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Chemical Contaminant Distributions in Peconic Estuary Sediments

Final Report

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by

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Study Objectives and Design

The National Estuary Program (NEP) is administered by the U.S. Environmental Protection Agency to assure the protection of our nation's estuaries. This mission is enacted through the development and implementation of Comprehensive Conservation and Management Plans (CCMPs). These CCMPs seek to assure the protection of estuarine resources by identifying priority corrective actions for conditions and processes that detrimentally affect water quality, sediment quality, fish and wildlife resources, and the overall value of the estuary to the ecosystem and the human population it supports.

In order to develop meaningful and effective management strategies, the physical, biological, and chemical dynamics of an estuary must be understood. The focus of this study within the technical framework of the Peconic Estuary Program is distributions of toxic chemical contaminants in sediments and their effects on living resources. Study objectives were developed by the Peconic Estuary Program and its Technical Advisory Group to optimize the relevance of data generated from this study to the Program's management objectives. The scientific objectives that guided the design of this study are as follows:

- Review available data on toxic chemical contaminant distributions in sediments and biota to identify (1) contaminants that may pose risk and (2) critical data gaps
- Examine spatial distributions of toxic chemical contaminants in estuarine sediments through chemical analyses of field samples
- Characterize sediment properties that may influence accumulation of toxic contaminants, such as grain size distribution and organic carbon content
- Identify chemical contaminants that may adversely affect biological resources of the Peconic Estuary
- Determine, to a general level, potential sources of chemical contaminants
- Compare concentrations of toxic contaminants in the Peconic Estuary to concentrations that have been shown to cause adverse effects to estuarine organisms
- Identify additional needs for research regarding sources, transport, and fate of toxic contaminants and impacts on living resources, human health, and the ecosystem

The study design uses sediment quality as an indicator of overall ecosystem health. The utility of using sediment quality as an integrative indicator of ecosystem health underlies the application of the Sediment Quality Triad method and similar assessment approaches. Toxic contaminants were analyzed in field-collected sediments, providing data for comparison with contaminant concentrations that have been shown to adversely affect benthic organisms (Long et al., 1995). These data were supplemented with a review of some historical data that were relevant to these study objectives. In order to provide some measure of sediment biological conditions, a Sediment Profile Imaging (SPI) survey was conducted in the Spring following the Fall 1994 sediment chemistry survey. Twelve stations were sampled for surface sediments; one of the stations could not be accessed for the SPI survey. The 12 sediment chemistry stations were selected from among the 16 stations established for the Peconic Estuary Program's Sediment Flux and Toxics Monitoring Programs (Figure ES-1).

