIF4516)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	11	6	3	25	<5	<50	<50	<500	<100	880411
<2	12	16	2	33	<5	<100	<50	<500	<100	880411
<2	19	9	<1	21	<2	<10	608	<10	<1	880801
<2	17	3	<1	20	<2	<10	708	<10	<1	880801
<2	25	14	<2	13	<2	110	80	<10	<1	881202
<2	13	5	<2	26	<2	30	200	<100	<10	890410
<2	12	6	<2	33	<2	200	400	<100	<10	890410

station: F1 (XIF5727)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	16	18	6	45	<5	<150	250	<500	<100	880411
<2	10	<2	2	10	<5	<200	940	<500	<100	880411
<2	16	4	<1	20	<2	224	247	<10	<1	880801
<2	8	3	<1	10	<2	295	243	<10	<1	880801
<2	32	2	2	10	5	<1	1300	<10	<1	881201
<2	61	12	<2	17	3	300	<1	560	<1	881201
<2	[illegible]	13	<2	13	<2	300	750	<10	300	890410
<2	22	4	4	23	6	300	800	4200	<1	890410
<2	14	27	3	20	<2	<10	<1	<10	<1	890807

station: F2 (XIG5704)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	10	3	2	10	<5	<200	330	<500	<100	880411
<2	58	78	2	15	<5	<500	550	<500	<100	880411
<2	18	3	<1	12	<2	238	263	<10	<1	880801
<2	8	4	2	13	<2	<10	208	<10	<1	880801
<2	37	5	2	18	<2	<1	1000	<10	<1	881201
<2	14	<2	<2	19	<2	130	300	450	200	890410
<2	15	4	<2	16	<2	200	1000	<10	<1	890410

Appendix B:(cont.)

yellow perch (07938028)

station: F4 (XIF2743)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	9	<2	<1	6	<5	290	720	<500	<100	871208
<2	31	35	5	30	<5	<100	310	<500	<100	880411

station: F3 (XIF4516)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	11	6	3	19	<5	<50	460	<500	<100	880411

station: F1 (XIF5727)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	6	<2	<1	7	<5	81	360	<500	<100	871208
<2	10	<2	2	11	<5	<200	<50	<500	<100	880411
<2	57	8	<1	10	<2	95	183	<10	<1	880801
<2	10	13	<2	13	<2	<10	<100	900	<1	890410
<2	13	2	<1	12	<2	<10	<1	<10	<1	890807

station: F2 (XIG5704)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<5	8	<2	<1	5	<5	89	310	<500	<100	871208
<2	36	7	2	14	<2	<1	<1	720	<1	881201

Hogchoker (07958009)

station: F3 (XIF4516)

Cr	Fe	Mn	Cu	Zn	Ni	Chlor	PCB's	Bis(2-E)	Di-n-b	Date
<2	19	57	2	26	<5	<50	170	<500	<100	880411

Appendix A: Hart-Miller Island Exterior Monitoring Program Samples Collected for 1988-89

