Sediment Core Chemistry Data Summary from the MQR Mound
August & December 1991

Disposal Area Monitoring System DAMOS

DAMOS

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13. ABSTRACT

Biological and chemical monitoring results from the Mill-Quinnipiac River Disposal Mound (MQR) have indicated slow, and perhaps retrograde, recolonization rates relative to other mounds formed within the same time period. These results triggered a more intensive investigation of the MQR mound.

In August of 1991, sediment was collected for a bioassy test, and, at the same time, six gravity cores were collected from the mound center. The cores were described, and sampled for inorganic and organic chemical analyses. Core samples were stored until completion of the bioassy test; results showed that the MQR sediment caused significant amphipod toxicity. Following the tiered approach to disposal mound monitoring, sediment samples from the coring cruise were analzyed in order to identify contaminant(s) potentially responsible for the benthic conditions at MQR.

Sediment core samples were analyzed for grain size, pesticides and polychlorinated biphenyls (PCB's), priority pollutant metals, polynuclear aromatic hydrocarbons (PAH's), and volatile organics. Core descriptions indicated that two primary lithologies had been recovered. The top 1-1.5 meters of each core consisted of black silt clay, overlying a sandier interval with clasts and plant fragments.

Physical and chemical analyses were used to construct a stratigraphy of the MQR mound in order to identify the origin of the surface sediments. Trace metal results were compared with historical data complied from the sources of the dredged material. Trace metal ratios indicated that most of the cored sediments were derived from the New Haven Harbor, the location of the capping material used to cover the MQR mound. The sandier sediments in the lower part of the cores appeared to be either Mill or Quinnipiac River sediments, or a combination of both.

Both bathymetric and modelled dredged material thickness estimates were consistent with the presence of a thick (1.5m) New Haven cap on the surface of MQR. The cap sediments contained relatively high PAH concentrations, indicating that the material dredged from New Haven Harbor for the MQR cap contained these contaminants at the time of disposal. PAH's have been included as part of the regional testing protocol since 1989, so that at the time of disposal (1982), the presence of PAH's would have been overlooked by routine chemical testing. New Haven Harbor material has been used successfully as cap material at other CLIS capped mounds. In the case of MQR, material may have been dredged from inner New Haven Harbor, which is influenced by the input of both Mill and Quinnipiac River sediments.

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EXECUTIVE SUMMARY

Biological and chemical monitoring results from the Mill-Quinnipiac River Disposal Mound (MQR) have indicated slow, and perhaps retrograde, recolonization rates relative to other mounds formed within the same time period. These results triggered a more intensive investigation of the MQR mound. Monitoring data have been collected as a part of the Disposal Area Monitoring System (DAMOS) Program since the formation of MQR during the 1982-1983 disposal seasons. MQR was constructed as one of several disposal mounds at the Central Long Island Sound Disposal Site (CLIS), including the two Cap Site mounds (CS-1 and CS-2) and the uncapped Field Verification Program mound (FVP).

REMOTS® sediment-profile photographs obtained in 1987 first identified the anomalous species assemblages and low organism-sediment indices at MQR as compared to both Cap Site mounds and FVP. Tissue body burden trace metal data were collected at several CLIS capped mounds in 1986 and indicated elevated levels at both MQR and FVP. Although benthic conditions had improved in the 1987 survey relative to the previous year, the 1991 CLIS monitoring survey indicated retrograde benthic recolonization as documented by REMOTS® photographs.

In August of 1991, sediment was collected for a bioassay test, and, at the same time, six gravity cores were collected from the mound center. The cores were described, and sampled for inorganic and organic chemical analyses. Core samples were stored until completion of the bioassay test; results showed that the MQR sediment caused significant amphipod toxicity. Following the tiered approach to disposal mound monitoring, sediment samples from the coring cruise were analyzed in order to identify the contaminant(s) potentially responsible for the benthic conditions at MQR.

Sediment core samples were analyzed for grain size, pesticides and polychlorinated biphenyls (PCBs), priority pollutant metals, polynuclear aromatic hydrocarbons (PAHs), and volatile organics. Core descriptions indicated that two primary lithologies had been recovered. The top 1-1.5 meters of each core consisted of black silty clay, overlying a sandier interval with clasts and plant fragments. Chemical results and core descriptions suggested that at least one core recovered ambient sediment below a depth of approximately 1.5 meters. This core was apparently recovered in the flanks of MQR, where the total thickness of dredged material was thinner.

Physical and chemical analyses were used to construct a stratigraphy of the MQR mound in order to identify the origin of the surface sediments. Trace metal results were compared with historical data compiled from the sources of the dredged material. Trace metal ratios indicated that most of the cored sediments were derived from the New Haven Harbor, the location of the capping material used to cover the MQR mound. The sandier sediments in the lower part of the cores appeared to be either Mill or Quinnipiac River sediments, or a combination of both.

Both bathymetric and modelled dredged material thickness estimates were consistent with the presence of a thick (1.5 m) New Haven cap on the surface of MQR. The cap sediments contained relatively high PAH concentrations, indicating that the material dredged from New Haven Harbor for the MQR cap contained these contaminants at the time of disposal. PAHs have been included as part of the regional testing protocol since 1989, so that at the time of disposal (1982), the presence of PAHs would have been overlooked by routine chemical testing. New Haven Harbor material has been used successfully as cap material at other CLIS capped mounds. In the case of MQR, material may have been dredged from inner New Haven Harbor, which is influenced by the input of both Mill and Quinnipiac River sediments.

1.0 INTRODUCTION

The Mill-Quinnipiac River Disposal Mound (MQR), which began receiving dredged material ten years ago, continues to be the most enigmatic capped mound monitored by the Disposal Area Monitoring System (DAMOS) Program. It is located in the southwest quadrant of the Central Long Island Sound Disposal Site (CLIS; Figure 1-1). The capped mound is actually a complex interlayered mound consisting of material from the Mill River, the Quinnipiac River, Black Rock Harbor, and New Haven Harbor.

Monitoring results from MQR have indicated slower biological recolonization rates after disposal relative to other CLIS mounds. These monitoring data have included REMOTS® photographs (as recently as the 1991 CLIS survey), sediment sampling and chemical analyses, and bioassay results. The complicated disposal history at MQR, in tandem with the unusual monitoring results gathered since disposal completion, prompted a more intensive investigation of the MQR mound following the tiered monitoring protocols initiated by the US Army Corps of Engineers, New England Division (NED) to manage dredged material disposal mounds (Germano et al. 1994). According to the protocols, unacceptable benthic community response as documented by REMOTS® should be followed up by a bioassay test. If there is a toxic response, the source of contamination should be analyzed through vertical profiling, or sediment coring (Germano et al. 1994).

Sediment cores were recovered from the MQR mound in the summer of 1991, described, and sampled at discrete depths representing visually distinct intervals. The objective of the coring operation was to identify sedimentary horizons within the MQR mound which represented the remnant disposed dredged material, and to use this stratigraphic reconstruction to explain the unusual postdepositional response at MQR. In order to accomplish this, core samples from the mound were visually and chemically compared with historical DAMOS data from MQR dredged material sources.

1.1 Disposal Operations at the MQR Mound, 1982-1983

During the spring of 1982, the NED initiated a capping project for sediments to be removed as part of federal maintenance dredging of areas in the Mill and Quinnipiac Rivers adjoining the northern limits of New Haven Harbor (Figure 1-2). Mill River material was characterized by high concentrations of fibrous residue or wood pulp, which limited sediment cohesion. This unique sediment texture combined with the relatively high water content percentages measured in the Mill River sediments increased the potential for sediment dispersion following disposal. In addition, chemical analysis of the Mill River sediments indicated high concentrations for most of the heavy metals tested. Cadmium (Cd), for example, was measured in concentrations up to 260 ppm (Table 1-1).

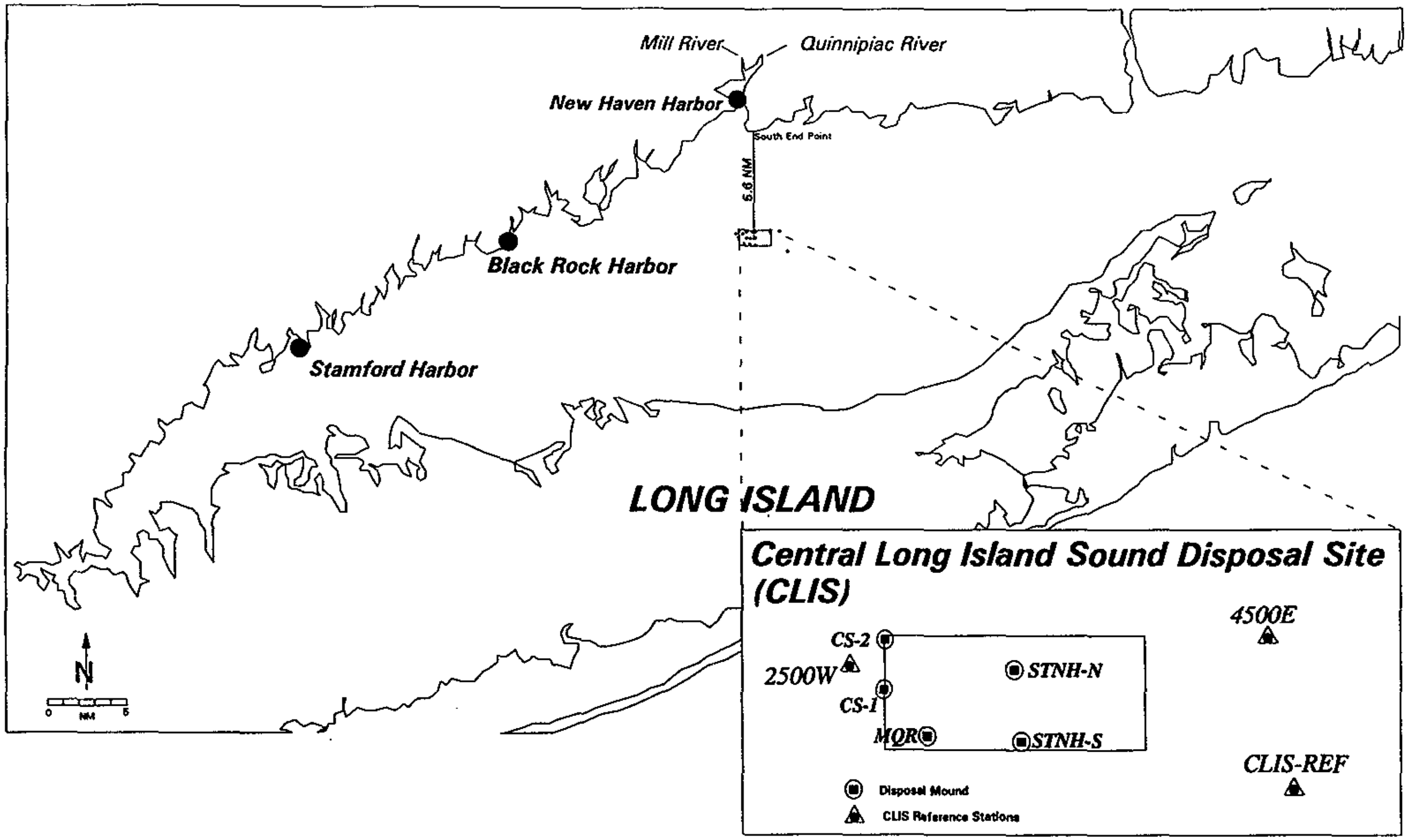


Figure 1-1. Long Island Sound and the Central Long Island Sound Disposal Site

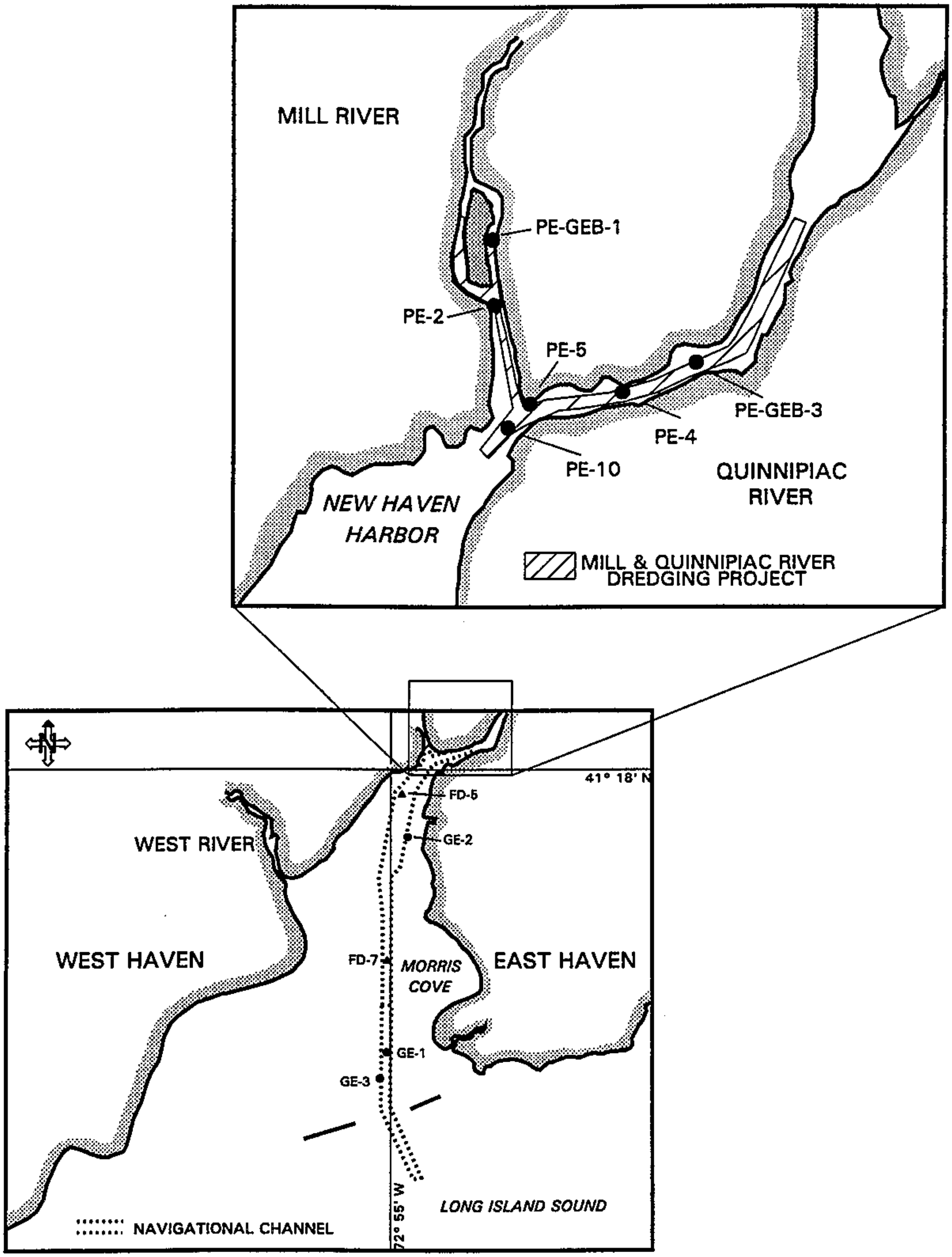


Figure 1-2. Mill and Quinnipiac Rivers with sample locations

Table 1-1

MQR Source Area Material Bulk Sediment Characteristics

Dredge Location: Sample ID*: Year Collected:	Mill River PE-1, PE-2 1980	Quinnipiac River PE-3, PE-4, PE-10 1980	Black Rock BR-1 to BR-37 1983	New Haven GE-1 to GE-3 FD-5, FD-7 1978
Liquid Limit	198 - 205	96 - 148	112 - 210	112 - 139
Plastic Limit	82 - 83	43 - 60	44 - 84	42 - 52
Plastic Index	103 - 115	53 - 88	32 - 142	69 - 87
% Solids	23 - 24	38.17 - 45.6	23.4 - 48.8	20.87 - 71.40
Sediment pH	6.7 - 7.0	6.4 - 7.2	7.0 - 7.6	6.8 - 7.5
% Volatile Solids NED	16.2 - 29.1	7.56 - 13	7.0 - 16.1	0.8 - 7.7
ppm Oil & Grease	10 - 500	2100 - 2410	8400 - 44,000	340 - 7740
ppm Mercury	2.4 - 4.1	1.8 - 2.9	0.12 - 1.41	0.25 - 0.74
ppm Lead	450 - 825	180 - 270	190 - 2200	38 - 210
ppm Zinc	625 - 1145	307 - 995	560 - 1180	41 - 472
ppm Arsenic	4	2 - 7	2.1 - 10.1	2.0 - 11.6
ppm Cadmium	200 - 260	330 - 490	7.5 - 58	0.1 - 7.0
ppm Chromium	NA	NA	NA	NA
ppm Copper	570 - 915	410 - 530	890 - 3400	59 - 367
ppm Nickel	89 - 95	85 - 94	50 - 250	25 - 87
ppm Vanadium	50 - 100	50 - 80	100 - 987	9 - 70

* Sampling Station Locations are shown in Figures 1-2,1-3, and 1-4.

NA = Not Available

Sediments to be dredged from the Quinnipiac River were geotechnically more stable, lacking the fibrous wood pulp component found in the Mill River sediments. However, they were only slightly less contaminated, with concentrations of mercury (Hg), lead (Pb), cadmium (Cd), and copper (Cu) still within the highly contaminated category of the New England River Basins Contaminated Sediment Classification (NERBC 1980; Table 1-2; Oceanic Society 1982). Laboratory bioassays and bioaccumulation studies of selected contaminants present in the dredging site materials showed minimal toxicity and uptake associated with exposure to either Mill or Quinnipiac River sediments (ERCO 1980a,b, ERCO 1981a,b). The Corps determined that open water disposal would be feasible only if the relatively mobile Mill River sediments were capped with the more stable Quinnipiac River materials.

Clamshell dredging of the Mill River began on 31 March 1982. Materials were transported by hopper barge to the MQR buoy. Water depths in this area ranged from 20 to 21 m. Barge logs indicated that approximately 42,000 m^3 of high water-content Mill River sediments were placed prior to the initiation of Quinnipiac River dredging. This latter operation, beginning in early May 1982 and completed prior to the first of June, resulted in the placement of approximately 133,200 m^3 of silts as a cap layer over the Mill River sediments. Dredged material volume estimates obtained by comparing bathymetric profiles before and after disposal of each unit disagreed substantially with the barge log values. Volume calculations based on depth differences were approximately 70,000 m^3 of sediment dredged from the Mill River and 190,000 m^3 from the Quinnipiac River (Morton et al. 1984a). The volume calculation data based on depth differences showed in-place volumes to be significantly larger than those detailed on the NED log. This in part may be a result of the unique textural quality of the disposed materials.

In late spring of 1983, the MQR mound received additional contaminated materials dredged from Black Rock Harbor near Bridgeport, Connecticut (Figure 1-3). Laboratory analyses of sediments from Black Rock Harbor indicated that the materials were predominantly classified as highly contaminated (NERBC 1980) with a variety of organic and inorganic compounds (Table 1-1; USACE 1982; Rogerson et al. 1985). Laboratory bioassays indicated that exposure to these materials had the potential to induce unacceptable mortalities in local biota (ERCO 1980c,d).

The results of the bulk chemical analyses and bioassays led to the determination that open water disposal of the Black Rock sediments should be followed by capping with cleaner materials to minimize biotic exposure and/or contaminant migration. To satisfy this requirement, NED proposed to cap the Black Rock Harbor sediments placed at the MQR mound with silts to be dredged from New Haven Harbor (Figure 1-4). Previous analyses had found these latter materials as containing generally moderate levels of the NERBC contaminants (Table 1-1; USACE 1978).