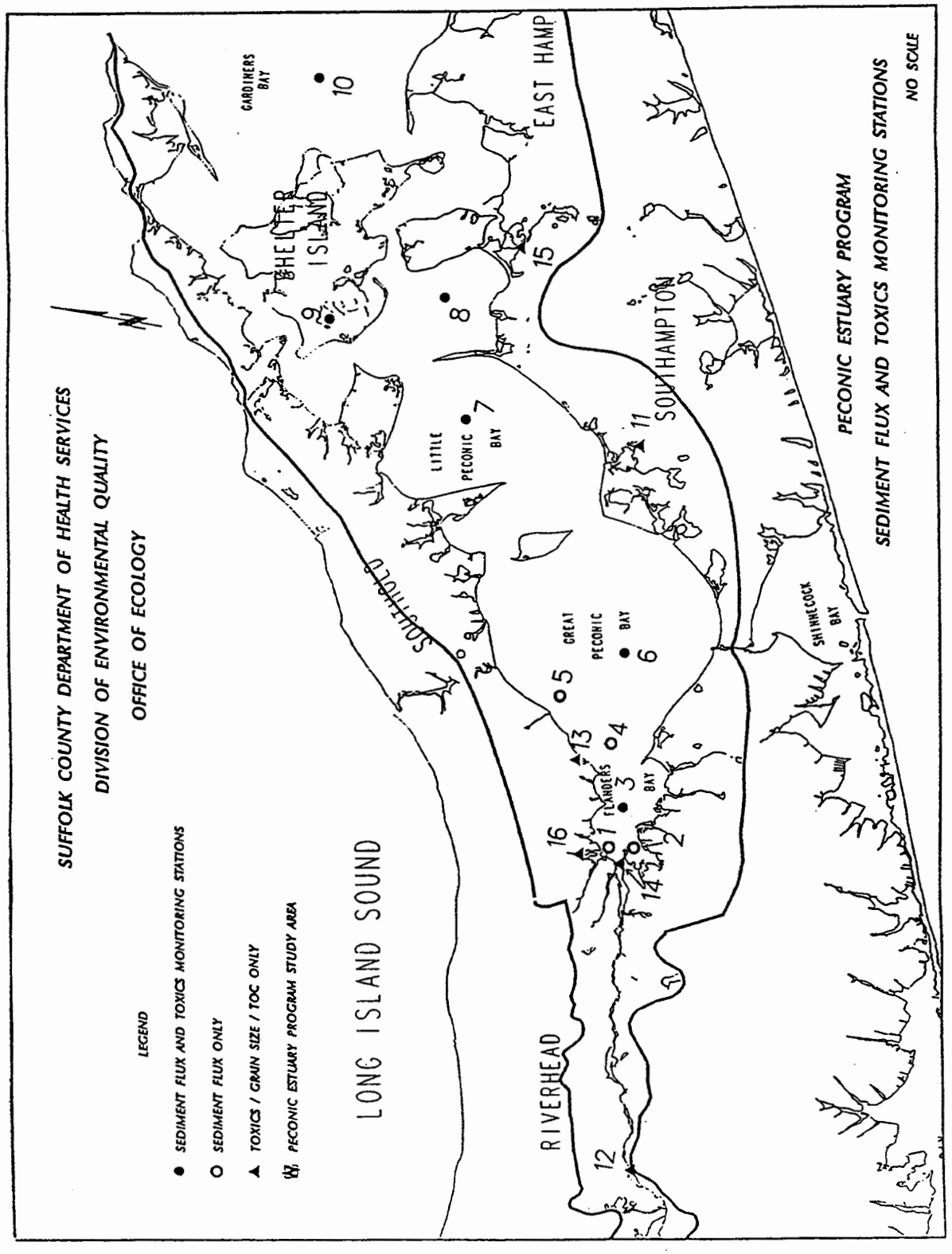


Figure ES-1: Peconic Estuary Program Study Area and Sampling Stations

Target contaminants and analytical methods for the sediment characterization followed the analytical strategy developed by the National Oceanic and Atmospheric Administration for its National Status and Trends Program. The success of this analytical approach, which was also adopted by the EPA for its Environmental Monitoring and Assessment Program, has been demonstrated through the achievements of the Status and Trends Program and in NEP studies for the Delaware Estuary Program (Costa and Sauer, 1994) and Massachusetts Bays Program (Hyland and Costa, 1995). The following organic contaminants were targeted at ultra-trace (parts per billion) detection limits: priority pollutant and alkylated polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) targeted as congeners, and organochlorine pesticides. Priority pollutant metals were also targeted at detection limits lower than those achievable using conventional methods. Sediment grain size and total organic carbon content were measured as auxiliary measurements to examine their influence on contaminant distributions. Specific data quality objectives and assessments were established in a Quality Assurance/Project Plan developed for this study, providing measures of data quality based on accuracy, precision, and traceability.

Comparison of Contaminant Concentrations with Biological Effects Ranges

Contaminant concentrations were compared to the Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values developed from the National Status and Trends Program database (Long et al., 1995). These sediment quality guidelines indicate contaminant concentrations at which benthic organisms are adversely affected. The "low" and "median" values derive from statistical analyses, but generally correspond to concentration ranges below which contaminant-induced adverse effects are unlikely (ER-L) and above which contaminant-induced effects are likely (ER-M).

Table ES-1 summarizes the concentrations of several summed organic compound classes and their ER-L and ER-M values, TOC concentrations, and silt + clay content. With the exception of the DDTs, organochlorine pesticides did not exceed ER-L concentrations in any of the sediments.

Polynuclear Aromatic Hydrocarbons (PAHs)

Depositional areas, fine-grained sediments (silt and clay material) and decaying organic matter tend to produce high TOC concentrations. High organic carbon content in sediments provides a favorable matrix for accumulating chemical contaminants. Thus, in assessing concentrations of chemical contaminants, it is important to look for corresponding trends between contaminants and TOC. When strong correspondence exists, conclusions may be drawn regarding the sources of contaminants and how they accumulate in certain locations. Based on the strong correspondence of PAH concentrations with TOC levels, PAH accumulations at the East Creek and Meetinghouse Creek stations are clearly driven by the nature of the substratum (very favorable for contaminant accumulations) rather than a local point source influence.