MES SAMPLE ID	UCB SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE *	TIDE	DEPTH IN FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSES REQUIRED
880817	3	11-15-88	YEAR 8, FALL		1		15	SEDIMENT	XIF3430	HENNESSEE	ORGANICS
880818	17	11-15-88	"		1		17.5	SEDIMENT	XIF3620	HENNESSEE	ORGANICS
880819	BC-3	11-15-88	"		1		4.2	SEDIMENT	XIF4615	HENNESSEE	ORGANICS
880820	24-1	11-15-88	"		1		16.7	SEDIMENT	XIF5302	HENNESSEE	ORGANICS
880821	24-1	11-15-88	"		1		16.7	SEDIMENT	XIF5302	HENNESSEE	ORGANICS
880822	24-3	11-15-88	"		1		16.7	SEDIMENT	XIF5302	HENNESSEE	ORGANICS
880823	20	11-15-88	"		1		19	SEDIMENT	XIC5497	HENNESSEE	ORGANICS
880824	21 B	11-15-88	"		1		13	SEDIMENT	XIF5505	HENNESSEE	ORGANICS
880825	BC-6	11-15-88	"		1		10.3	SEDIMENT	XIF5925	HENNESSEE	ORGANICS
880826	23	11-15-88	"		1		11	SEDIMENT	XIF4442	HENNESSEE	ORGANICS
880881	HM 16-1	12-1-88	YEAR 8, FALL	1020	1		16	RANGIA	XIF3325	DUGUAY	MET/ORG
880882	HM 16-2	12-1-88	"	1020	1		16	MACOMA	XIF3325	DUGUAY	MET/ORG
880883	HM 16-3	12-1-88	"	1020	1		16	CYATHURA	XIF3325	DUGUAY	MET/ORG
880884	S 6-1	12-1-88	"	1100	1		9	RANGIA	XIF4327	DUGUAY	MET/ORG
880885	S 6-2	12-1-88	"	1100	1		9	MACOMA	XIF4327	DUGUAY	MET/ORG
880886	S 6-3	12-1-88	"	1100	1		13	CYATHURA	XIF4715	DUGUAY	MET/ORG
880887	S 4-1	12-1-88	"	1200	1		13	RANGIA	XIF4715	DUGUAY	MET/ORG
880888	S 4-2	12-1-88	"	1200	1		13	MACOMA	XIF4715	DUGUAY	MET/ORG
880889	S 4-3	12-1-88	"	1200	1		13	CYATHURA	XIF4715	DUGUAY	MET/ORG
880890	S 2-1	12-1-88	"	1340	1		12	BALANUS	XIF5406	DUGUAY	MET/ORG
880891	S 2-2	12-1-88	"	1340	1		12	CONGERIA	XIF5406	DUGUAY	MET/ORG
880892	S 2-3	12-1-88	"	1340	1		12	RITHROPANOPEUS	XIF5406	DUGUAY	MET/ORG
880893	S 2-4	12-1-88	"	1340	1		12	RANGIA	XIF5406	DUGUAY	MET/ORG
880894	S 1-1	12-1-88	"	1443	1		6	RANGIA	XIF5710	DUGUAY	MET/ORG
880895	S 1-2	12-1-88	"	1443	1		6	RANGIA	XIF5710	DUGUAY	MET/ORG
880896	S 1-3	12-1-88	"	1443	1		6	POLYCHAETES	XIF5719	DUGUAY	MET/ORG

* WEATHER CODE: 1 - CLEAR

Appendix A (cont.)

MES SAMPLE ID	VSA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE *	TIDE	DEPTH IN FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSES REQUIRED
880897	S 1-4	12-1-88	*	1443	1		4	CYATHURA	XIF5710	DUGWAY	MET/ORG
880898	BM 22-1	12-1-88	*	1530	1		15	RANGIA, LG	XIG7609	DUGWAY	MET/ORG
880899	BM 22-2	12-1-88	*	1530	1		15	RANGIA, MD	XIG7609	DUGWAY	MET/ORG
880900	UNIT 1-1	12-1-88	*	1615	1		8	WHITE PERCH	39 15'21" X 76 25'5" (CENTER OF 5" TOW)	DUGWAY	MET/ORG
880901	UNIT 1-2	12-1-88	*	1615	1		8	WHITE PERCH	*	DUGWAY	MET/ORG
880902	UNIT 1-3	12-1-88	*	1615	1		8	SPOT	*	DUGWAY	MET/ORG
880903	UNIT 2-1	12-1-88	*	1600	1		15	WHITE PERCH	39 15'44" X 76 28'22"	DUGWAY	MET/ORG
880904	UNIT 2-2	12-1-88	*	1600	1		15	YELLOW PERCH	*	DUGWAY	MET/ORG
880905	UNIT 2-3	12-1-88	*	1600	1		15	SPOT	*	DUGWAY	MET/ORG
880906	UNIT 4-1	12-1-88	*	0935	1		15	WHITE PERCH	39 12'44" X 76 24'19"	DUGWAY	MET/ORG
880907	UNIT 4-2	12-2-88	*	0935	1		15	WHITE PERCH	*	DUGWAY	MET/ORG
880908	UNIT 4-3	12-2-88	*	0935	1		15	MENHADEN	*	DUGWAY	MET/ORG
880909	UNIT 3-1	12-2-88	*	1015	1		14	WHITE PERCH	39 14'20" X 76 21'34"	DUGWAY	MET/ORG
880910	UNIT 3-2	12-2-88	*	1015	1		14	MENHADEN	*	DUGWAY	MET/ORG
880911	UNIT 3-3	12-2-88	*	1015	1		14	SPOT	*	DUGWAY	MET/ORG