Table 1-2

New England River Basins Commission Sediment Classifications

	Low (ppm)	Moderate (ppm)	High (ppm)
As	<10	10-20	>20
Hg	<0.5	0.5-1.5	>1.5
Total PCBs	NA	NA	>1.0
DDT	NA	NA	>0.5
Pb	<100	100-200	>200
Cd	<3	3-7	>7
Cr	<100	100-300	>300
V	<75	75-125	>125
Zn	<200	200-400	>400
Ni	<50	50-100	>100
Cu	<200	200-400	>400

	Class I	Class II	Class III
% Oil & Grease	<0.2	0.2-0.75	>0.75
% Volatile Solids	<5.0	5-10	>10
% Fines (silt & clay)	<60	60-90	>90

From: NERBC 1980 NA = Not Available

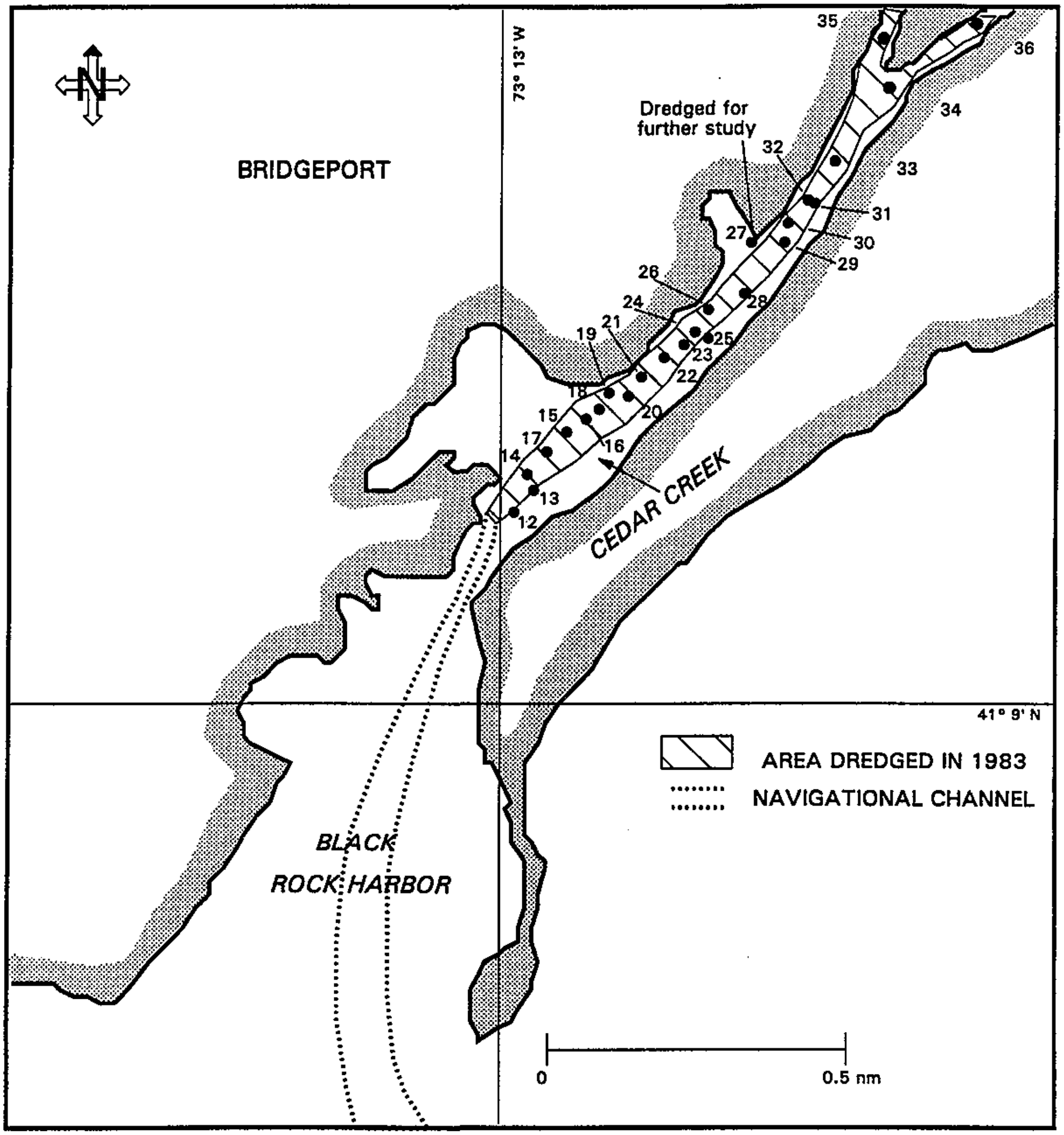


Figure 1-3. Black Rock Harbor, Connecticut with sample locations

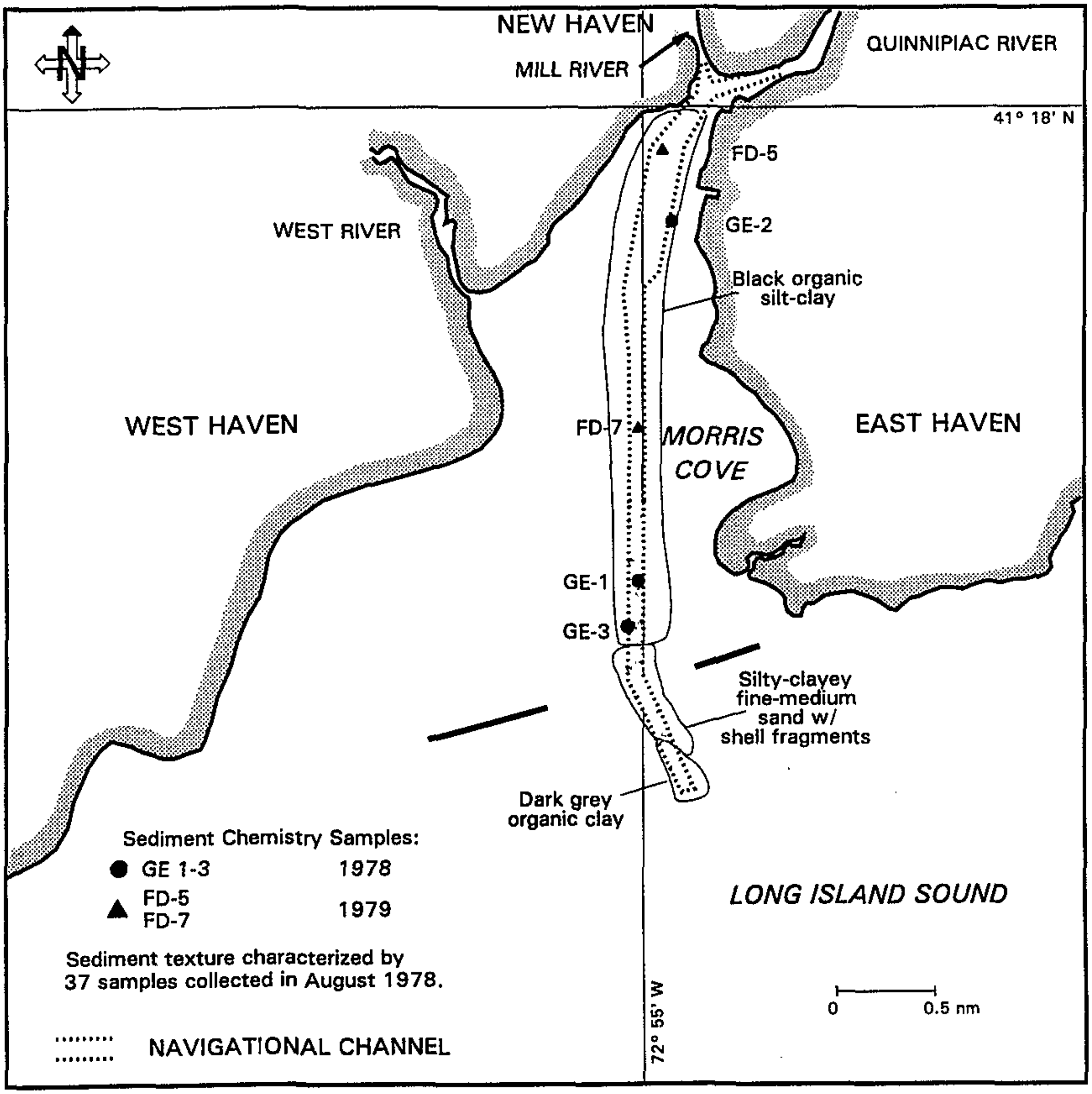


Figure 1-4. New Haven Harbor, Connecticut with sample locations

The periods of deposition of Black Rock and New Haven Harbor material overlapped to some extent (Figure 1-5). Clamshell dredging of Black Rock Harbor and subsequent disposal at MQR began on 9 March 1983 and continued through 18 April 1983. Dredging of New Haven Harbor began on 29 March 1983, and was completed on 17 May 1983 (Figure 1-5). Approximately 64,000 m^3 of Black Rock sediment was placed at the MQR mound and capped with approximately 400,000 m^3 of additional New Haven material. The majority of Black Rock material was disposed before New Haven. Subsequent to the final New Haven cap deposition, however, two barge loads of Black Rock material (approximately 3,000 m^3) were deposited at the MQR mound. This disposal sequence complicated evaluation of the project, and may have resulted in a thin layer of Black Rock material at the surface.

1.2 Biological Monitoring at MQR

Biological monitoring at MQR has included several REMOTS® surveys since deposition of the New Haven cap, body burden sampling and chemical analysis, and an amphipod bioassay. This sequence of events followed closely the recently adopted tiered approach to monitoring capped mounds (Germano et al. 1994). The observed amphipod bioassay toxicity prompted the coring operation.

A REMOTS® photographic survey of MQR in January 1983, following deposition of both Mill and Quinnipiac River sediments and prior to Black Rock/New Haven sediments, showed benthic conditions to be normal for a newly deposited disposal mound (Morton et al. 1984b). Stage I organisms dominated the surface area of the mound, and Organism-Sediment Index (OSI) values ranged between 4 and 11. Successional stages and the multiparameter OSI were used to characterize habitat disturbance. The parameters used to calculate OSI included the apparent depth of the oxygenated layer (redox potential depth, or RPD), the presence of methane, and the presence or absence of three successional stages of benthic organisms (SAIC 1988).

REMOTS® surveys at MQR in 1986, three years after deposition of the New Haven cap, continued to show a dominance of Stage I species on the three-year-old cap with OSI values ranging between 2 and 9 (SAIC 1990a). The 1987 survey indicated a continued dominance of Stage I organisms with Stage III beginning to appear at depth. Associated OSI values increased slightly but remained lower than those found concurrently at CLIS mounds Cap Site 1 and 2 (CS-1 and CS-2), formed during the same 1983 disposal season of Black Rock and New Haven Harbor sediments (SAIC 1990b).

The causes of the evident differences in recolonization rates at the MQR disposal mound were not clear. Because these differences were not apparent prior to the disposal of the Black Rock/New Haven materials, it seemed likely that the recolonization difficulties were related to this disposal operation. It also was hypothesized that seasonal hypoxic events in Central Long Island Sound may have contributed to the slow recovery of MQR (SAIC

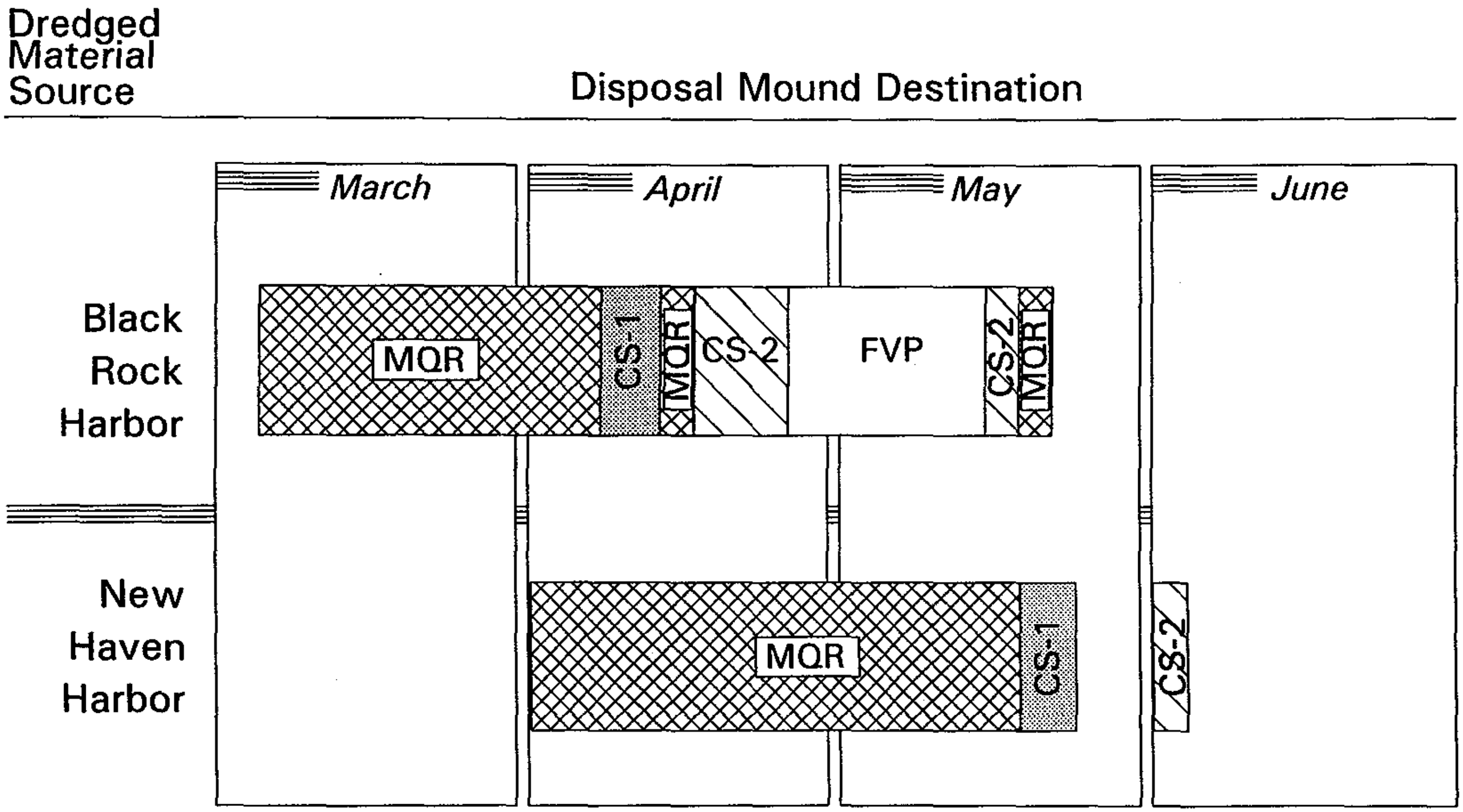


Figure 1-5. Disposal operations schedule, Black Rock and New Haven Harbors, Spring 1983

1989). Black Rock material was also disposed at the experimental Field Verification Program (FVP) mound during the spring of 1983. This mound was left uncapped as a comparison to the capped mound projects. The apparently healthy response of the uncapped FVP mound in comparison to MQR was especially anomalous (e.g., SAIC 1990b).

The 1987 MQR REMOTS® monitoring survey indicated that the mound, although recolonizing slower than mounds formed in the same time period, was beginning to show signs of normal recolonization. The 1991 CLIS monitoring cruise, however, which included a REMOTS® survey of the MQR mound, resulted in a completely different picture. Results of this cruise were to be used to test hypotheses and predictions formed as part of the DAMOS tiered monitoring and management protocols (Germano et al. 1994). Thirteen stations at MQR were located 100 m apart in a cross-shaped grid. In addition, three CLIS reference stations were sampled (2500W, 4500E, and CLIS REF).

Results from the 1991 survey indicated that the benthic recolonization at MQR had regressed since the previous 1987 sampling. The mean apparent RPDs at all of the MQR stations were anomalously shallow relative to the three reference stations (Table 1-3). The median OSI values were also significantly lower (Table 1-3). Evidence of Stage III species was found at all stations except 200N, 100E, and 200S. Stage III organisms were found at all stations at FVP in photographs taken during the same cruise (Wiley and Charles 1994).

In addition to REMOTS® monitoring, other biological monitoring data has been collected at MQR. As part of the normal CLIS monitoring cruise in August 1986, body burden concentrations of trace metals were measured in *Nephtys incisa* (Stage III species) collected at CLIS capped mounds (SAIC 1990a). At the MQR and FVP mounds, Cr, Cu, and Pb concentrations were elevated above reference values both in surface sediments and in the tissue of the polychaetes (Table 1-4).

The June 1991 monitoring cruise results triggered a management response according to the tiered approach to disposal mound monitoring (Germano et al. 1994). An amphipod bioassay was conducted to test the toxicity potential of the MQR sediments. The bioassay sample was collected during the same cruise as the sediment cores in August of 1991. One gallon of surface sediment was collected from near the center of the MQR mound for a 10-day amphipod bioassay. Following delivery of the MQR sediment, specimens of *Ampelisca* were collected and introduced into both the sediment collected from the MQR mound, and into a separate laboratory reference sediment. The test containers were monitored for ten days, and then counted for *Ampelisca* mortality rates. Percent survival rates for amphipods exposed to MQR sediments ranged from 10 to 45%, as compared with reference station survival rates which ranged from 75 to 100% (Table 1-5).

Table 1-3

Results of the June 1991 REMOTS® Survey of MQR

Site Name	Station Name	Mean Apparent RPD (cm)	Median OSI
2500W	CTR	2.2	8.5
4500E	CTR	2.5	6.0
CLIS REF	CTR	2.5	8.5
MQR	100E	1.0	2.0
MQR	100N	1.0	5.0
MQR	100S	0.7	2.0
MQR	100W	1.0	2.5
MQR	200E	0.8	-2.5
MQR	200N	1.0	1.0
MQR	200S	1.8	3.0
MQR	200W	0.7	-2.5
MQR	300E	2.0	1.5
MQR	300N	1.6	5.5
MQR	300S	1.4	6.0
MQR	300W	1.3	1.5
MQR	CTR	0.6	-1.0

Table 1-4

Trace Metals in Body Tissues of *Nephtys* Collected at CLIS, August 1986

	(ppm wet weight)							
Station	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Pb**	**Zn**
Reference 1	4.0	0.14	0.03	2.6	99	0.02	0.58	26
Reference 2	3.8	0.18	0.05	3.5	124	0.01	0.63	32
Reference 3	2.9	0.09	0.03	2.7	91	0.04	0.49	26
Mean	3.6	0.14	0.04	2.9	105	0.02	0.07	28
±STD	0.6	0.05	0.01	0.5	17	0.02	0.07	3
FVP 1	2.6	0.12	0.08	6.4	50	0.02	1.2	27
FVP 2	2.9	0.14	0.14	8.2	72	0.02	1.4	29
FVP 3	2.8	0.14	0.35	7.0	99	0.03	1.2	23
Mean	2.8	0.13	0.19	7.2	74	0.02	1.3	26
±STD	0.2	0.01	0.14	0.9	25	0.01	0.1	3
MQR 1	2.6	0.18	0.12	5.6	103	0.02	1.6	33
MQR 2	3.6	0.18	0.20	5.6	135	0.02	1.7	34
MQR 3	1.6	0.14	0.19	4.2	115	<0.008	1.6	29
Mean	2.6	0.17	0.17	5.1	118	---	1.6	32
±STD	1.0	0.02	0.04	0.8	16	---	0.1	3

-- = Not Applicable

Table 1-5

MQR Amphipod Bioassay Sediment Toxicity Results

Sample	No. Exposed	No. Survive	Percent Survival
Reference	20	19	95.0
Reference	20	20	100.0
Reference	20	19	95.0
Reference	20	15	75.0
Reference	20	18	90.0
MQR	20	2	10.0
MQR	20	9	45.0
MQR	20	9	45.0
MQR	20	6	30.0
MQR	20	5	25.0

Summary of the survival data for 10-day solid phase test with *Ampelisca abdita*.