In looking at distributions of PAHs, it is useful to look at the high-molecular-weight PAHs (primarily pyrogenic sources) and low-molecular-weight PAHs (primarily petrogenic sources) separately. This way of looking at PAHs helps identify the relative importance of PAH point sources, which are typically responsible for elevations of

Table ES-1: Summary of Organic Compound Distributions

	% TOC	% Silt+Clay	Concentrations (ng/g dry wt)				
			LMW PAHs	HMW PAHs	TPAH	TPCBs	Total DDTs
ER-L			552	1700	4022	22.7	1.58
ER-M			3160	9600	44792	180	46.1
Flanders Bay (Station 3)	0.18	2.85	7.13	19.5	26.6	0.072	ND
Great Peconic Bay (Station 6)	2.04	96.86	114	467	581	4.26	ND
Little Peconic Bay (Station 7)	1.67	91.76	235	1011	1246	14.8	ND
Noyac Bay (Station 8)	2.09	88.66	269	1107	1376	11.5	0.54
West Neck Bay (Station 9)	3.21	96.41	200	754	954	24.8	ND
Gardiners Bay (Station 10)	1.43	86.97	376	1332	1708	23.7	ND
Fish Cove (Station 11)	3.98	89.53	321	1365	1686	23.6	1.2
Peconic River (Station 12)	0.67	1.82	214	1356	1570	6.57	0.68
East Creek (Station 13)	6.56	98.1	735	3310	4045	10.7	31.8
Mouth of Peconic River (Station 14)	3.11	50.42	915	2997	3912	12.4	0.63
Upper Sag Harbor Cove (Station 15)	4.06	26.72	594	2279	2873	19.6	10.9
Meetinghouse Creek (Station 16)	9.48	97.9	1296	5625	6921	87.2	20.4

Note: Underlined values exceed applicable ER-L concentrations
LMW PAHs- Low Molecule Weight (2-, 3-ringed) PAHs
HMW PAHs - High Molecule Weight (4-, 5-, 6-ringed) PAHs
TPAH - Total PAHs
DDT - Dichlorodiphenyltrichloroethene
ND - Not Detected

petrogenic PAHs, versus PAH nonpoint sources, which are typically responsible for elevations of pyrogenic PAHs. Additionally, the primary modes of toxicity differ between the low- and high-molecular-weight PAHs with the 2- and 3-ringed PAHs (low) more likely to cause mortality and the 4-, 5-, and 6-ringed PAHs (high) more likely to cause sublethal effects. Both subclasses of PAHs exhibit similar spatial trends, with the highest concentrations being attributable to favorable conditions for accumulation in organic-rich fine-grained sediments.

In comparing Peconic sediment concentrations with PAH effects levels, ER-Ls were exceeded at East Creek, the Mouth of the Peconic River, Upper Sag Cove Harbor, and Meetinghouse Creek. ER-M values were not exceeded at any study stations. Concentrations of the high-molecular-weight PAHs were consistently three to five times higher than low-molecular-weight PAH concentrations (Table ES-1). This consistency also points to a predominant nonpoint source influence driving PAH distributions throughout the estuary.

PAH compositions were examined for patterns of alkylated PAHs, which provide additional clues regarding the nature of PAH sources. Figures ES-2 through ES-4 show PAH compositions for stations representing low, medium, and high relative PAH concentration ranges within the Peconic estuary. The relative abundances of the individual PAH compounds and compound groups to each other are nearly identical in the patterns seen in Figures ES-2 through ES-4. This similarity in the PAH composition, or fingerprint, extends to the nine additional stations. This single PAH fingerprint, seen in all samples analyzed for this study, confirms that PAH distributions throughout the estuary derive primarily from pyrogenic sources. Airborne pyrogenic PAHs can be introduced into the estuary by fallout during rain, freshwater flow from rivers, runoff through municipal sewer/stormwater discharges, and watershed drainage through ground water underflow. Thus, PAHs into the Peconic estuary may be considered to derive primarily from nonpoint sources.