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* - CLEAR

H.M.I. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS REQUIRED
890219	HM 16-1	4/10/89	YEAR #9 SPRING	1040	C	N/A	16	RANGIA	XIF3325	PFITZENMEYER	MET/ORG
890220	HM 16-2	4/10/89	"	1040	C	N/A	16	MACOMA	XIF3325	PFITZENMEYER	MET/ORG
890221	HM 16-3	4/10/89	"	1040	C	N/A	16	CYANTHURA	XIF3325	PFITZENMEYER	MET/ORG
890222	S 6-1	4/10/89	"	1105	C	N/A	10	RANGIA	XIF4327	PFITZENMEYER	MET/ORG
890223	S 6-2	4/10/89	"	1105	C	N/A	10	MACOMA	XIF4327	PFITZENMEYER	MET/ORG
890224	S 6-3	4/10/89	"	1105	C	N/A	10	CYANTHURA	XIF4327	PFITZENMEYER	MET/ORG
890225	S 4-1	4/10/89	"	1155	C	N/A	14	RANGIA	XIF4715	PFITZENMEYER	MET/ORG
890226	S 4-2	4/10/89	"	1155	C	N/A	14	LEPTOCHANS	XIF4715	PFITZENMEYER	MET/ORG
890227	S 7-1	4/10/89	"	1330	C	N/A	14	RANGIA	XIG5405	PFITZENMEYER	MET/ORG
890228	S 1-1	4/10/89	"	1405	C	N/A	5	RANGIA	XIF5710	PFITZENMEYER	MET/ORG
890229	HM 22-1	4/10/89	"	1440	C	N/A	11	RANGIA (L)	XIG7689	PFITZENMEYER	MET/ORG
890230	HM 22-2	4/10/89	"	1440	C	N/A	11	RANGIA (S)	XIG7689	PFITZENMEYER	MET/ORG
890231	HMIT 1-1	4/10/89	"	1600	C	N/A	10	WHITE PERCH	39 15'44"-76 22'44"	PFITZENMEYER	MET/ORG
890232	HMIT 1-2	4/10/89	"	1600	C	N/A	10	WHITE PERCH	39 15'44"-76 22'44"	PFITZENMEYER	MET/ORG
890233	HMIT 1-3	4/10/89	"	1600	C	N/A	10	YELLOW PERCH	39 15'44"-76 22'44"	PFITZENMEYER	MET/ORG
890234	HMIT 2-1	4/10/89	"	1625	C	N/A	15	WHITE PERCH	39 15'44"-76 20'44"	PFITZENMEYER	MET/ORG
890235	HMIT 2-2	4/10/89	"	1625	C	N/A	15	WHITE PERCH	39 15'44"-76 20'44"	PFITZENMEYER	MET/ORG
890236	HMIT 3-1	4/10/89	"	1642	C	N/A	13	WHITE PERCH	39 14'28"-76 21'34"	PFITZENMEYER	MET/ORG
890237	HMIT 3-2	4/10/89	"	1642	C	N/A	13	WHITE PERCH	39 14'28"-76 21'34"	PFITZENMEYER	MET/ORG
890238	HMIT 4-1	4/10/89	"	1700	C	N/A	15	WHITE PERCH	39 12'44"-76 24'19"	PFITZENMEYER	MET/ORG
890239	HMIT 4-2	4/10/89	"	1700	C	N/A	15	WHITE PERCH	39 12'44"-76 24'19"	PFITZENMEYER	MET/ORG