Station	Percent Survival	Statistically Significant	Biologically Significant
Reference	91		
MQR	31	*	**

* Statistically significant reduction relative to the performance of the control. One way t-test, alpha = 0.05, n=5.

** Biologically significant: significant reduction relative to control and less than 80% of control response.

1.3 1991 Coring Operations

In response to continuing evidence suggesting unusually poor benthic habitat conditions at MQR, NED planned a sediment coring operation. The objective of the coring operation was to identify the cause of this unusual postdepositional response at MQR. In order to accomplish this, sediment cores were taken, described, and sampled. Upon the receipt of the negative bioassay results, core samples were analyzed by the NED laboratory for a variety of contaminants. The objective was to identify the contaminant(s) potentially responsible for the toxicity, and to make inferences about the causes of the retrograde benthic community conditions at MQR.

Historical data from MQR disposal operations were compiled for comparison with the new coring data. Data from samples taken from both the Mill and Quinnipiac Rivers before dredging operations (Figure 1-2), as well as from Black Rock and New Haven Harbors (Figures 1-3 and 1-4), were incorporated into the MQR database. Samples taken from the MQR mound following deposition of Mill River, Quinnipiac River, and after both Black Rock and New Haven Harbors were also included in the comparison.

2.0 METHODS

2.1 Sample Collection

Six cores were collected on 6 August 1991 on board the M/V *Beavertail* using a gravity corer and PVC core liner. All cores were successfully recovered, with only a loss of a few centimeters of material from the first core (MQR1). Cores were recovered as the vessel was positioned near the center of the mound.

After cores were recovered on deck, they were split with a handsaw, and PVC shavings were removed from the exterior of the core before sampling. The cores were described, photographed, and sampled. Because the top 1 m of MQR appeared homogenous, samples were taken at the surface, at 30 and 100 cm, and above and below distinctive visual boundaries between lithologic intervals. Sediment was sampled using teflon-coated utensils rinsed in sea water and distilled water, and placed in 250 ml I-Chem precleaned glass jars for chemical analysis. Another subsample of sediment was placed in plastic bags for grain size analysis. Samples were stored in ice chests at approximately 4° C and delivered to the NED laboratory.

Sediment samples were delivered to the NED laboratory on 9 August 1991. The samples were stored refrigerated until the time of analysis. Core samples were analyzed for grain size using ASTM methods (Table 2-1); pesticides, polychlorinated biphenyls (PCBs), priority pollutant metals, and polynuclear aromatic hydrocarbons (PAHs) according to EPA protocols (Table 2-1).

Following the August MQR coring survey, additional surface grab samples were taken on 17 December 1991. Samples were collected on board the R/V *UCONN* using a 0.1 m^2 teflon-coated Van Veen grab sampler. Five separate grab samples were taken near the center of the MQR mound. Subsamples were taken with teflon-coated utensils from approximately the top 2 cm of the grab sampler. No sediment in contact with the surfaces of the grab was included as part of the sample. All utensils in contact with sediment samples were rinsed with methanol or isopropanol, distilled water, and sea water between each grab sample. Sediment for volatile organics and metals analyses were placed in one precleaned I-Chem 250 ml glass jar to be stored frozen. Sediment for semivolatile analyses were placed in another 250 ml glass jar to be stored refrigerated before analysis. Grain size samples were stored in plastic bags. Samples were stored in ice chests at approximately 4° C before delivery to the NED laboratory. Sediment surface samples were delivered to NED on 18 December 1991. Surface samples were analyzed for volatile organic compounds (VOCs) using EPA methods (Table 2-1) on 30 December 1991.

Table 2-1

Methods Used for Analysis of MQR Core and Surface Grab Samples

Analysis	**EPA Method**	**Instrumentation**
Sediment Samples		
PCBs	3540/8080	GC/MS
Pesticides	3540/8080	GC/MS
Priority Pollutant Metals:		
Antimony	3051/7060	ICP
Arsenic	3051/6010	GFAA
Beryllium	3051/6010	ICP
Cadmium	3051/6010	ICP
Chromium	3051/6010	ICP
Copper	3051/6010	ICP
Lead	3051/7421	GFAA
Mercury	7470	CVAA
Nickel	3051/6010	ICP
Selenium	3051/7740	GFAA
Silver	3051/6010	ICP
Thallium	3051/7841	GFAA
Zinc	3051/6010	ICP
Volatile Organics	8240	GC/MS
Polynuclear Aromatic Hydrocarbons	3540/8270	GC/MS

GC/MS = Gas Chromatograph/Mass Spectrometer
ICP = Inductively Coupled Argon Plasma Emission Spectrometry
GFAA = Graphite Furnace Atomic Absorption
CVAA = Cold Vapor Atomic Absorption

2.2 Laboratory Analyses

The final and complete data report dated 23 June 1992 included a case summary, sample and quality control (QC) data, chains-of-custody, and a Quality Assurance (QA) Review. Laboratory data included both physical (grain size) and chemical (organic and inorganic) analyses.

2.2.1 Physical Analyses

Physical analyses were performed on all of the MQR core samples. The NED laboratory physical analyses included visual classification, specific gravity, and grain size analysis (sieve and hydrometer) using ASTM Method D-422 (ASTM 1990). Samples were analyzed in the same manner as CLIS reference stations samples taken in June of 1991 (Wiley and Charles 1994). The >62.5 μm (sand and gravel) fraction was separated by sieving, and the <62.5μm fraction (silt and clay) was separated by particle settling. Grain size curves were prepared from the grain size test data. The fractional components (gravel, sand, silt, and clay) were determined and reported as percentages.

2.2.2 Chemical Analyses

Chemical results were evaluated on the basis of completeness, precision, and accuracy. Samples that were considered to be of the highest priority from lithological descriptions were analyzed for the specified constituents. Precision and accuracy were evaluated by the laboratory by analyzing several QC samples with each method.

Data were assessed using protocols developed by the Environmental Protection Agency (EPA; method-specific references are included in the discussion below). Data qualifiers were assigned to the data when necessary. No data were rejected based on quality analysis. The qualifiers "J" and "UJ" were assigned to detected and undetected results, respectively, as described below.

According to the QA Review submitted by the NED laboratory, holding times were exceeded (as discussed below) because of the time delay in the decision process to determine what analyses were required, confirming a potential negative bias of the data. Data qualified due to exceeded holding times should be considered minimum values because of the potential loss/degradation of contaminant constituents.

2.2.2.1 Pesticide and Total PCB Analyses

Pesticides and PCBs were analyzed using EPA protocols (EPA 1986). Twenty-three marine sediment samples were analyzed, with three accompanying QC samples: a method blank, a blank spike, and a blank spike duplicate sample. Sample data were evaluated using protocols developed by the EPA Contract Laboratory Program (CLP; EPA 1988a).

Samples analyzed for pesticides were extracted 146 days after sample collection, and analyzed 79 days after sample extraction. Samples analyzed for total PCBs were extracted 146 days after sample collection, and analyzed 50 days after sample extraction (Table 2-2). EPA guidelines suggest maximum holding times for pesticide and PCB samples of 14 days from sampling to extraction, and 40 days from extraction to analysis. Due to these excessive holding times, the pesticide and PCB data were qualified as estimated, and given the qualifier code J for detected values and UJ for undetected values.

Each sample analyzed for pesticides was spiked with two system monitoring compounds, or surrogates (dibutyl chlorendate and TCMX). Surrogate QC samples were analyzed as a check on the laboratory's ability to extract known concentrations of compounds not found normally in the sample, and were a measure of laboratory accuracy. Three pesticide samples (MQR2-E, MQR5-A, and MQR6-A) had low TCMX recoveries, and the method blank had a very low dibutyl chlorendate recovery (9%). Since all of the pesticide samples had already been qualified, no further qualifications were necessary. Every PCB sample was also spiked with one surrogate compound (TCMX). One sample exceeded control limits for TCMX recovery (MQR5-A); since this sample had already been qualified, no further qualification was necessary.

The pesticide and the PCB method blanks were both below detection for all compounds, indicating no laboratory contamination problem. A blank spike and a blank spike duplicate sample were analyzed for both total PCBs and pesticides as an indication of laboratory accuracy and precision. Accuracy was evaluated by calculating the recovery of the spiked compound in the blank. Precision was evaluated by calculating the relative percent difference (RPD) between blank spike duplicate samples.

Recoveries of total PCBs for both blank spikes were within control limits. Pesticide blank duplicate samples were spiked with five pesticide compounds: lindane, heptachlor, aldrin, dieldrin, endrin, and 4,4'-DDT. Only one recovery of aldrin (124%) in one blank spike sample was above control limits (120%). Accuracy of both pesticide and PCB data was considered acceptable. Precision of both pesticide and PCB data was good; all RPDs were less than 20%.

Sample MQR5-E resulted in a very high concentration of total PCBs (31 ppm); this result was investigated and confirmed by the NED laboratory. Except for the exceeded holding times, all pesticide and PCB data were considered acceptable.

Table 2-2

Holding Times Summary

Sample Name	Sample Date	Pesticides				Total PCBs				Semivolatiles				Volatiles		Metals*		Hg	
		DOE	HT(1)	DOA	HT(2)	DOE	HT(1)	DOA	HT(2)	DOE	HT(1)	DOA	HT(2)	DOA	HT(3)	DOA	HT(1)	DOA	HT(1)
Core Data																			
MQR1-E	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/30/92	28			02/03/92	181	01/30/92	177
MQR2-A	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/30/92	28			02/03/92	181	01/30/92	177
MQR2-B	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/30/92	28			02/03/92	181	01/30/92	177
MQR2-C	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	01/31/92	22			02/03/92	181	01/30/92	177
MQR2-D	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/31/92	29			02/03/92	181	01/30/92	177
MQR2-E	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/16/92	14			02/03/92	181	01/30/92	177
MQR3-A	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	01/31/92	22			02/03/92	181	01/30/92	177
MQR3-B	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/16/92	14			02/03/92	181	01/30/92	177
MQR3-C	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/16/92	14			02/03/92	181	01/30/92	177
MQR3-D	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/31/92	29			02/03/92	181	01/30/92	177
MQR3-E	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/31/92	29			02/03/92	181	01/30/92	177
MQR3-F	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/31/92	29			02/03/92	181	01/30/92	177
MQR5-A	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/16/92	14			02/03/92	181	01/30/92	177
MQR5-B	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/02/92	149	01/31/92	29			02/03/92	181	01/30/92	177
MQR5-C	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	01/31/92	22			02/03/92	181	01/30/92	177
MQR5-D	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	01/31/92	22			02/03/92	181	01/30/92	177
MQR5-E	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	02/03/92	25			02/03/92	181	01/30/92	177
MQR6-A	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	01/16/92	7			02/03/92	181	01/30/92	177
MQR6-B	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	01/31/92	22			02/03/92	181	01/30/92	177
MQR6-C	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	01/31/92	22			02/03/92	181	01/30/92	177
MQR6-D	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	01/31/92	22			02/03/92	181	01/30/92	177
MQR6-E	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	01/16/92	7			02/03/92	181	01/30/92	177
Surface Data																			
MQR-SFC	08/06/91	12/30/91	146	03/18/92	79	12/30/91	146	02/18/92	50	01/09/92	156	01/31/92	22			02/03/92	181	01/30/92	177
MQR1-CTR	12/17/91													12/30/91	13				
MQR2-CTR	12/17/91													12/30/91	13				
MQR3-CTR	12/17/91													12/30/91	13				
MQR4-CTR	12/17/91													12/30/91	13				
MQR5-CTR	12/17/91													12/30/91	13				

*Dates given are supplied by laboratory for date extracted; date analyzed was given as "2/31/92".
DOE = Date of Extraction; DOA = Date of Analysis
HT(1) = Time elapsed (days) between sample collection and sample extraction.
HT(2) = Time elapsed (days) between sample extraction and sample analysis.
HT(3) = Time elapsed (days) between sample collection and sample analysis (when no extraction is required).

2.2.2.2 Priority Pollutant Metal Analyses

Twenty-three marine sediment samples were analyzed for priority pollutant metals. Antimony (Sb), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), silver (Ag), and zinc (Zn) were analyzed by inductively coupled argon plasma emission spectrophotometry (ICP). Arsenic (As), lead (Pb), selenium (Se), and thallium (Tl) were analyzed by graphite furnace atomic adsorption techniques (GFAA). Mercury (Hg) was analyzed using cold vapor atomic adsorption (CVAA); all metals were analyzed using standard EPA procedures (Table 2-1; EPA 1986). Three QC samples were analyzed with the samples: a method blank, a blank spike, and a blank spike duplicate sample. Sample data were evaluated using protocols developed by the EPA CLP (EPA 1988b).

Samples analyzed for all metals except for Hg were digested 181 days after sample collection, and analysis was conducted approximately 28 days later (Table 2-2). Mercury samples were digested 177 days after sampling and analyzed the following day. EPA guidelines suggest a maximum holding time for metals analyses of 6 months, and 28 days for Hg. Due to the excessive holding time for the Hg samples, Hg results were qualified as estimated, and given the qualifier code J for detected values and UJ for undetected values.

The metals sample method blank was below detection for all metals except for Zn (4.3 ppm). All samples contained zinc in concentrations greater than 5 times the concentration detected in the method blank, so no qualifications were necessary (EPA 1988b).

A blank spike and a blank spike duplicate sample were analyzed for metals as an evaluation of laboratory accuracy and precision. All spike recoveries were well within control limits (84-105%) except for one duplicate spike recovery of Ag. Precision, also, was acceptable as all RPDs were $<10\%$ except for the silver duplicate RPD. Because of the low recovery of one Ag sample, all non-detects of Ag were qualified as estimated, and assigned a qualifier of UJ. The laboratory stated in the Quality Assurance Review that the low silver recovery is being investigated. The accuracy and precision of all metals data except for Ag were considered acceptable.

2.2.2.3 Polynuclear Aromatic Hydrocarbon (PAH) Analyses

PAHs were analyzed using EPA protocols. Twenty-three marine sediment samples were analyzed with four accompanying QC samples: a method blank, a standard reference material (SRM) sample, a blank spike, and a blank spike duplicate sample. Sample data were evaluated using protocols developed by the EPA (EPA 1988a).

Samples analyzed for PAHs were extracted 149-156 days after sample collection, and analyzed 7-29 days after sample extraction. EPA guidelines suggest maximum holding times for PAH samples of 14 days from sampling to extraction, and 40 days from extraction to analysis (EPA 1988a). All of the PAH data were qualified as estimated (J/UJ) for exceeded extraction holding times (Table 2-2).

Each sample analyzed for PAHs was spiked with three surrogate compounds (2-fluorobiphenyl, nitrobenzene-D_5, and terphenyl-D_{14}) as a measure of accuracy. All PAH surrogate recoveries were within acceptance limits except for two high recoveries of nitrobenzene-D_5 and terphenyl-D_{14} in sample MQR5-E, and one high recovery of terphenyl-D_{14} in sample MQR-6C. The PAH concentrations in MQR5-E were high; the high surrogate recoveries were potentially caused by matrix interference. Since all data were already qualified for holding time violations, no data were qualified based on these surrogate recoveries.

The PAH method blank sample results were below the practical quantitation limit (PQL) for all compounds. Three estimated compounds were below the PQL but above the detection limit: benzo(a)anthracene (0.19 ppm), chrysene (0.063 ppm), and phenanthrene (0.075 ppm). Since the samples were already qualified for exceeded holding times, again no further qualifications were necessary.

Accuracy of the PAH results was evaluated based on the results of standard reference material (SRM) and the blank spike results. The SRM data contained one high recovery of naphthalene and one low recovery of fluoranthene. Once more, no additional qualifications were necessary. The laboratory stated in the Quality Assurance Review that the cause of these results is being investigated. The other PAH compounds were recovered within acceptable ranges. A blank spike and a blank spike duplicate sample were analyzed for two PAH compounds (acenaphthene and pyrene). All recoveries were within limits, indicating acceptable data accuracy. The RPDs of the duplicate spike samples were also within acceptable ranges, indicating acceptable PAH data precision.

Relatively high concentrations of PAHs detected in MQR3-F and MQR5-E were investigated by the laboratory and confirmed. These two samples were diluted to obtain results for several compounds. Other than the qualifications due to exceeded holding times, the data are considered acceptably accurate and precise.

2.2.2.4 Volatile Organic Analyses

Volatile organic compounds (VOCs) were analyzed using EPA protocols (EPA 1986). Five marine sediment samples were analyzed with three accompanying QC samples: a method blank, a blank spike, and a blank spike duplicate sample. Sample data were evaluated using protocols developed by the EPA (EPA 1988a).

Samples analyzed for VOCs were analyzed 13 days after sample collection. EPA guidelines suggest maximum holding times for VOC samples of 14 days (EPA 1988a). No data were qualified for exceeded holding times.

Each sample analyzed for VOCs was spiked with three surrogate compounds (1,2-dichloroethane-d_4, toluene-d_8, and 4-bromofluorobenzene [BFB]) as a measure of accuracy. All BFB recoveries were within acceptance limits. Two samples and the method blank had unacceptably high recoveries of 1,2-dichloroethane-d_4, and one sample had an unacceptably low recovery of toluene-d_8. Because of the high recoveries of 1,2-dichloroethane-d_4 in two samples and the method blank, detected volatile data in samples MQR1-CTR and MQR2-CTR were qualified as estimated (J); the undetected volatile data in sample MQR4-CTR were qualified UJ.

The VOC method blank sample results were below detection for all compounds; therefore, there was no concern about laboratory contamination of the samples. A blank spike and a blank spike duplicate sample were analyzed for five VOC compounds (1,1-dichloroethene [1,1-DCE], benzene, trichloroethene, toluene, and chlorobenzene). One recovery of 1,1-DCE in one blank spike sample was below control limits (54%, under a lower limit of 59%). The RPD of the 1,1-DCE analyses was also unacceptably high due to this one low recovery. No data were qualified based on the low spike recovery.

Acetone was detected in every sample; concentrations were above the upper calibration limit in samples MQR1-CTR, MQR3-CTR, and MQR4-CTR and below the practical quantitation limit (PQL) in samples MQR2-CTR and MQR5-CTR. The values out of the calibration range were qualified as estimated (J); those below the PQL were already qualified by the laboratory.

3.0 RESULTS

3.1 Sediment Core Descriptions

Cores were photographed and described in the field notebook. After the cruise, core descriptions were transcribed and redrawn for interpretation (Figures 3-1, 3-2, and 3-3). The most commonly described lithology was "black silty clayey mud" which was present in the top 1-1.5 meters of every core. Discrete sandy intervals, often in thin layers, were present in all of the cores. Organic remnants (plant fragments) and small clasts (shells, pebbles) were also present in discrete intervals in all of the cores. Material which closely resembled ambient Central Long Island Sound sediment (olive grey-green with burrows) was described at the base of MQR1 and MQR6 (Figures 3-1 and 3-3). The implications of the recovery of ambient material is discussed below (Section 4.1). A strong hydrocarbon smell and spots of oil sheen were noted in the descriptions for all of the cores except MQR1.