Polychlorinated biphenyls

Total PCB concentration at Meetinghouse Creek exceeded the ER-L (Table ES-1). Although the influence of TOC and fine-grained sediments affects PCB accumulations the same as with PAH accumulations, it is notable that East Creek (Station 13), with similar TOC and silt + clay content, is nearly an order of magnitude lower in total PCB concentration than the composite sample from Meetinghouse Creek. This result may suggest a localized source of PCBs influencing Meetinghouse Creek; none of the other reported PCB concentrations would appear to indicate PCB point sources outweighing background nonpoint source contributions.

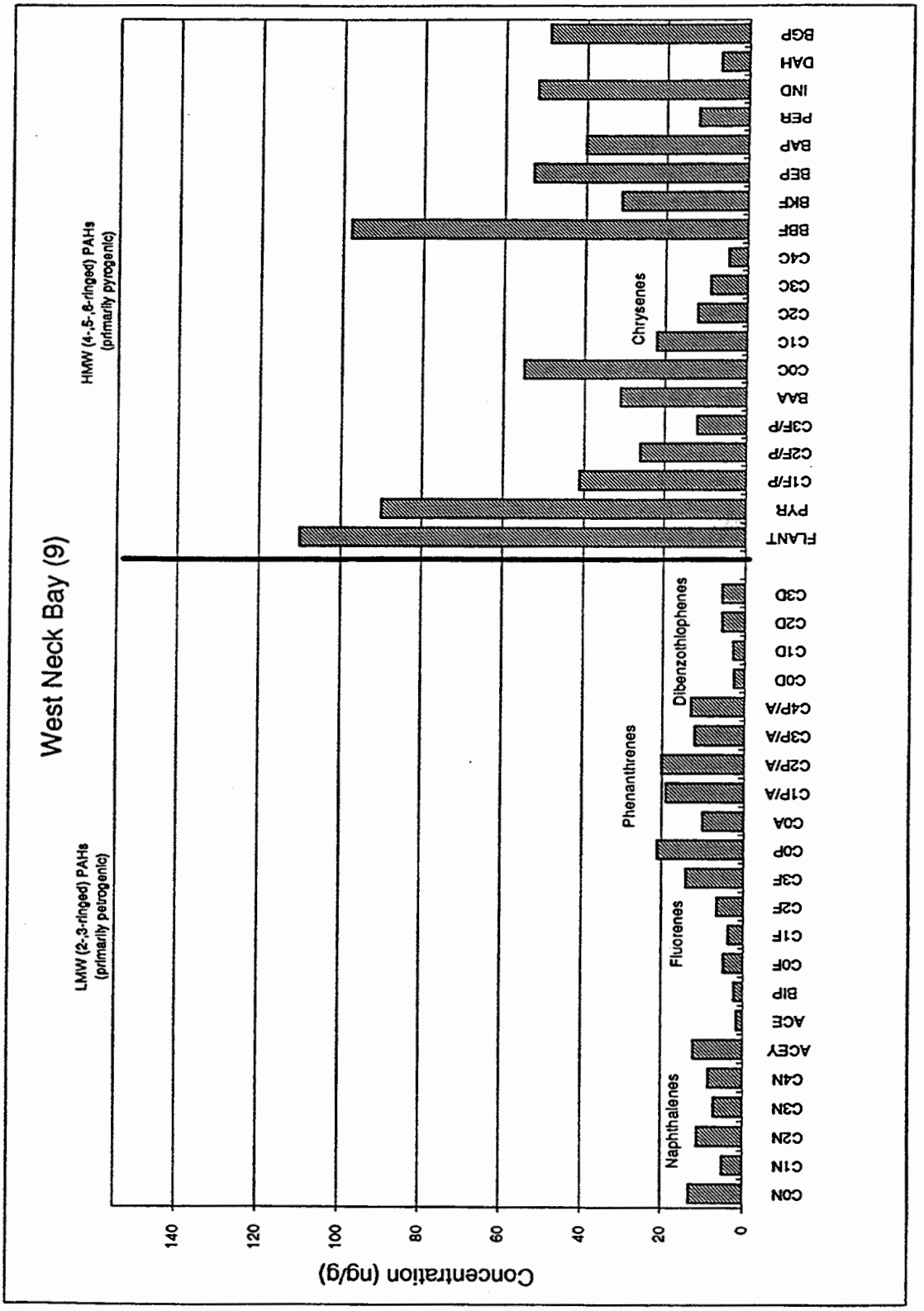


Figure ES-2: Sediment PAH Composition at West Neck Bay (Station 9). Similar Concentrations and Compositions Measured at Great Peconic Bay (Station 6), Little Peconic Bay (Station 7), and Noyac Bay (Station 8).