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

SAMPLES DELIVERED TO HMI LABORATORY ON: 4/11/89 SAMPLES RELINQUISED BY: DR.PFITZENMEYER & DR.DUGUAY
SAMPLES DELIVERED TO MARTEL LABORATORY ON: 4/12/89 SAMPLES RECIEVED BY: S.MISTRY

Appendix A (cont.)

H.M.I. PLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE CODE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS TO BE DONE
890209	3	04/03/89	YEAR #8 SPRING	N/A	N/A	N/A	15	SEDIMENT	XIF 3430	HENNESSEE	ORGANICS
890210	19	04/03/89	"	N/A	N/A	N/A	18	SEDIMENT	XIF 3620	HENNESSEE	ORGANICS
890211	BC-3	04/03/89	"	N/A	N/A	N/A	15	SEDIMENT	XIF 4615	HENNESSEE	ORGANICS
890212	24-1	04/03/89	"	N/A	N/A	N/A	20	SEDIMENT	XIF 5302	HENNESSEE	ORGANICS
890213	24-2	04/03/89	"	N/A	N/A	N/A	20	SEDIMENT	XIF 5302	HENNESSEE	ORGANICS
890214	24-3	04/03/89	"	N/A	N/A	N/A	20	SEDIMENT	XIF 5302	HENNESSEE	ORGANICS
890215	28	04/03/89	"	N/A	N/A	N/A	19	SEDIMENT	XIG 5699	HENNESSEE	ORGANICS
890216	21 B	04/03/89	"	N/A	N/A	N/A	13	SEDIMENT	XIF 5505	HENNESSEE	ORGANICS
890217	BC-6	04/03/89	"	N/A	N/A	N/A	11	SEDIMENT	XIF 5925	HENNESSEE	ORGANICS
890218	23	04/03/89	"	N/A	N/A	N/A	11	SEDIMENT	XIF 4642	HENNESSEE	ORGANICS

OTHER PERTINENT INFORMATION: 10

SAMPLES WERE COLLECTED IN GLASS JARS WITH TEFLON LIDS * SAMPLES HAVE BEEN REFRIGERATED SINCE COLLECTION

) SAMPLES DELIVERED TO HMI LABORATORY ON: 04/03/89 — SAMPLES RELINQUISED BY: E.L. HENNESSEE; SAMPLES RECIEVED BY: S.MISTRY

) SAMPLES DELIVERED TO MARTEL LABORATORY ON: 04/12/89 — SAMPLES RELINQUISED BY: S.MISTRY; SAMPLES RECIEVED BY: MARTEL LABORATORY

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

Appendix A (cont.)