3.2 Grain Size Results

Samples from all six MQR cores were analyzed for grain size (Table 3-1). Generally, silt was the dominant grain size, followed by clay, and then by sand. Silt content ranged from 21.9 to 87.8%, clay from 9.3 to 44.9%, and sand from 2.5 to 61.9% (Table 3-1). Sand constituted <10% of more than half of the samples (18 out of 33). However, several samples contained relatively high sand content (>50%), generally deeper in the cores (Figure 3-4).

3.3 Chemistry Results

Samples from four of the six MQR cores were analyzed for pesticides/PCBs, metals, and PAHs. All of the surface samples collected in December 1991 were analyzed for volatile organics.

3.3.1 Pesticide/PCB Results

Total PCBs were detected in every sample, with concentrations ranging from 0.012 to 2.2 ppm, except for one high value (31 ppm) in sample MQR5-E (Table 3-2; Figure 3-5). The very high detection of 31 ppm was confirmed by the laboratory. Samples taken from the upper meter of all of the cores had generally the lowest total PCB concentrations (<0.35 ppm; Figure 3-5). The lowest total PCBs value, however, was measured in the deepest sample of MQR-6 (0.013 ppm).

The PCB results from MQR were compared with the NERBC sediment classification (Table 1-2), and samples collected previously through the DAMOS Program. All but two sample results were lower than the NERBC highly contaminated category (>1 ppm; NERBC

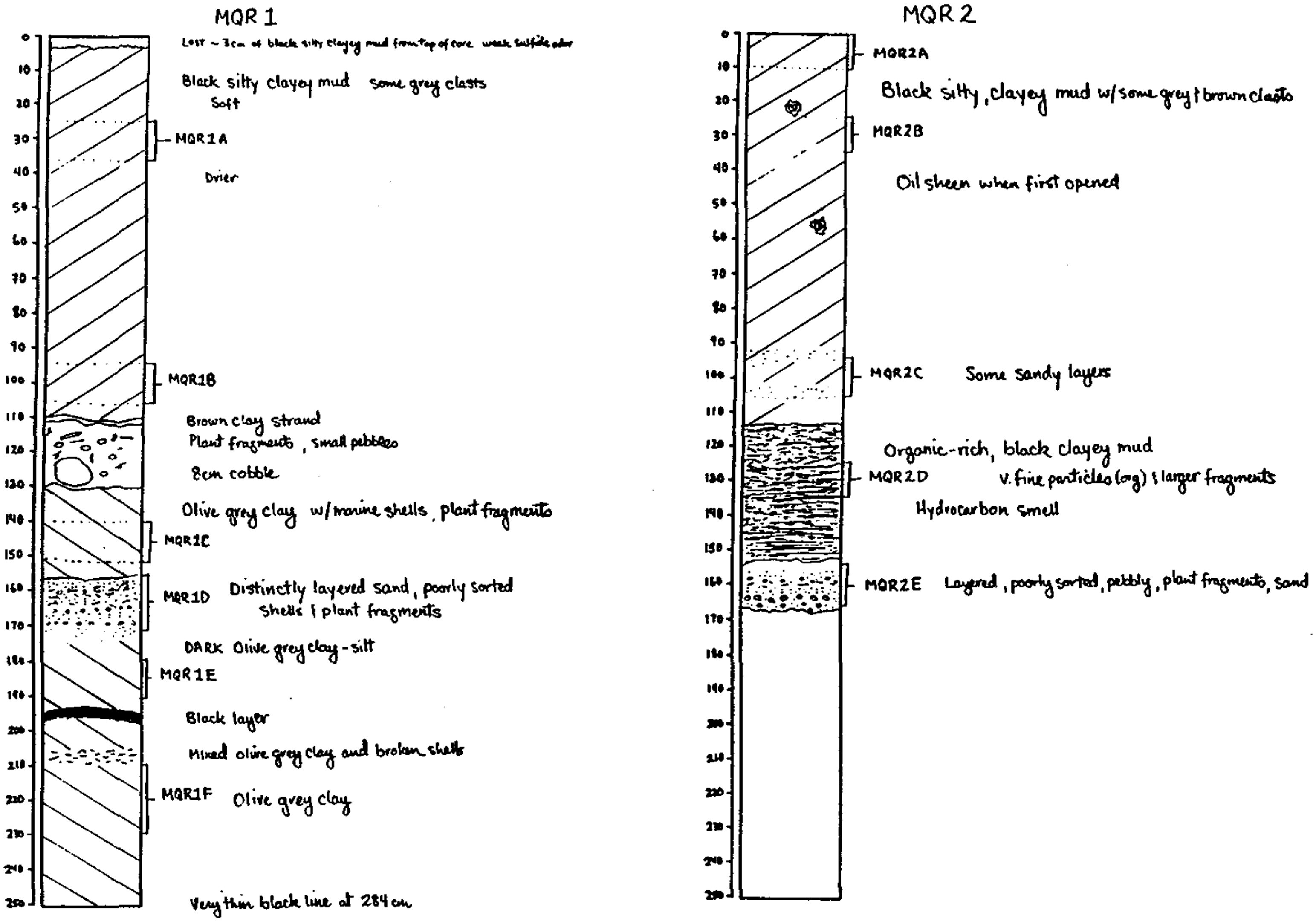


Figure 3-1. Core descriptions compiled from field log for cores MQR1 and MQR2

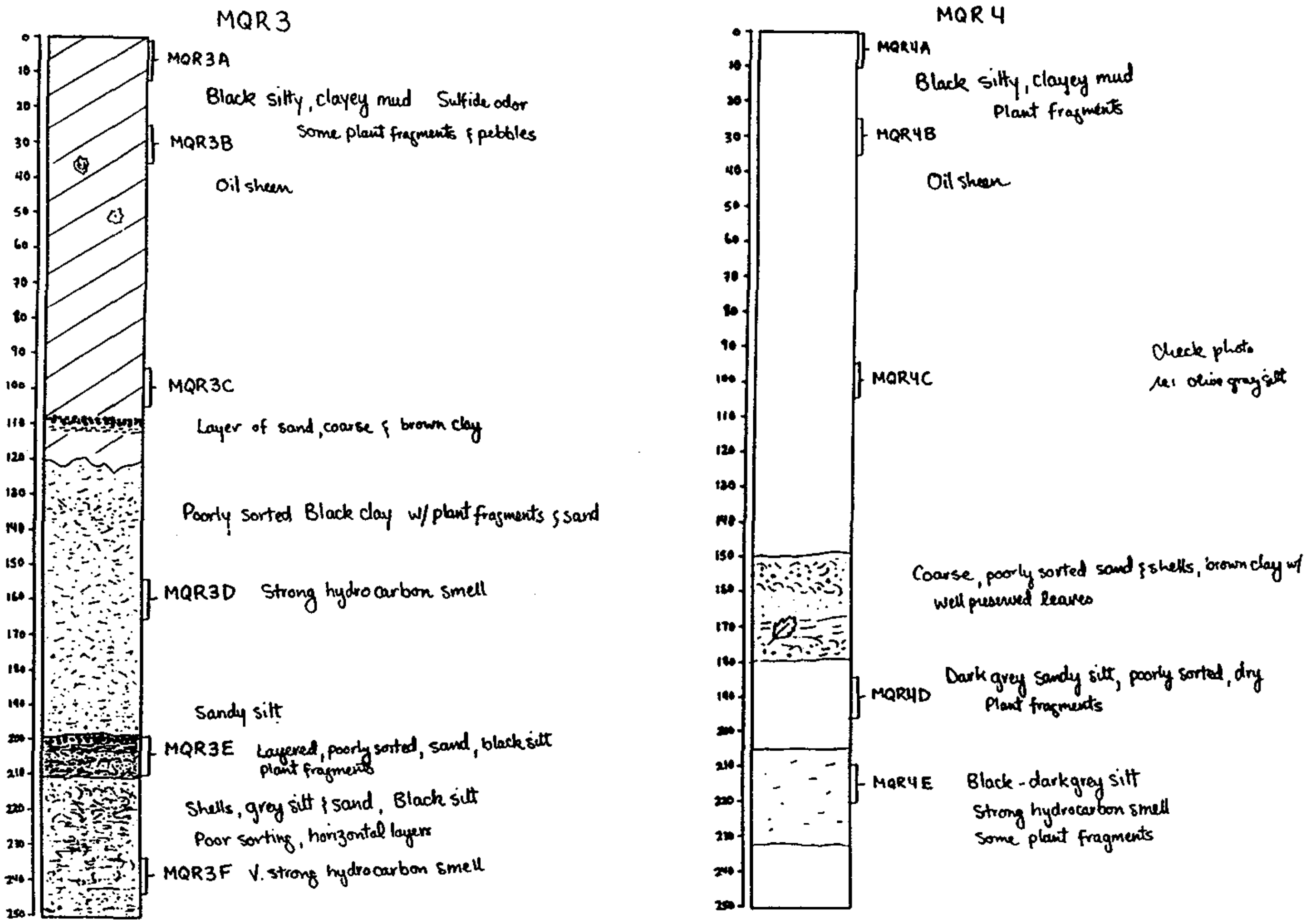


Figure 3-2. Core descriptions compiled from field log for cores MQR3 and MQR4

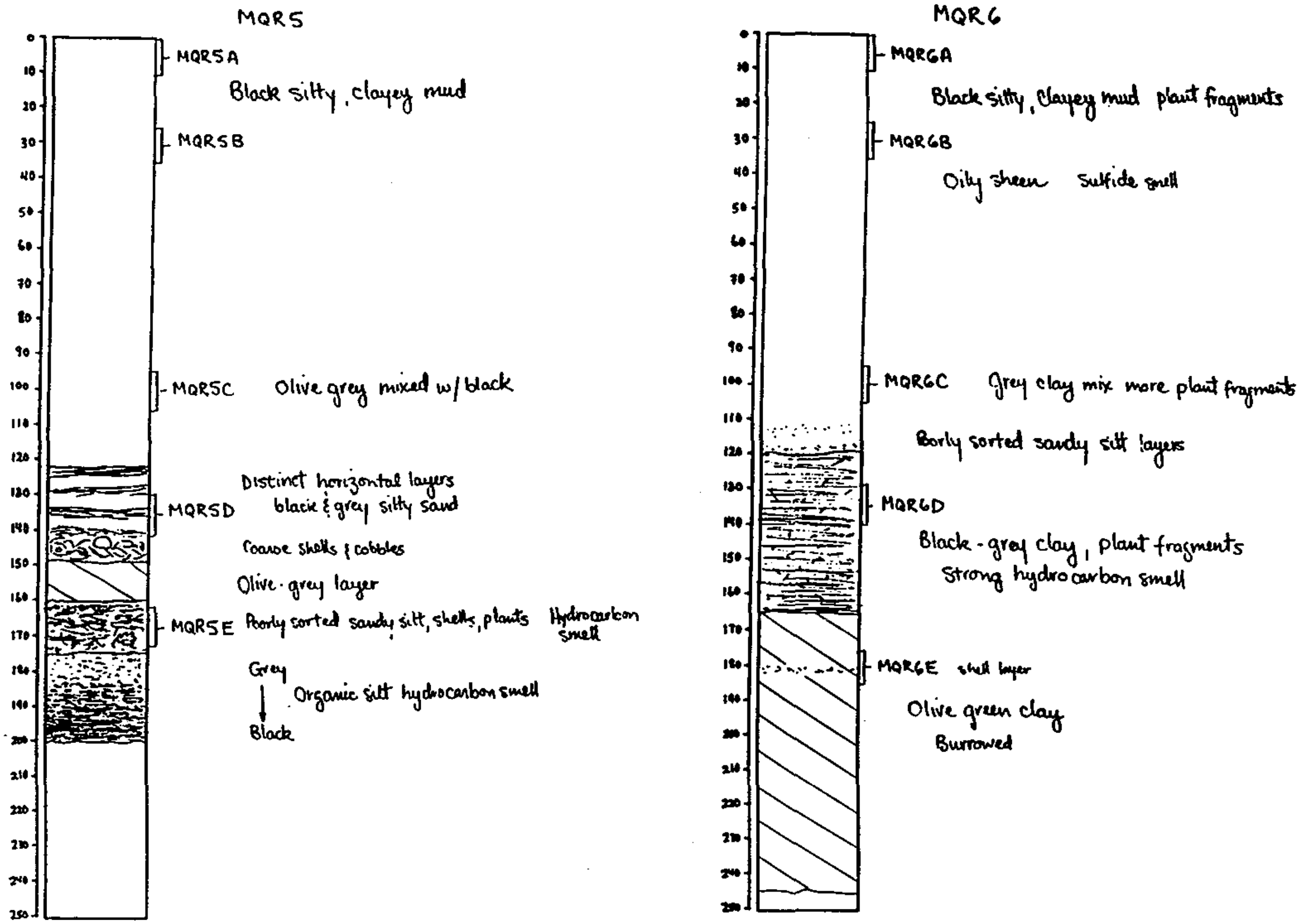


Figure 3-3. Core descriptions compiled from field log for cores MQR5 and MQR6

Table 3-1

Grain Size Results

Sample Name	Date Sampled	Interval Sampled Top (cm)	Bottom (cm)	Silt (%)	Clay (%)	Sand (%)
Core Data						
MQR1-A	06-Aug-91	25	35	73.3	19.8	6.9
MQR1-B	06-Aug-91	95	105	73.2	20.5	6.3
MQR1-C	06-Aug-91	140	150	49.7	44.9	5.4
MQR1-D	06-Aug-91	160	170	25.1	13.1	61.9
MQR1-E	06-Aug-91	180	190	69.1	26.4	4.4
MQR1-F	06-Aug-91	210	230	56.5	41	2.5
MQR2-A	06-Aug-91	0	10	87.8	9.3	2.9
MQR2-B	06-Aug-91	25	35	75.7	20.8	3.4
MQR2-C	06-Aug-91	95	105	45.5	29.4	25.1
MQR2-D	06-Aug-91	125	135	75.9	17.7	6.4
MQR2-E	06-Aug-91	155	165	27.3	19.1	53.7
MQR3-A	06-Aug-91	0	10	75.2	16.5	8.3
MQR3-B	06-Aug-91	25	35	68.5	27.6	3.9
MQR3-C	06-Aug-91	95	105	55.6	26.4	18
MQR3-D	06-Aug-91	155	165	52.4	29.9	17.6
MQR3-E	06-Aug-91	200	210	37.5	20.1	42.4
MQR3-F	06-Aug-91	235	245	25.9	16	58.1
MQR4-A	06-Aug-91	0	10	63.5	30.9	5.6
MQR4-B	06-Aug-91	25	35	55.3	38.2	6.5
MQR4-C	06-Aug-91	95	105	35.9	27.5	36.6
MQR4-D	06-Aug-91	185	195	47.2	24.4	28.4
MQR4-E	06-Aug-91	206	233	57.7	26.9	15.4
MQR5-A	06-Aug-91	0	10	44.8	43.1	12.1
MQR5-B	06-Aug-91	25	35	37.2	34.1	28.7
MQR5-C	06-Aug-91	95	105	48.6	42.5	8.9
MQR5-D	06-Aug-91	123	149	25.2	20	54.8
MQR5-E	06-Aug-91	161	175	21.9	14.1	64
MQR6-A	06-Aug-91	0	10	55.9	38.2	5.9
MQR6-B	06-Aug-91	25	35	54.5	42.3	3.3
MQR6-C	06-Aug-91	95	105	36.4	29.8	33.8
MQR6-D	06-Aug-91	120	165	54.9	36.8	8.3
MQR6-E	06-Aug-91	175	185	62.2	34.5	3.3
Surface Data						
MQR-SFC	17-Dec-91	0	0	50.6	34.8	14.7
CLIS REF	June 1991	0	0	57.4	29.5	13.1
2500W	June 1991	0	0	51.1	35.5	13.4
4500E	June 1991	0	0	59.1	29.5	11.4

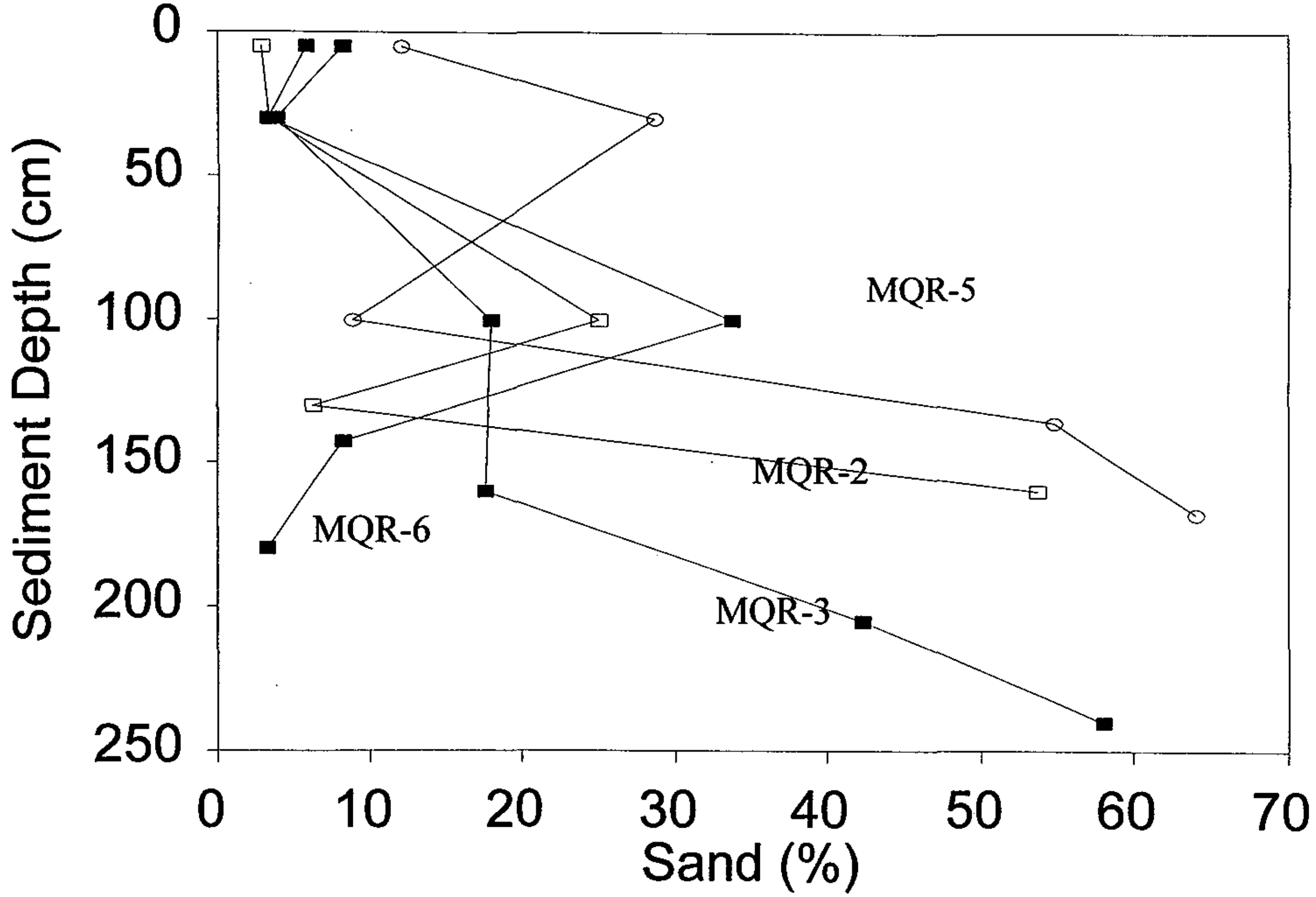


Figure 3-4. Sand percentage of samples from four MQR cores as a function of depth in the core

Table 3-2

Pesticide and PCB Results

Sample Name	Total PCBs (ppb)	Pesticides (ppb)							
		Alpha-B	Lindan	Beta-BHC	Heptachlor	Delta-BHC	Aldrin	Heptachlor Epoxide	Endosulfan I
Core Data									
MQR1-E	12	<5.4	<5.4	<5.4	<5.4	<5.4	<5.4	<5.4	<5.4
MQR2-A	120	<8.0	<8.0	<8.0	<8.0	<8.0	<8.0	<8.0	<8.0
MQR2-B	78	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1
MQR2-C	57	<6.3	<6.3	<6.3	<6.3	<6.3	<6.3	<6.3	<6.3
MQR2-D	240	<8.8	31	<8.8	<8.8	<8.8	<8.8	<8.8	<8.8
MQR2-E	180	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1
MQR3-A	180	<8.9	<8.9	<8.9	<8.9	<8.9	<8.9	<8.9	<8.9
MQR3-B	110	<7.9	<7.9	<7.9	<7.9	<7.9	<7.9	<7.9	<7.9
MQR3-C	96	<6.2	63	<6.2	<6.2	<6.2	<6.2	<6.2	<6.2
MQR3-D	560	<7.8	<7.8	<7.8	<7.8	<7.8	<7.8	<7.8	<7.8
MQR3-E	2200	<5.8	<5.8	<5.8	<5.8	<5.8	<5.8	<5.8	<5.8
MQR3-F	920	<6.8	<6.8	<6.8	<6.8	<6.8	<6.8	<6.8	<6.8
MQR5-A	110	<7.8	<7.8	<7.8	<7.8	<7.8	<7.8	<7.8	<7.8
MQR5-B	61	<5.5	<5.5	<5.5	<5.5	<5.5	<5.5	<5.5	<5.5
MQR5-C	130	<6.8	31	<6.8	<6.8	<6.8	<6.8	<6.8	<6.8
MQR5-D	490	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3
MQR5-E	31000	<5.8	<5.8	<5.8	<5.8	<5.8	<5.8	<5.8	<5.8
MQR6-A	190	<8.6	<8.6	<8.6	<8.6	<8.6	<8.6	<8.6	<8.6
MQR6-B	200	<8.3	<8.3	<8.3	<8.3	<8.3	<8.3	<8.3	<8.3
MQR6-C	350	<5.1	<5.1	<5.1	<5.1	<5.1	<5.1	<5.1	<5.1
MQR6-D	830	<7.6	<7.6	<7.6	<7.6	<7.6	<7.6	<7.6	<7.6
MQR6-E	13	<5.4	<5.4	<5.4	<5.4	<5.4	<5.4	<5.4	<5.4
Surface Data									
MQR-SFC	150	<5.9	19	<5.9	<5.9	<5.9	<5.9	<5.9	<5.9

Data below detection is reported as less than (<) the detection limit.

All data qualified as J-H (detected) and UJ-H (below detection) for holding time violation (see page 19)

Table 3-2 (cont.)

Sample Name	Pesticides (ppb)								
	4,4'-DDE	Dieldrin	Endrin	4,4'-DDD	Endosulfan II	4,4'-DDT	Endrin Aldehyde	Endosulfan Sulfate	Methoxychlor
Core Data									
MQR1-E	<11	<11	<11	<11	<11	<11	<11	<11	<54
MQR2-A	<16	<16	<16	20	<16	20	<16	<16	<80
MQR2-B	<14	<14	<14	<14	<14	<14	<14	<14	<71
MQR2-C	<13	<13	<13	<13	<13	<13	<13	<13	<63
MQR2-D	<18	<18	<18	<18	<18	<18	<18	<18	<88
MQR2-E	<8.3	<8.3	<8.3	<8.3	<8.3	<8.3	<8.3	<8.3	<41
MQR3-A	<18	<18	<18	<18	<18	<18	<18	<18	<89
MQR3-B	<16	<16	<16	19	<16	20	<16	<16	<79
MQR3-C	<12	<12	<12	<12	<12	43	<12	<12	<62
MQR3-D	<16	<16	<16	<16	<16	23	<16	<16	<78
MQR3-E	<12	<12	<12	<12	<12	<12	<12	<12	<58
MQR3-F	<14	<14	<14	<14	<14	<14	<14	<14	<68
MQR5-A	<16	<16	<16	<16	<16	20	<16	<16	<78
MQR5-B	<11	<11	<11	<11	<11	13	<11	<11	<55
MQR5-C	<14	<14	<14	<14	<14	<14	<14	<14	<68
MQR5-D	<11	<11	<11	<11	<11	<11	<11	<11	<53
MQR5-E	<12	<12	<12	<12	<12	<12	<12	<12	<58
MQR6-A	<17	<17	<17	<17	<17	21	<17	<17	<86
MQR6-B	<17	<17	<17	<17	<17	<17	<17	<17	<83
MQR6-C	<10	<10	<10	<10	<10	<10	<10	<10	<51
MQR6-D	<15	<15	<15	<15	<15	<15	<15	<15	<76
MQR6-E	<11	<11	<11	<11	<11	<11	<11	<11	<54
Surface Data									
MQR-SFC	<12	<12	<12	<12	<12	<12	<12	<12	<59

Data below detection is reported as less than (<) the detection limit.

All data qualified as J-H (detected) and UJ-H (below detection) for holding time violation (see page 19)

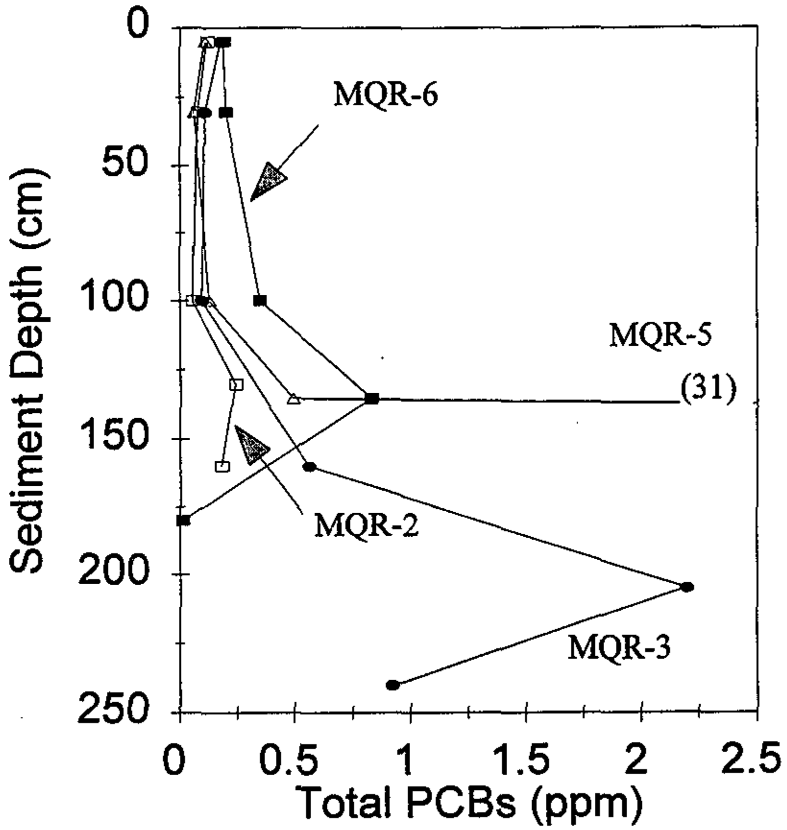


Figure 3-5. Total PCBs as a function of depth in samples from MQR cores

1980). All of the samples taken in the upper 1 meter of the cores had PCB concentrations less than the maximum value (0.81 ppm) measured in MQR surface sediments following final disposal (SAIC 1990a). Also, PCBs (Arochlor 1254 only) were measured in Black Rock Harbor samples prior to dredging and disposal at MQR, and ranged from 0.11 to 9.17 ppm. The anomalously high value of 31 ppm was an indication of the inhomogeneity and patchiness of the source materials present in the MQR mound.

All but three of the pesticide compounds were undetected in all samples. Four samples had detected values of lindane (19-63 ppb, 19 ppb at the surface), two samples had detections of 4,4'-DDD (DDD; 19-20 ppb), and 7 samples had detections of 4,4'-DDT (DDT; 13-43 ppb). These are relatively low concentrations of pesticides as compared to recent measurements from other CLIS cores. For example, samples from CS-2, which also received sediments from Black Rock Harbor, contained up to 929 ppb DDD, and 150 ppb DDT. Original measurements of total DDT in Black Rock Harbor sediments were all below detection.

3.3.2 Metal Results

The range of metals concentrations was generally small (Table 3-3). One sample had the highest value of all metals except Sb, As, and Se (MQR-6D), but was only higher by approximately a factor of 2-3 over the lowest detected values. For example, Cu ranged from 80 to 610 ppm, with no obvious down-core pattern (Figure 3-6). Several samples were below detection in Se and Tl, and only four samples contained detectable amounts of Ag. Chromium and Hg were below detection in one sample, Cd was below detection in 2 samples, and Be was below detection in 5 samples.

Normalizing the trace metal data to the percentage fine grain size reduced the variation between cores and showed a distinct pattern of increasing metals concentrations with depth (Figure 3-7). This increase in normalized metals concentrations is a direct function of the increase in the sand fraction (Figure 3-4). Metals previously have been analyzed for MQR source sediments, at the MQR mound, and also at other cores at CLIS. These results were compared in detail with the MQR core sample results below (Section 4.2).

3.3.3 PAH Results

Although several PAH compounds were below detection limits in the core samples, no individual PAH compound was below detection in every sample. In addition, no sample was below detection in every PAH compound (Table 3-4). PAHs were relatively high in many samples. Two samples stood out as having the highest PAH compound concentrations (MQR3-F and MQR5-E); for example, phenanthrene had a concentration of 212 ppm and 322 ppm, respectively (Figure 3-8). This trend was similar for all low and high

Table 3-3

Metal Results

Sample Name	Antimony (ppm)	Arsenic (ppm)	Beryllium (ppm)	Cadmium (ppm)	Chromium (ppm)	Copper (ppm)	Lead (ppm)	Mercury (ppm)	Nickel (ppm)	Selenium (ppm)	Silver (ppm)	Thallium (ppm)	Zinc (ppm)
Core Data													
MQR1-E	94	5.3	0.52	<0.83	53	81	41	0.15 J-H	21	<0.5	<2.7 UJ-S	<0.5	160
MQR2-A	160	9.4	<0.15	6.6	230	330	270	0.6 J-H	42	0.95	<2.7 UJ-S	0.6	520
MQR2-B	140	7.2	0.74	4.7	200	270	180	0.41 J-H	40	0.71	3.6	0.56	400
MQR2-C	79	5.7	<0.15	<0.83	110	130	73	0.27 J-H	25	<0.5	<2.7 UJ-S	<0.5	220
MQR2-D	140	8.9	0.49	8.4	280	380	230	0.67 J-H	46	0.84	<2.7 UJ-S	<0.5	640
MQR2-E	37	4.6	<0.15	0.97	79	140	100	0.22 J-H	21	<0.5	<2.7 UJ-S	<0.5	320
MQR3-A	140	8.3	<0.15	5.7	200	260	180	0.55 J-H	37	0.71	<2.7 UJ-S	<0.5	460
MQR3-B	130	9.8	0.2	7	240	320	190	0.6 J-H	42	0.85	<2.7 UJ-S	0.6	560
MQR3-C	110	6	0.33	2.3	110	140	96	0.27 J-H	27	<0.5	<2.7 UJ-S	<0.5	230
MQR3-D	120	7.8	<0.15	5.6	240	340	180	0.57 J-H	41	0.75	<2.7 UJ-S	<0.5	460
MQR3-E	68	4.7	0.37	4.5	<1.1	240	120	0.32 J-H	21	<0.5	<2.7 UJ-S	<0.5	310
MQR3-F	84	6.8	0.39	8.4	200	350	160	0.52 J-H	37	0.8	<2.7 UJ-S	<0.5	610
MQR5-A	140	8.1	0.65	3.3	190	250	73	0.41 J-H	35	0.55	<2.7 UJ-S	<0.5	380
MQR5-B	100	5.5	0.55	2.1	100	130	73	0.23 J-H	24	0.8	<2.7 UJ-S	0.54	220
MQR5-C	140	6.5	0.68	4.8	180	240	110	0.27 J-H	36	0.62	<2.7 UJ-S	0.57	300
MQR5-D	75	4.6	0.73	4.9	120	200	98	0.51 J-H	24	<0.5	4.8	<0.5	330
MQR5-E	55	4	0.19	3.6	100	260	140	<0.02 UJ-H	25	0.66	2.7	<0.5	340
MQR6-A	170	8	0.65	6.5	210	270	170	0.49 J-H	38	0.89	<2.7 UJ-S	0.57	440
MQR6-B	160	8.5	0.66	7.5	220	280	140	0.5 J-H	39	<0.5	<2.7 UJ-S	<0.5	480
MQR6-C	90	6.3	0.44	2.4	160	290	92	0.31 J-H	26	0.56	<2.7 UJ-S	<0.5	310
MQR6-D	140	7.5	1.8	14	410	610	390	0.93 J-H	76	0.8	12	0.63	920
MQR6-E	120	6.9	0.71	1.2	55	80	44	0.17 J-H	26	0.57	<2.7 UJ-S	<0.5	170
Surface Data													
MQR-SFC	140	6.3	0.65	4.7	150	190	330	0.28 J-H	33	<0.5	<2.7 UJ-S	<0.5	300
Mean	113	6.8	0.49	4.8	168	254	143	0.41	34	0.66	3.3	0.53	399
Std. Dev.	36	1.6	0.36	3.1	89	115	79	0.20	12	0.15	2.0	0.04	175

Data below detection is reported as less than (<) the detection limit.
Means and standard deviations calculated with detection limit for values below detection.
J/UJ-H = Qualified due to holding time violation; UJ-S = Qualified due to poor spike recovery.

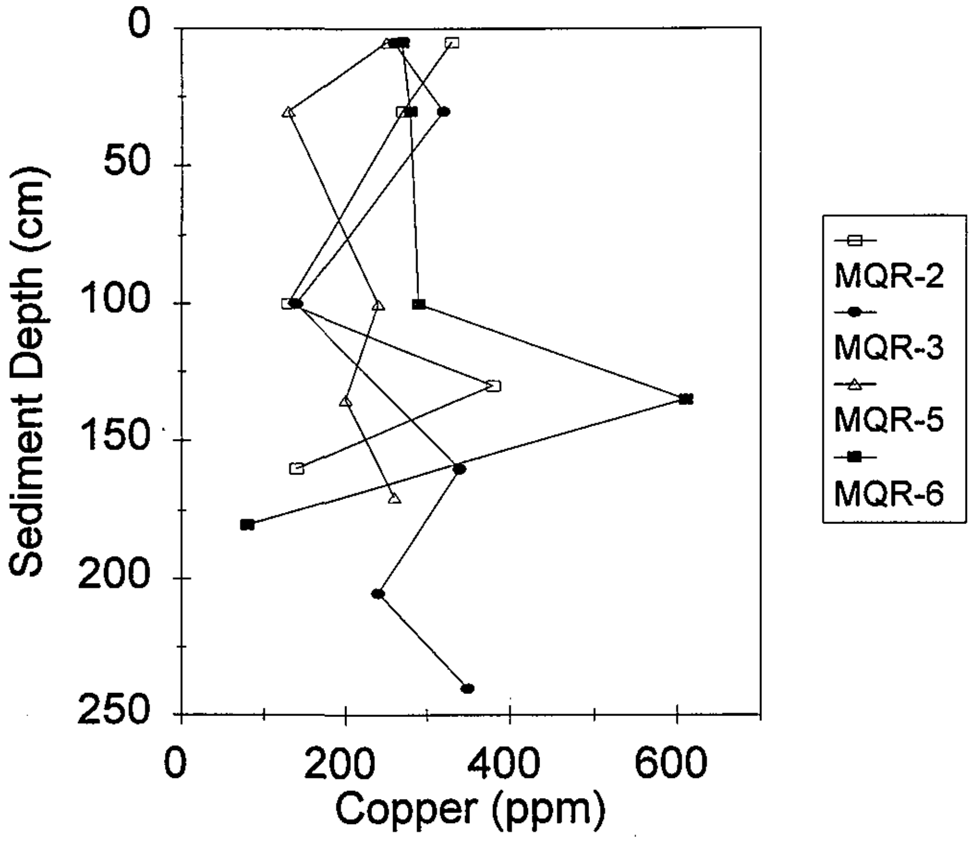


Figure 3-6. Copper as a function of depth in samples from MQR cores

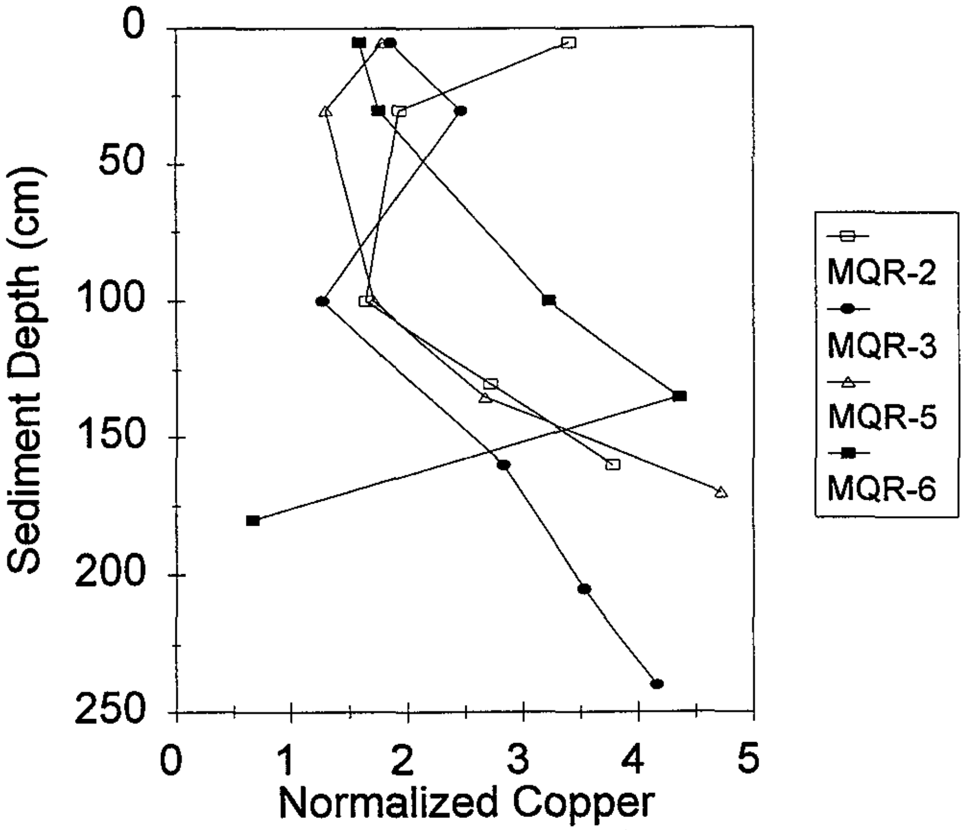


Figure 3-7. Copper normalized to the percentage fine grain size (silt and clay) in samples from MQR cores