H.M.I. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING QUARTER	TIME	WEATHER CODE	TIDE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS REQUIRED
890587	HM 16-1	8/7/89	YEAR #9 SUMMER	1040	0	N/A	15	RANGIA	XIF3325	PFITZENMEYER	MET/ORG
890588	HM 16-2	8/7/89	"	1040	0	N/A	15	MACOMA	XIF3325	PFITZENMEYER	MET/ORG
890589	HM 16-3	8/7/89	"	1040	0	N/A	15	CYANTHURA	XIF3325	PFITZENMEYER	MET/ORG
890590	HM 16-4	8/7/89	"	1040	0	N/A	15	MACOMA	XIF3325	PFITZENMEYER	MET/ORG
890591	HM 16-5	8/7/89	"	1040	0	N/A	15	POLYCHAETES	XIF3325	PFITZENMEYER	MET/ORG
890592	S 6-1	8/7/89	"	1131	0	N/A	12	RANGIA	XIF4327	PFITZENMEYER	MET/ORG
890593	S 6-2	8/7/89	"	1131	0	N/A	12	MACOMA	XIF4327	PFITZENMEYER	MET/ORG
890594	S 6-3	8/7/89	"	1131	0	N/A	12	CYANTHURA	XIF4327	PFITZENMEYER	MET/ORG
890595	S 4-1	8/7/89	"	1219	0	N/A	12	RANGIA	XIF4715	PFITZENMEYER	MET/ORG
890596	S 4-2	8/7/89	"	1219	0	N/A	12	RANGIA	XIF4715	PFITZENMEYER	MET/ORG
890597	S 4-3	8/7/89	"	1219	0	N/A	12	CYANTHURA	XIF4715	PFITZENMEYER	MET/ORG
890598	S 2-1	8/7/89	"	1353	0	N/A	10	RANGIA	XIF5406	PFITZENMEYER	MET/ORG
890599	S 2-2	8/7/89	"	1353	0	N/A	10	RANGIA	XIF5406	PFITZENMEYER	MET/ORG
890600	S 1-1	8/7/89	"	1411	0	N/A	6	RANGIA	XIF5710	PFITZENMEYER	MET/ORG
890601	S 1-2	8/7/89	"	1411	0	N/A	6	RANGIA	XIF5710	PFITZENMEYER	MET/ORG
890602	S 1-3	8/7/89	"	1411	0	N/A	6	CYANTHURA	XIF5710	PFITZENMEYER	MET/ORG
890603	S 1-4	8/7/89	"	1411	0	N/A	6	POLYCHAETES	XIF5710	PFITZENMEYER	MET/ORG
890604	HM 22-1	8/7/89	"	1447	0	N/A	10.2	RANGIA (LARGE)	XIG7689	PFITZENMEYER	MET/ORG
890605	HM 22-2	8/7/89	"	1447	0	N/A	10.2	RANGIA (SMALL)	XIG7689	PFITZENMEYER	MET/ORG
890606	HMIT 1-1	8/7/89	"	1607	0	N/A	10	WHITE PERCH	XIF5727	PFITZENMEYER	MET/ORG
890607	HMIT 1-2	8/7/89	"	1607	0	N/A	10	YELLOW PERCH	XIF5727	PFITZENMEYER	MET/ORG
890608	HMIT 2-1	8/7/89	"	1633	0	N/A	15	SPOT	XIG5704	PFITZENMEYER	MET/ORG
890609	HMIT 2-2	8/7/89	"	1633	0	N/A	15	SPOT	XIG5704	PFITZENMEYER	MET/ORG
890610	HMIT 3-1	8/7/89	"	1654	0	N/A	15	SPOT	XIF4516	PFITZENMEYER	MET/ORG
890611	HMIT 3-2	8/7/89	"	1654	0	N/A	15	SPOT	XIF4516	PFITZENMEYER	MET/ORG
890612	HMIT 4-1	8/7/89	"	1714	0	N/A	12	SPOT	XIF2743	PFITZENMEYER	MET/ORG
890613	HMIT 4-2	8/7/89	"	1714	0	N/A	12	SPOT	XIF2743	PFITZENMEYER	MET/ORG

H.M.I. SAMPLE ID	WRA SAMPLE ID	DATE	SAMPLING TIME QUARTER	WEATHER CODE	TIDE	DEPTH FEET	SAMPLE TYPE	SAMPLE LOCATION	SAMPLER	ANALYSIS REQUIRED

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

) SAMPLES DELIVERED TO HMI LABORATORY ON: 8/08/89 SAMPLES RELINQUISED BY: DR.PFITZENMEYER & DR.DUGUAY
)SAMPLES DELIVERED TO MARTEL LABORATORY ON: 8/23/89 SAMPLES RECIEVED BY: S.MISTRY & T.HUMBLES

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