Table 3-4

Semivolatile Organic (PAH) Results

Core Samples:	MQR1-E	MQR2-A	MQR2-B	MQR2-C	MQR2-D	MQR2-E	MQR3-A	MQR3-B	MQR3-C	MQR3-D	MQR3-E	MQR3-F
Compound Name	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Naphthalene	0.1 J	2.9	1.2	0.58	1.9	4.9	1.6	2.4	0.56	3.4	6	162
2-Methyl-naphthalene	0.048 J	0.42	0.19 J	0.082 J	0.47	1.2	0.21 J	0.3	0.088 J	2.5	2.2	122
Acenaphthylene	0.064 J	0.32	0.24	0.12 J	0.41	0.55	0.24 J	0.25	0.12 J	0.38	0.95	11
Acenaphthene	<0.016	0.15 J	0.071 J	0.051 J	0.21	2.5	0.1 J	0.12 J	0.052 J	1.3	4	97
Fluorene	<0.016	0.3	0.18 J	0.084 J	0.58	3.8	0.25	0.28	0.098 J	0.95	5.8	139
Phenanthrene	0.19	1.4	1.1	0.4	2.4	10	1	1.4	0.49	2.6	15	322
Anthracene	0.056 J	0.52	0.34	0.17	0.77	4	0.4	0.45	0.18	0.71	7.6	137
Fluoranthene	0.45	3.7	2.6	1.2	4.6	10	2.6	2.6	1.1	4	17	310
Pyrene	0.34	3	2	0.84	3.6	10	2.2	2.7	1.2	3.6	15	315
Benzo(a)-anthracene	0.19	1.1	0.71	0.36	1.4	4	0.82	0.81	0.38	1.3	5.9	116
Chrysene	0.23	1.4	0.91	0.43	1.6	4	1	1	0.47	1.5	5.5	105
Benzo(b)-fluoranthene	0.24	1.1	1	0.51	1.3	3.3	1.2	1.1	0.57	1.2	4.3	79
Benzo(k)-fluoranthene	0.24	1.1	1	0.49	1.2	3.2	1.2	1	0.56	1.2	4.2	78
Benzo(a)-pyrene	0.19	0.85	0.67	0.36	1.1	2.9	0.77	0.78	0.38	1	3.6	76
Dibenzo(a,h)-anthracene	<0.016	<0.025	<0.02	<0.016	<0.021	0.21	<0.025	<0.025	<0.016	<0.02	0.4	8.6
Benzo(g,h,i)-perylene	0.081 J	0.45	0.34	0.16	0.707	1.3	0.42	0.5	<0.016	0.65	1.6	34
Indeno(1,2,-3-cd)pyrene	<0.016	<0.025	<0.02	<0.016	<0.021	2.2	<0.025	<0.025	<0.016	0.65	2.2	43

Data below detection is reported as less than (<) the detection limit.

J = Estimated value; analyte detected at < the practical quantitation limit.

All data qualified as estimated (J/UJ-H) for holding time violations.

Table 3-4 (cont.)

Core Samples:	MQR5-A	MQR5-B	MQR5-C	MQR5-D	MQR5-E	MQR6-A	MQR6-B	MQR6-C	MQR6-D	MQR6-E	Surface	MQR-SFC
Compound Name	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	Data:	ppm
Naphthalene	1.1	0.36	0.35	9.5	150	1.3	1	1	1	0.27		0.65
2-Methyl-naphthalene	0.21 J	0.082 J	0.12 J	4.8	105	0.21 J	0.26	0.73	0.53	0.13 J		0.15 J
Acenaphthylene	0.24 J	0.13 J	0.17 J	0.72	6.9	0.23 J	0.24	1.2	0.57	0.1 J		0.24
Acenaphthene	0.11 J	0.071 J	0.097 J	5.7	22	0.13 J	0.09 J	1.7	0.43	0.061 J		<0.02
Fluorene	0.13 J	0.19	0.21	8.1	94	0.16 J	0.26	1.6	0.77	0.1 J		0.083 J
Phenanthrene	0.56	0.49	0.8	20	212	0.64	1.4	5.8	3.7	0.44		0.55
Anthracene	0.34	0.19	0.28	6.9	82	0.33	0.41	11	1.1	0.13 J		0.63
Fluoranthene	2.2	1	1.9	19	242	2.2	2.8	7.6	6.7	0.65		2
Pyrene	2.4	0.83	1.7	15	124	2.4	2.5	9.2	7.5	0.76		1.8
Benzo(a)-anthracene	0.68	0.34	0.56	6.1	69	0.76	0.88	5.4	2.3	0.27		0.69
Chrysene	0.9	0.45	0.68	5.2	62	0.93	1	9.2	2.6	0.28		0.83
Benzo(b)-fluoranthene	0.99	0.54	0.59	4.7	50	0.74	0.84	3	2.6	0.35		0.83
Benzo(k)-fluoranthene	0.97	0.54	0.57	4.7	69	0.74	0.82	2.9	2.7	0.33		0.81
Benzo(a)-pyrene	0.73	0.34	0.43	3.7	46	0.69	0.71	3.4	1.8	0.28		0.65
Dibenzo(a,h)-anthracene	<0.024	<0.015	<0.017	0.24	6.9	<0.024	<0.022	0.36	<0.02	<0.016		<0.02
Benzo(g,h,i)-perylene	<0.024	0.15	0.24	1.6	26	0.4	0.43	1.3	1.2	<0.016		0.31
Indeno(1,2,-3-cd)pyrene	<0.024	<0.015	<0.017	2.3	24	<0.024	0.43	2.8	1.7	<0.016		0.35

Data below detection is reported as less than (<) the detection limit.
J = Estimated value; analyte detected at < the practical quantitation limit.
All data qualified as estimated (J/UJ-H) for holding time violations.

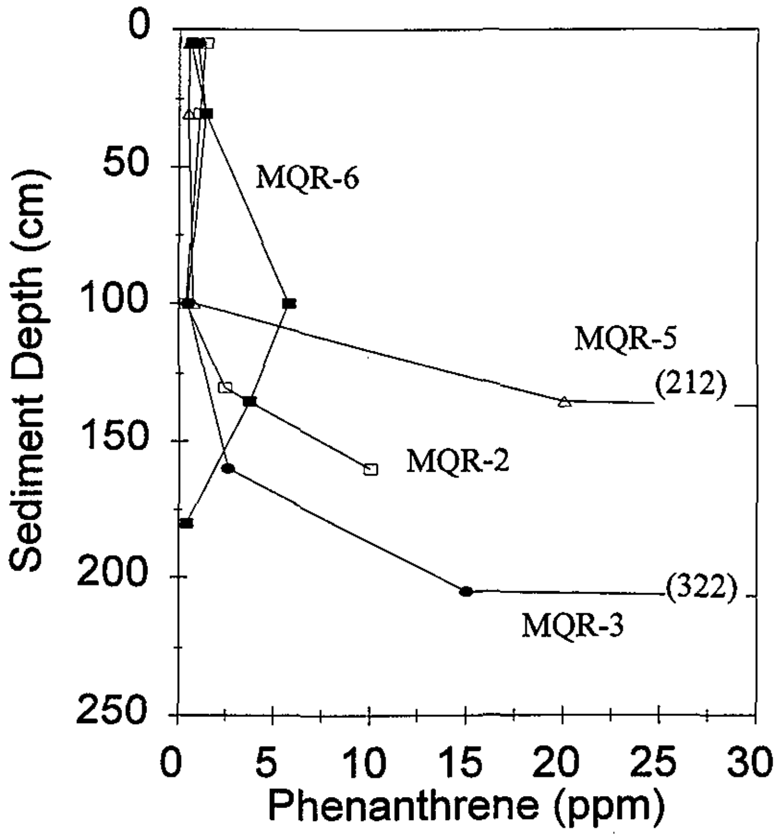


Figure 3-8. Phenanthrene as a function of depth in samples from MQR cores

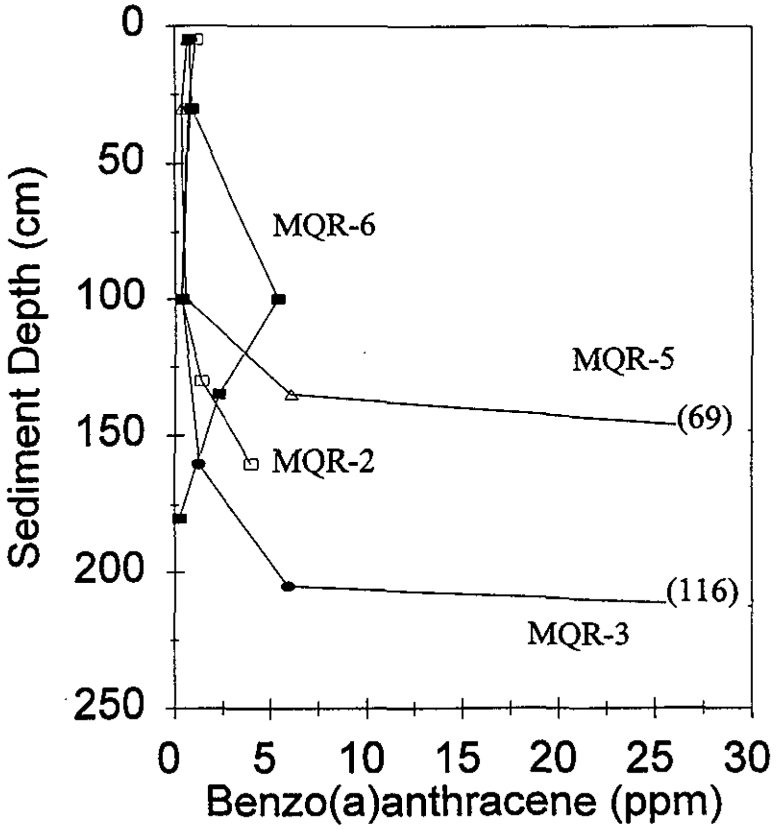


Figure 3-9. Benzo(a)anthracene as a function of depth in samples from MQR cores

molecular weight PAHs (e.g., Figure 3-9). Limited Black Rock Harbor sediment PAH data, analyzed before disposal in 1983, ranged from .017 ppm (naphthalene) to 5.0 ppm (phenanthrene) to 9.8 ppm (benzo[a]anthracene).

MQR PAH results were compared with recently analyzed data from three other capped CLIS mounds (Section 4.3). Except for the two specific samples mentioned above, all PAH concentrations are within the range of samples identified in other CLIS mounds as remnant capped material (from Stamford and Black Rock Harbors). These results are discussed further below (Section 4.3).

3.3.4 Volatile Organic Results

The only detected VOCs were acetone, methylene chloride, carbon disulfide, 2-butanone, and 2-hexanone (Table 3-5). Several of these detections were actually below the practical quantitation limit and reported as estimated, including all detections of 2-butanone and 2-hexanone. The relative detections of acetone, carbon disulfide, and methylene chloride in each of the five samples are similar (volatile ratios). All of these are common laboratory reagents, yet the method blank contained no detections of these compounds, suggesting that laboratory contamination was not a factor.

The possibility of field contamination for these three compounds is remote as the solvents used for cleaning sampling tools were methanol and isopropanol. The remaining possibility is that the detections of these compounds are indicative of actual sediment concentrations. Considering the volatile nature of these organic compounds, and the variation in concentration in the five adjacent surface sediments, this possibility also seems unlikely.

Table 3-5

Volatile Organic Results

Compound	MQR1-CTR (ppb)	MQR2-CTR (ppb)	MQR3-CTR (ppb)	MQR4-CTR (ppb)	MQR5-CTR (ppb)
Chloromethane	<15	<16	<14	10	<22
Vinyl chloride	<15	<16	<14	<12	<22
Bromomethane	<15	<16	<14	<12	<22
Chloroethane	<15	<16	<14	<12	<22
1,1-Dichloroethene	<6.1	<6.6	<5.5	<4.8	<8.9
Acetone	751 U	203 J	1144 U	908 U	254 J
Carbon disulfide	16	<6.6	119	53	<8.9
Methylene chloride	44	6.6 J	25	20	12 J
trans-1,2-Dichloroethene	<6.1	<6.6	<5.5	<4.8	<8.9
1,1-Dichloroethane	<6.1	<6.6	<5.5	<4.8	<8.9
cis-1,2-Dichloroethene	<6.1	<6.6	<5.5	<4.8	<8.9
2-Butanone	<92	99 J	163 J	<73	<134
Chloroform	<6.1	<6.6	<5.5	<4.8	<8.9
1,1,1-Trichloroethane	<6.1	<6.6	<5.5	<4.8	<8.9
Carbon tetrachloride	<6.1	<6.6	<5.5	<4.8	<8.9
Benzene	<6.1	<6.6	<5.5	<4.8	<8.9
1,2-Dichloroethane	<6.1	<6.6	<5.5	<4.8	<8.9
Trichloroethene	<6.1	<6.6	<5.5	<4.8	<8.9
1,2-Dichloropropane	<6.1	<6.6	<5.5	<4.8	<8.9
Bromodichloromethane	<6.1	<6.6	<5.5	<4.8	<8.9
4-Methyl-2-pentanone	<61	<66	<55	<48	<89
cis-1,3-Dichloropropene	<6.1	<6.6	<5.5	<4.8	<8.9
Toluene	<6.1	<6.6	<5.5	<4.8	<8.9
trans-1,3-Dichloropropene	<6.1	<6.6	<5.5	<4.8	<8.9
1,1,2-Trichloroethane	<6.1	<6.6	<5.5	<4.8	<8.9
Tetrachloroethene	<6.1	<6.6	<5.5	<4.8	<8.9
2-Hexanone	<61	66 J	<55	<48	<89
Dibromochloromethane	<6.1	<6.6	<5.5	<4.8	<8.9
Chlorobenzene	<6.1	<6.6	<5.5	<4.8	<8.9
Ethylbenzene	<6.1	<6.6	<5.5	<4.8	<8.9
m/p Xylene	<6.1	<6.6	<5.5	<4.8	<8.9
o-xylene	<6.1	<6.6	<5.5	<4.8	<8.9
Styrene	<6.1	<6.6	<5.5	<4.8	<8.9
Bromoform	<6.1	<6.6	<5.5	<4.8	<8.9
1,1,2,2-Tetrachloroethane	<6.1	<6.6	<5.5	<4.8	<8.9

Samples were collected from surface grabs on 12/17/91.

Qualifier codes:

J = Estimated value; analyte detected at < the practical quantitation limit.

U = Above the upper calibration limit.

4.0 DISCUSSION

The original hypothesis of this study was that the slow recolonization rates documented by REMOTS® photographs, and the bioassay results, were due to a surface layer remnant of the 3,000 m^3 of Black Rock material which was disposed of last in the MQR depositional sequence. The coring data were used to construct a stratigraphic sequence to test this hypothesis by identifying New Haven, Black Rock, Mill River, and Quinnipiac River materials. These stratigraphic units were identified by (1) estimating the thickness of each material disposed; (2) comparing the core sample metals data with historical metals data collected from each source area; and (3) evaluating the organic contaminant data on the basis of more recent sediments also collected from capped mounds at CLIS.

Core descriptions indicated that the top 1-1.5 meters of each core recovered relatively homogenous material. In order to identify whether a thickness of over 1 meter of a similar material was realistic, the thicknesses of each dredged material unit were estimated using the DAMOS Capping Model. Results of the model also were compared with bathymetric depth-difference volume maps between successive depositional intervals. These volume estimates were used as a first-order prediction of thicknesses of individual units recovered in the cores (Section 4.1).

Historical metals data from the source areas (Mill and Quinnipiac Rivers, Black Rock and New Haven Harbors), and from the MQR mound itself, were compared with the MQR core data in order to identify the origin of individual samples in the MQR cores (Section 4.2). If successful, these comparisons would allow a stratigraphic correlation of the cores, and potentially allow identification of the source of the surficial sediments causing the retrograde benthic faunal conditions at MQR.

Finally, chemistry results indicated that several samples, specifically MQR-3F, and MQR-5E, contained distinctively elevated levels of organic contaminants. The suite of organic contaminant data from the MQR cores was compared with recent coring results from other CLIS capped mounds to further elucidate the source areas for each MQR sample (Section 4.3). These data were also analyzed in light of the current knowledge of bioaccumulation potential and resulting negative effects.

4.1 Volume Estimates of MQR Source Materials

The DAMOS Capping Model, a computer program developed for NED that predicts the thicknesses of disposed dredged material, was used to estimate the volumes of each of the different source materials at MQR. These estimates do not consider postdepositional settling of the mound sediments. The model allows for a dual-phase depositional scenario; since MQR was actually completed in at least 4 phases, several runs were completed. Thicknesses were estimated over a predicted 150 m radius of operations, unless otherwise stated. The value used for the volume of a single barge load was 2000 m^3, and the grain size distribution was kept constant at 20% sand, 40% silt, and 40% clay, with a density of 1.45 g/cc.

The Capping Model predicted that 1-3 m of Quinnipiac River material (190,000 m^3) would overlie a base of 0.5-2 m of Mill River material (70,000 m^3). Bathymetric analyses following deposition of Mill River sediments (April 1982) generally agreed with the modelled results. Two bathymetric surveys were conducted following deposition of Quinnipiac River sediments and before New Haven/Black Rock Harbor deposition, in June 1982 and December 1982. Bathymetric results from the June 1982 survey indicated that the Quinnipiac sediment layer was thinner (<1 m) than predicted by the Capping Model, assuming no consolidation of Mill River sediments. The December survey, however, indicated that both Mill and Quinnipiac River sediments had settled approximately 0.5 m in the period between June and December, suggesting a maximum total consolidation of Mill and Quinnipiac River sediments from bathymetric estimates of approximately 2 m.

Modelling the disposal of point-dumped (operational radius of 50 m) Black Rock Harbor sediments (67,000 m^3) following the combined disposal of Mill and Quinnipiac River sediments (260,000 m^3) resulted in a thickness of Black Rock sediments of 2-4 m. No bathymetric survey was conducted following deposition of Black Rock Harbor material. In addition, the Capping Model was used to predict the thickness of a 3,000 m^3 layer of Black Rock material deposited following final capping of New Haven material. The result was that the hypothetical thin layer of Black Rock was indistinguishable from the huge mound of material below it.

New Haven Harbor sediments were disposed not as a taut-wired point-dumping operation, but rather as a widely distributed LORAN-C controlled disposal operation for more comprehensive coverage of cap material. Ten disposal points were concentrically arranged, one in the center, three at 80 m, and six at 120 m from the center. The Capping Model predicted a thickness range of 1.5-3.5 m of New Haven sediments (400,000 m^3) overlying the cumulative sum of the other units within a 300 m radius of operations. Bathymetric observations, obtained after deposition of both Black Rock and New Haven sediments (June 1983), resulted in a minimum total post-Mill and Quinnipiac River sediment thickness of 1-2 m (again assuming no postdepositional settling). These results are consistent with a New Haven cap of 1.5 meters recovered in the cores. The recovery of ambient material below this interval in MQR-6, however, indicates that at least this core was recovered from the mound flanks, where the total thickness of dredged material is thinner than at the center of the mound.

The differences in the modelled thicknesses and those measured by bathymetric volume-difference analyses are a function of sediment consolidation and the diameter of disposal operations. Much of the material is dispersed in the flanks around the mound and is not detectable by use of bathymetric methods. The use of different types of methods to calculate dredged material volumes are currently under investigation (Murray 1994).

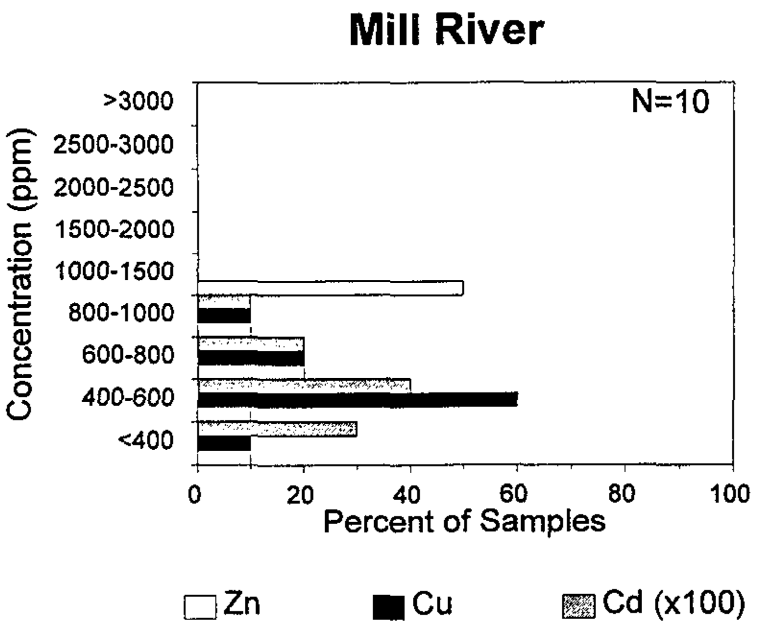
4.2 Metal Ratios of MQR Source Materials

Trace metal data from the four sources of dredged material present at the MQR mound, in addition to historical CLIS reference station data, were compiled. Zinc, Cu, and Cd concentrations were plotted for each source (Figure 4-1). The few samples from the Mill and Quinnipiac Rivers (n=10 and 6, respectively) reduce the statistical significance of the frequency distributions; however, some trends are worth noting. In general, higher Zn and Cu concentrations were present in Mill River sediments, while higher Cd concentrations were measured in Quinnipiac River sediments (Figure 4-1). Black Rock Harbor sediments had, overall, the highest concentrations of all three metals (Figure 4-2). New Haven Harbor sediments were generally low in all three metals relative to the other source areas; however, some of the New Haven samples still had 10 times the trace metal concentrations of CLIS reference station samples (Figure 4-3).

Sediment samples were taken and analyzed for trace metals at the completion of each phase of formation of the MQR mound (Morton et al. 1984b). Results confirmed that Cd concentrations of Quinnipiac River sediments were higher than those of Mill River (Figure 4-4). Chemistry samples taken at the surface of the MQR mound following deposition of Black Rock/New Haven Harbor sediments have indicated fairly stable and relatively low trace metal concentrations since final cap deposition (Figure 4-4).

Most of the trace metal concentrations of the MQR core samples fell within upper New Haven/lower Quinnipiac Zn and Cu concentration ranges (Figure 4-5, A, B). The distribution of New Haven Harbor, Mill River, and Quinnipiac River Zn and Cu concentrations overlapped, probably since some of the sediment from the two rivers are transported to, and settle into, the New Haven Harbor. Two theoretical "mixing lines" established the separation of Black Rock Harbor from the other sources, primarily due to the excess of Cu in Black Rock Harbor sediments (Figure 4-5, A).

The high Cu concentration in Black Rock sediments has been noted since the original Black Rock Harbor results were reported, and were confirmed in the recent coring operations at three other CLIS capped mounds (SAIC 1994). The three mounds cored were Stamford-New Haven North (STNH-N), Stamford-New Haven South (STNH-S), and Cap Site 2 (CS-2). Results from these cores showed that many of the samples taken from the mounds fell into New Haven Harbor concentration ranges and were classified as being capping material (Figure 4-6). STNH-N and STNH-S received contaminated material to be capped from Stamford Harbor, whereas CS-2 received material from Black Rock Harbor at the same time as MQR. Samples from these three capped mounds reflected these two source areas when compared with the original data collected at the time of disposal (Figure 4-6).



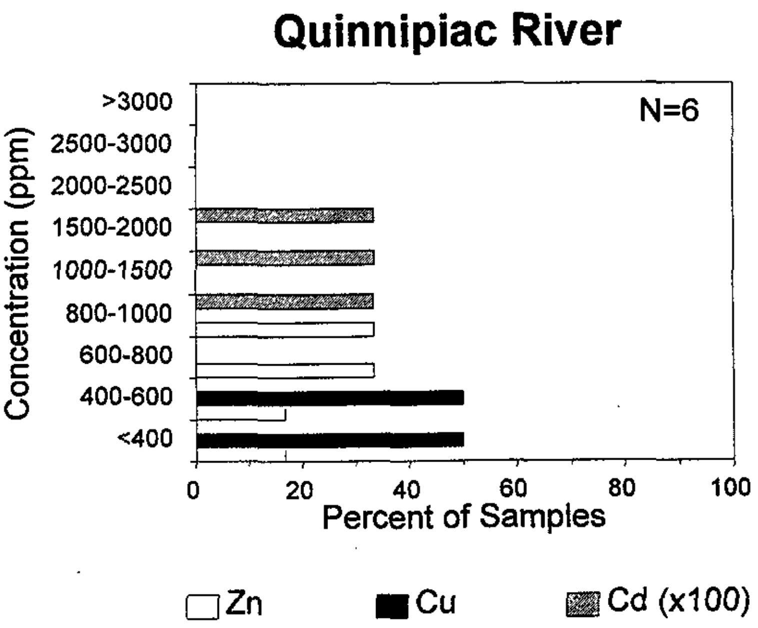
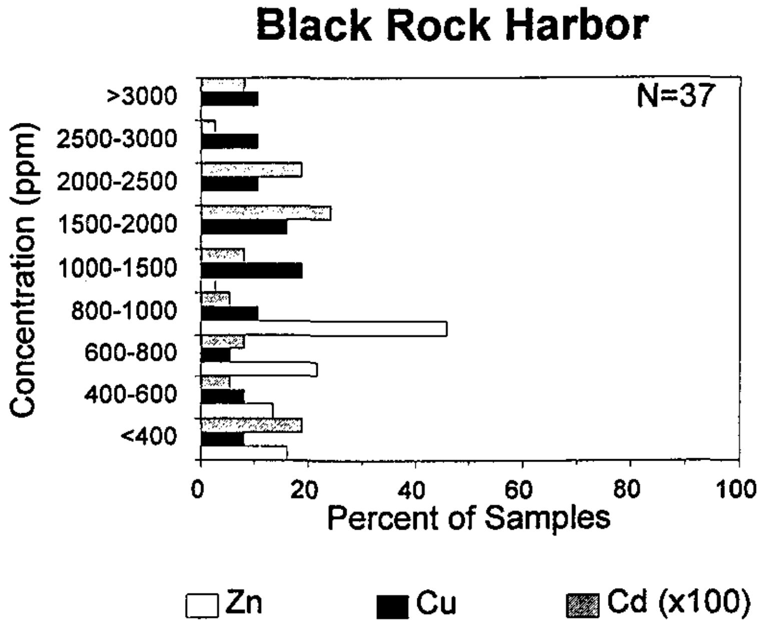


Figure 4-1. Trace metal (Zn, Cu, Cd) concentration frequency distributions of samples from the Mill and Quinnipiac Rivers



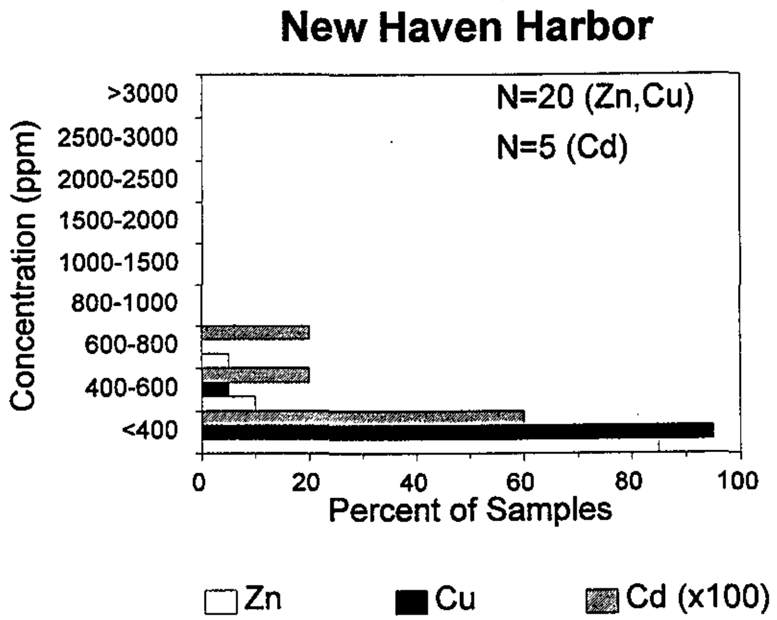


Figure 4-2. Trace metal (Zn, Cu, Cd) concentration frequency distributions of samples from the Black Rock and New Haven Harbors

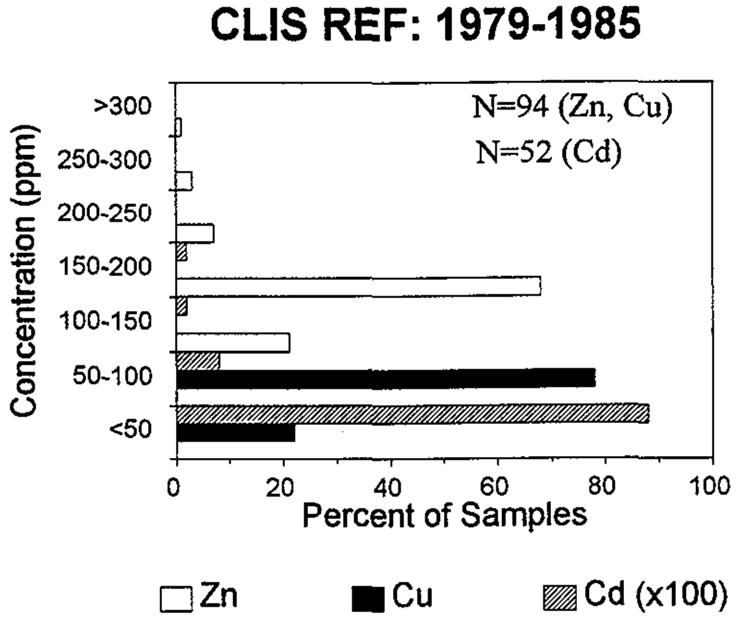


Figure 4-3. Trace metal (Zn, Cu, Cd) concentration frequency distribution of samples from the CLIS Reference Station (CLIS REF), cumulated over the years 1979–1985

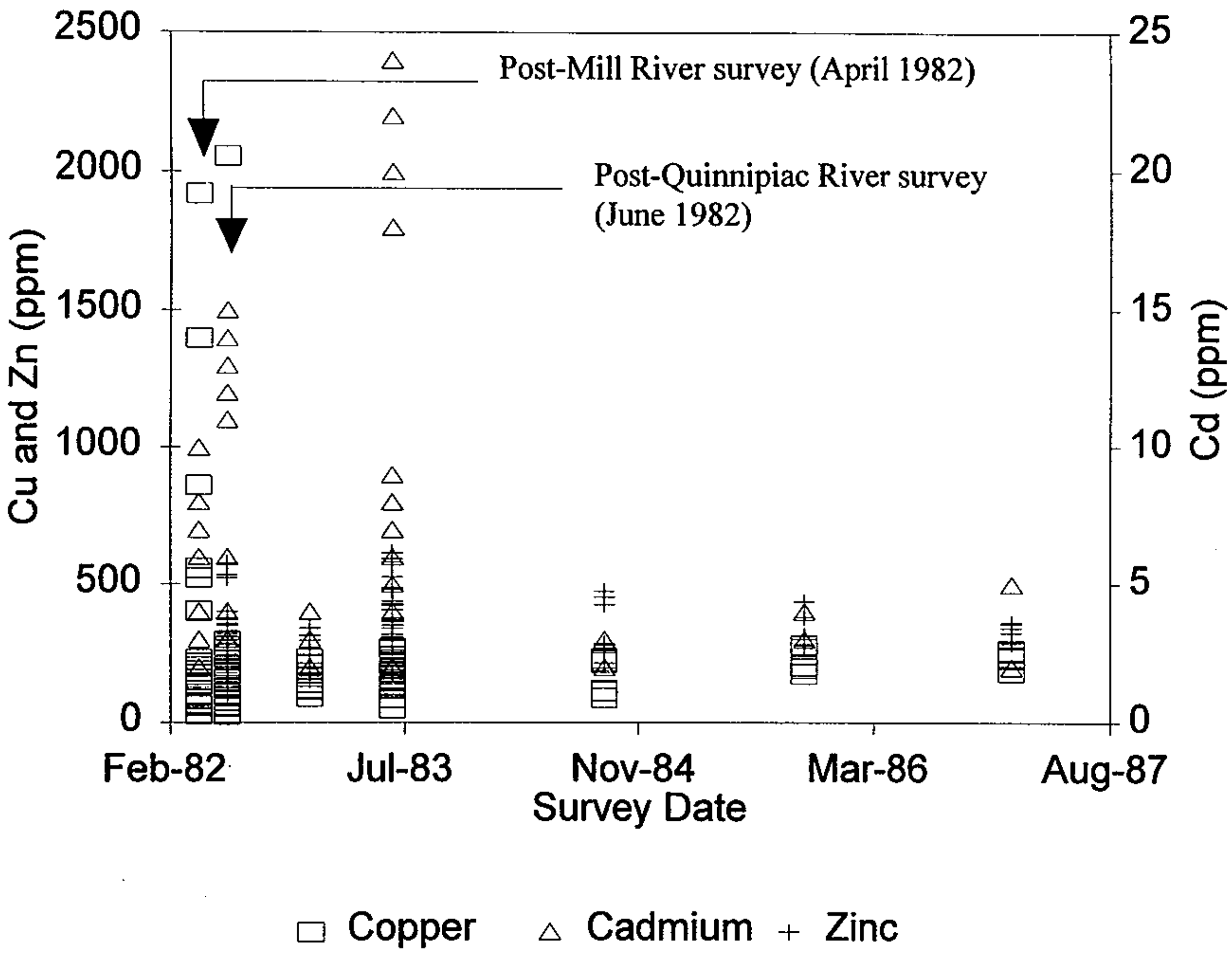


Figure 4-4. Trace metal data from surface grabs collected from the MQR mound during successive stages of formation

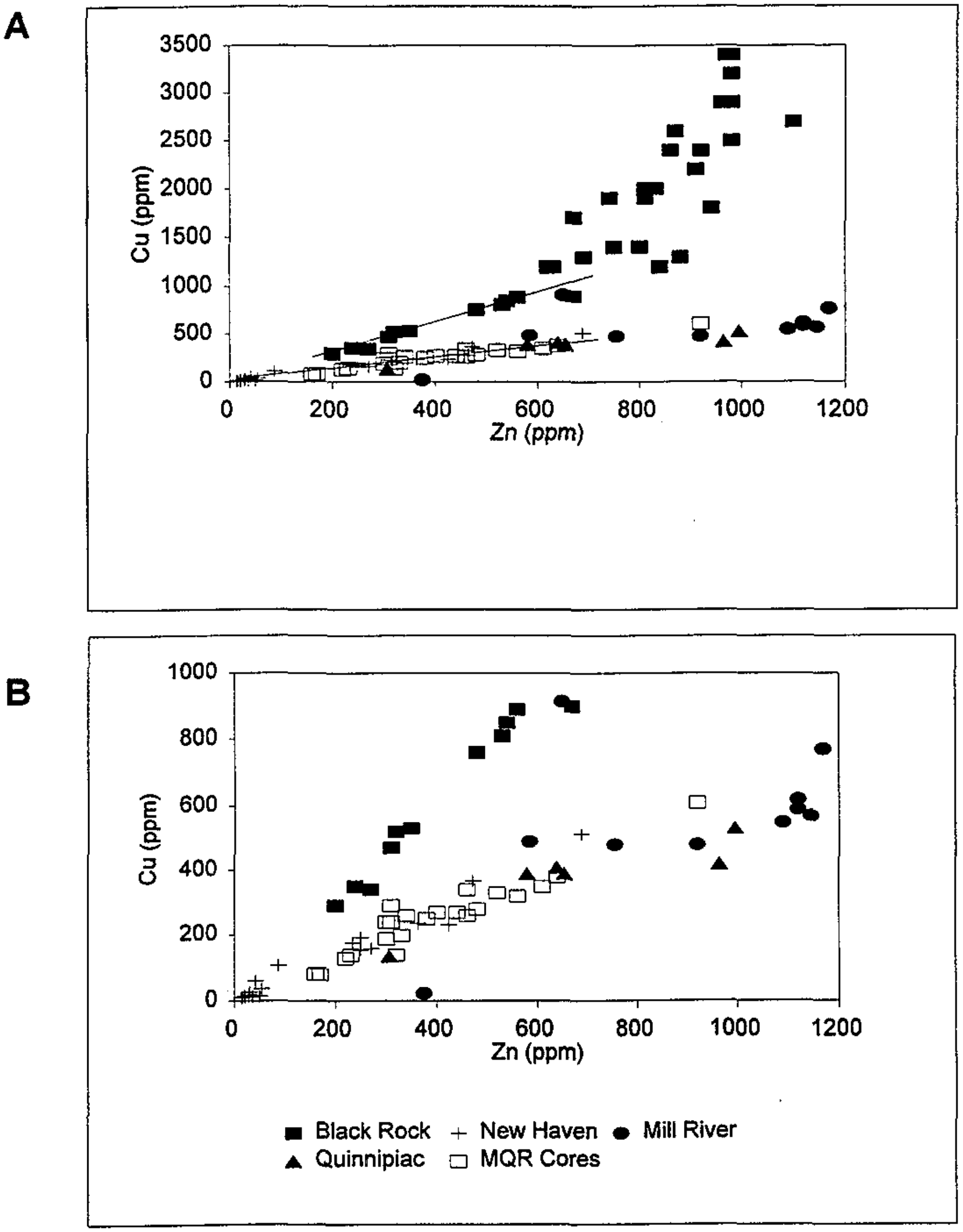


Figure 4-5. Zinc and Cu concentrations of MQR sources and core samples: (A) Two lines are estimated slopes for Black Rock (top) and New Haven/Mill/Quinnipiac (bottom) materials; (B) Enlargement of above showing distribution of lower copper values.

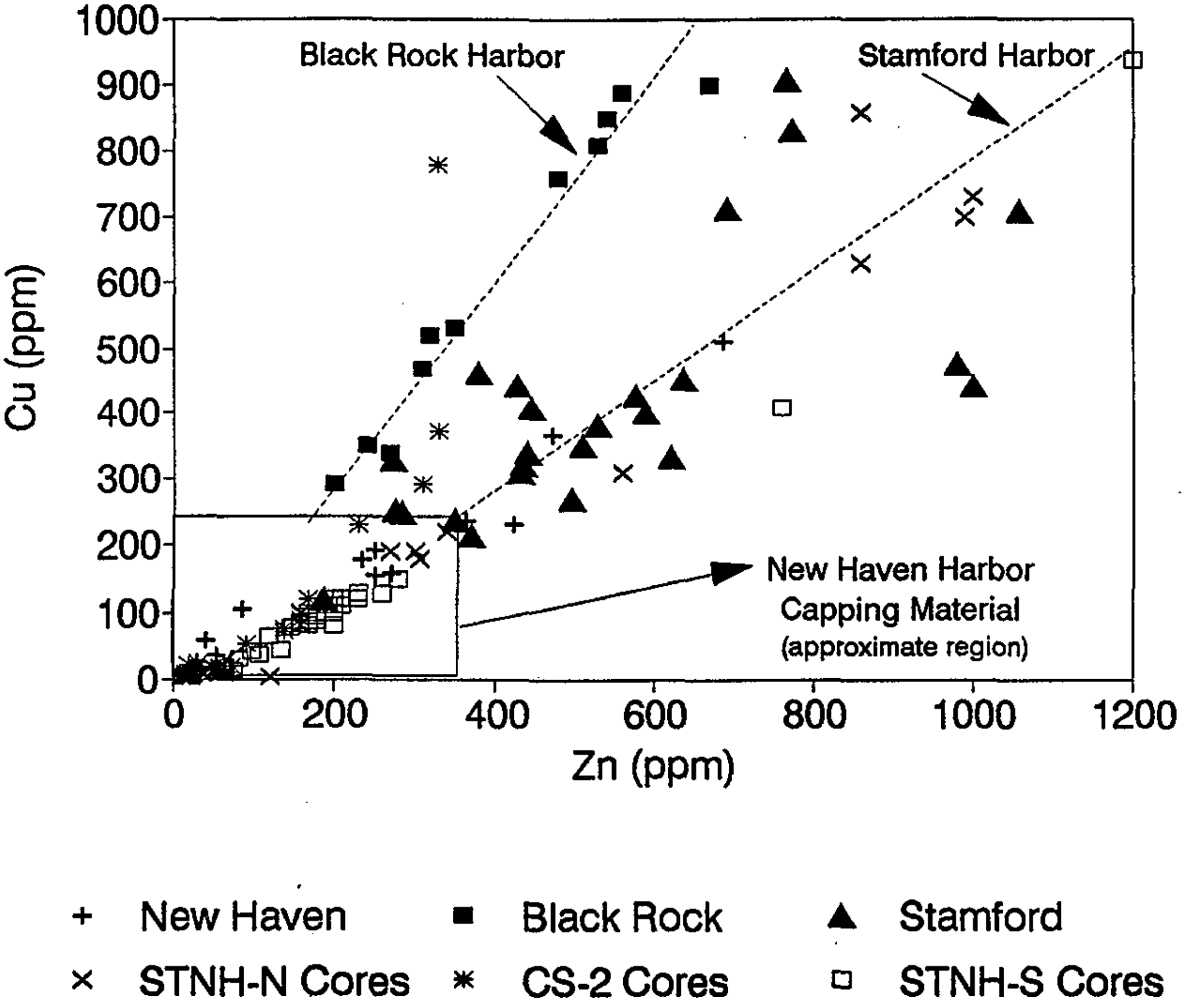


Figure 4-6. Results from the first CLIS coring operations as compared to historical data. Capping material for all mounds was derived from New Haven Harbor. Capped material was derived from Stamford Harbor (STNH-N, STNH-S) and Black Rock Harbor (CS-2).

Metal ratios were compared by normalizing both Cd and Zn data to Cu, resulting in relatively discrete fields for each of the MQR source areas (Figure 4-7, A). Cd/Cu and Zn/Cu Black Rock Harbor metal ratios were minimized and concentrated in a field due to high Cu concentrations. Quinnipiac and Mill River sediments were separated because of the relatively higher Cd concentration of Quinnipiac sediments. New Haven sediments fell in a field between Mill River and Quinnipiac sediments, as predicted according to the discussion above (Figure 4-7, A).

All of the MQR core samples fell within a field dominated by New Haven and Mill River sediments (Figure 4-7, B). Considering trace metal concentrations alone, the results indicated that no samples representative of remnant Black Rock Harbor sediments were taken from the MQR cores. If any Black Rock Harbor material was sampled, it was either not representative of average Black Rock Harbor material, or in such a thin layer that it was diluted by sediment originating from somewhere else. These results also suggested that most of the MQR core samples could be remnant New Haven Harbor capping material. These results do not exclude the possibility that unmeasured contaminants (e.g., PAHs) contributed to the biological disturbance.

4.3 Organic Contamination of MQR Sediments

Core descriptions and grain size data were available for all six cores recovered. These data indicated that only MQR1 and MQR6 recovered potential ambient material. PAH results from MQR6-E were consistent with this conclusion as the base sample decreases to low PAH levels relative to the sample above (Figures 3-8 and 3-9). Interpreting organic contaminant results from the MQR mound was hampered by the paucity of historical data. Analytical methods have been modified, and detection limits improved, over the past ten years. Due to the lack of historical organic data, MQR core samples were compared with the more recent CLIS coring results.

Two PAH compounds were plotted against each other from the four CLIS mounds (Figure 4-8). These results indicated that most of the MQR samples have PAH concentrations comparable to sediments classified as remnant Black Rock and Stamford Harbor, except for MQR-3F and MQR-5E. These two samples had exponentially higher PAH concentrations relative to the rest of the samples (Figure 4-8). MQR-5E was also the sample with the excessively high PCB value (31 ppm).

Most significantly, all of the MQR PAH concentrations were higher than the majority of samples classified as capping material in the other CLIS mounds. Plotting pyrene at the same scale in the three cored capped mounds, concentrations approached zero in the top 50-100 cm of STNH-N and CS-2, while the average of the MQR pyrene concentrations was approximately 2 ppm in the same depth interval of MQR cores (Figure 4-9). The decrease

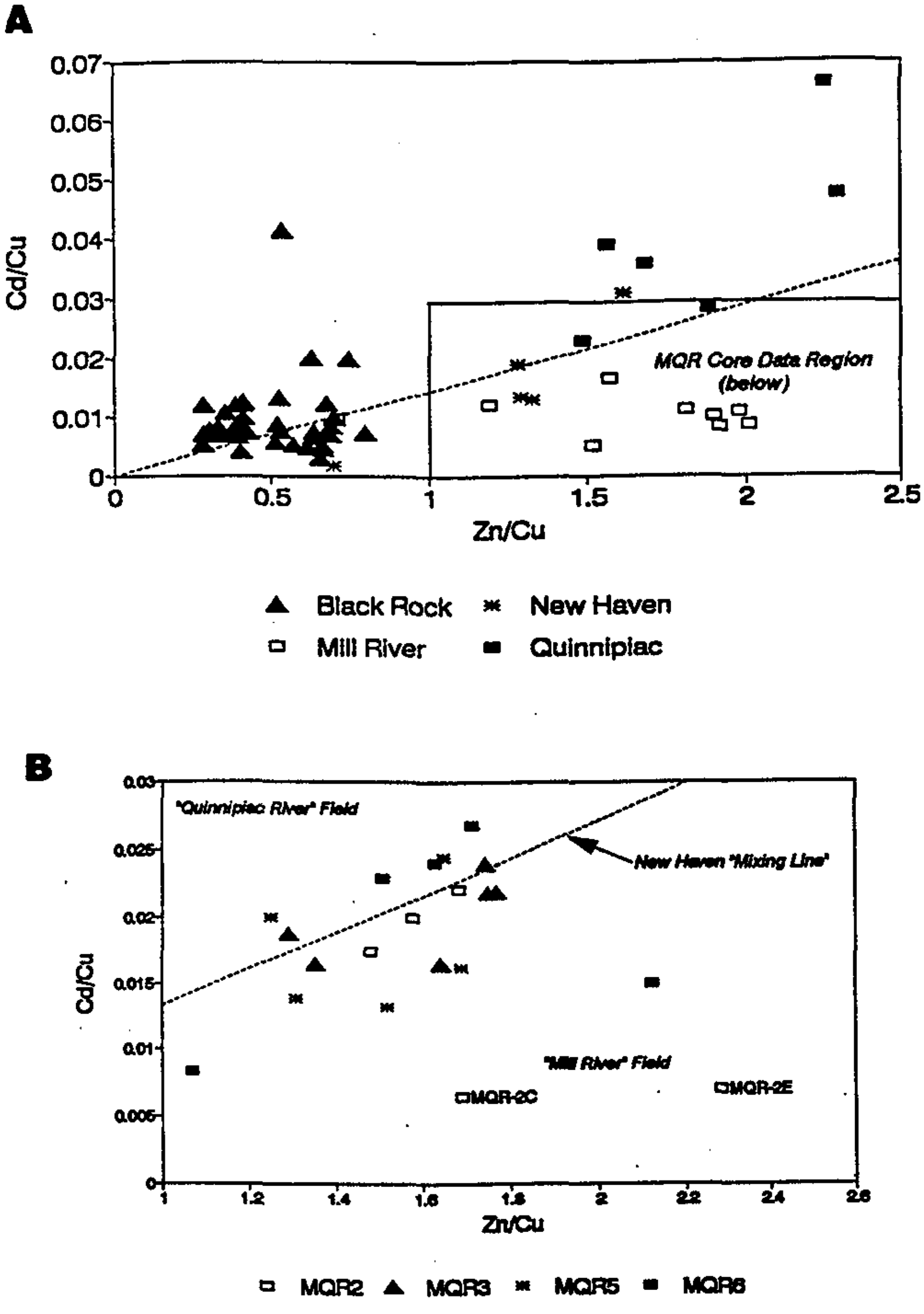


Figure 4-7. Zinc and Cd concentrations normalized to Cu for (A) MQR source areas and (B) MQR core samples. Dashed line separates Mill and Quinnipiac River fields, and follows the range of New Haven samples. MQR samples are clustered along this New Haven axis.

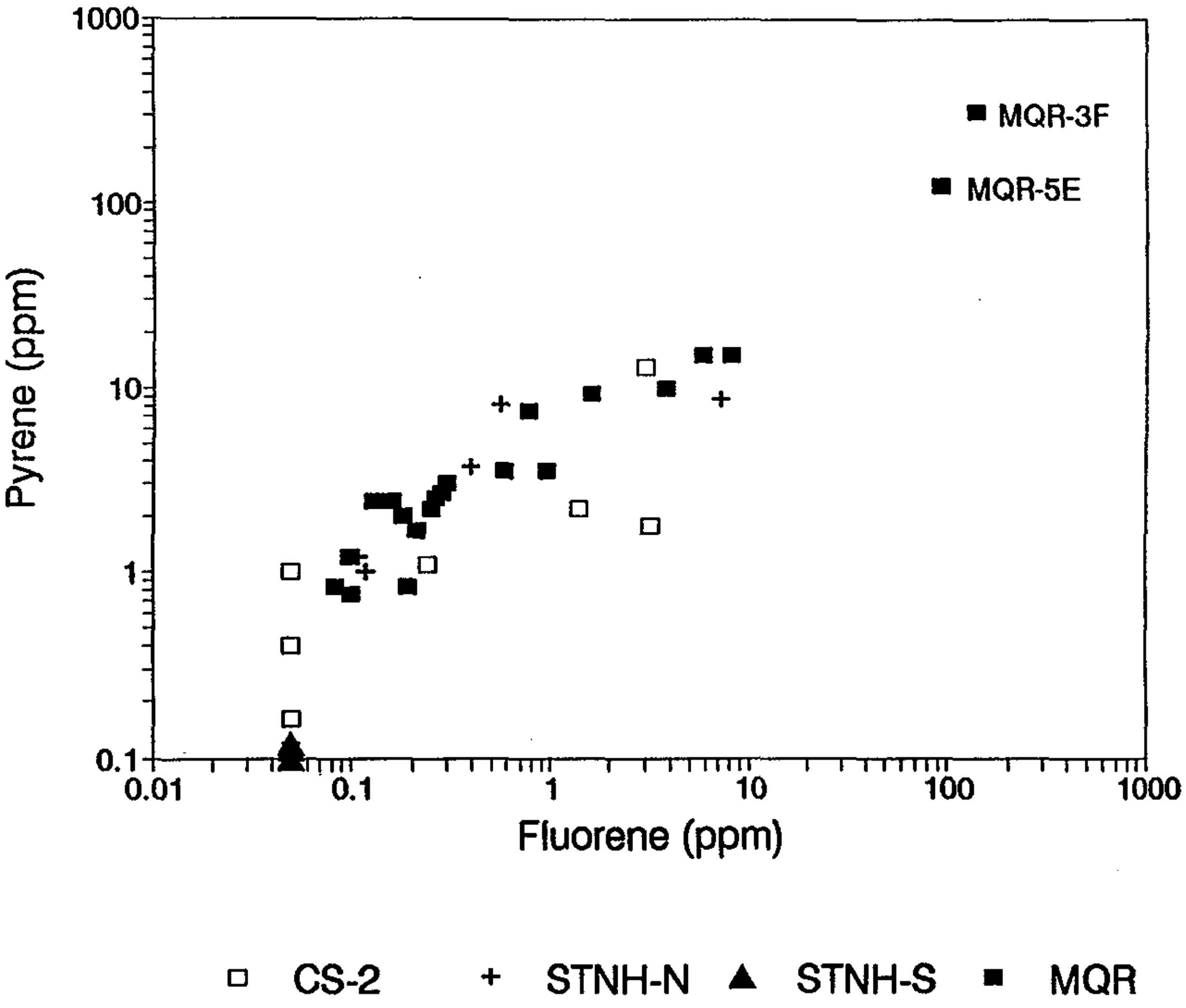


Figure 4-8. Pyrene and fluorene concentrations of samples taken in four CLIS capped mounds

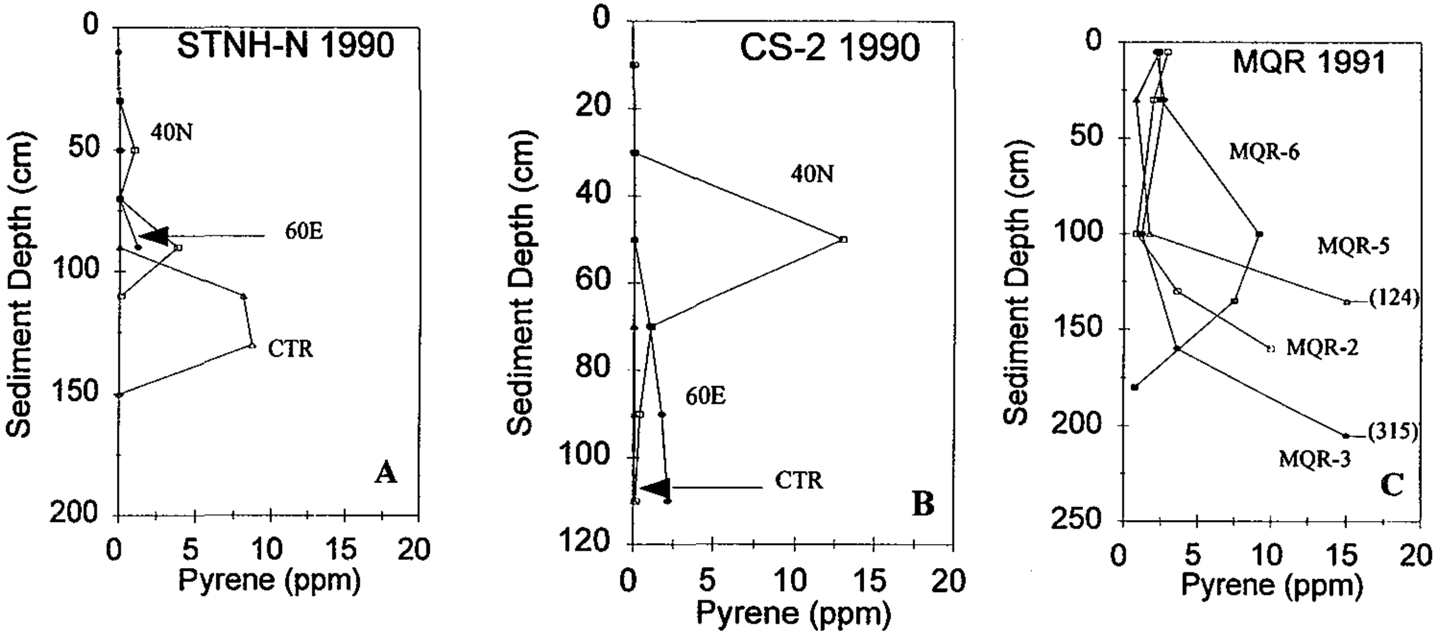


Figure 4-9. Pyrene concentrations as a function of depth in sediment samples from three CLIS capped mounds: (A) STNH-N, cored in 1990; (B) CS-2, cored in 1990; and (C) MQR, cored in 1991

of PAH in the base sample of MQR6 was consistent with the visual interpretation of the recovery of basement material.

PAH concentrations in MQR core samples were compared with previously measured PAH data. The average value of pyrene of 2 ppm was lower than the recently measured average value in New Bedford Harbor sediments (3.5 ppm; Pruell et al. 1990), and higher than the average measured at the surface of the Mud Dump Site in New York (0.98 ppm; Charles and Muramoto 1991).

Because of the lack of historical organic contaminant data, a "contaminant stratigraphy" of the MQR cores cannot be assembled. However, the PAH data do indicate that much of the entire dredged material mound at MQR has relatively high PAH concentrations, and discrete intervals of very high PCB concentrations. Because of the estimated thicknesses of New Haven sediment, the cores should consist of at least one meter of New Haven material. Organic data suggest two alternative conclusions: (1) PAH concentrations are indicative of the original concentrations of New Haven Harbor capping material at the time of disposal, or (2) PAHs have remobilized from the capped materials and infiltrated the capping material.

Two points are important to note in order to draw the most reasonable conclusion. Although PAHs are readily adsorbed onto particulate matter, biodegradation and oxidation may occur in the sediment column (e.g., Kennish 1992). There is no current evidence, however, to support the organic contaminant flux scenario, and in previous CLIS cores, capping material remained relatively low in contaminant constituents (SAIC 1994). Secondly, the samples with high PAH and PCB concentrations lie in the Mill and Quinnipiac River fields, as defined by metals ratios. Considering that both the Mill and the Quinnipiac Rivers eventually flow into New Haven Harbor, it is not inconceivable that the final capping material dredged from New Haven Harbor was obtained from the upper reaches influenced by Mill and Quinnipiac River input. Thus, the first conclusion is also the most plausible.

5.0 CONCLUSIONS

- Three primary lithologies were recovered in MQR cores. The top 1-1.5 meters of every core contained black silty clay with uniform metals concentrations. Thickness estimates of dredged material units indicated that this unit was New Haven Harbor material. Sandier material containing plant fragments and clasts was recovered in every core below the upper New Haven unit. Trace metal ratios indicated that these samples were remnants of either Mill or Quinnipiac River sediments, rather than from Black Rock Harbor. Basement material representing Central Long Island Sound background sediment was recovered in at least one core (MQR6), indicating that this core was recovered from the mound flanks.

- Comparison with prior core data from capped mounds recovered at CLIS indicated that New Haven material from the MQR cap contained higher concentrations of PAHs relative to the New Haven material caps of other CLIS mounds. Since there has been no prior evidence of mobilization of PAHs from capped sediments into the overlying caps, the capping sediments at MQR most likely were originally higher in these compounds.

- Trace metal ratios indicated that New Haven sediments were intermediate in chemical character to Mill and Quinnipiac River sediments. From these data and the disposal sequence, it is clear that the cap material was derived from inner New Haven Harbor, and contained some of the contaminants associated with the inflowing Mill and Quinnipiac rivers.

- According to tiered monitoring protocols, the coring results indicate that MQR should be recapped as soon as material is available.

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