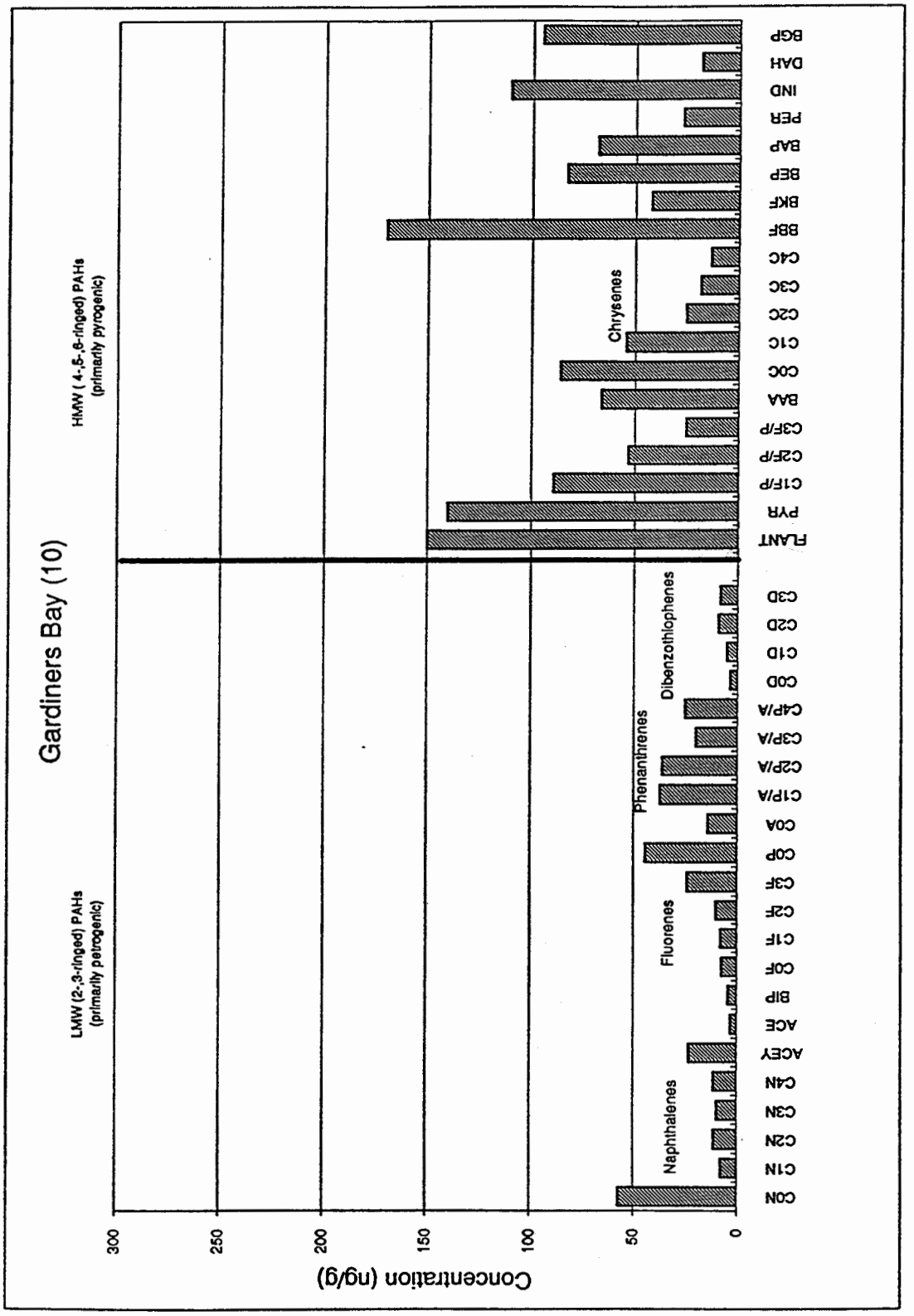


Figure ES-3: Sediment PAH Composition at Gardiners Bay (Station 10). Similar Concentrations and Compositions Measured at Fish Cove (Station 11), Peconic River (Station 12), and Upper Sag Harbor Cove (Station 15).

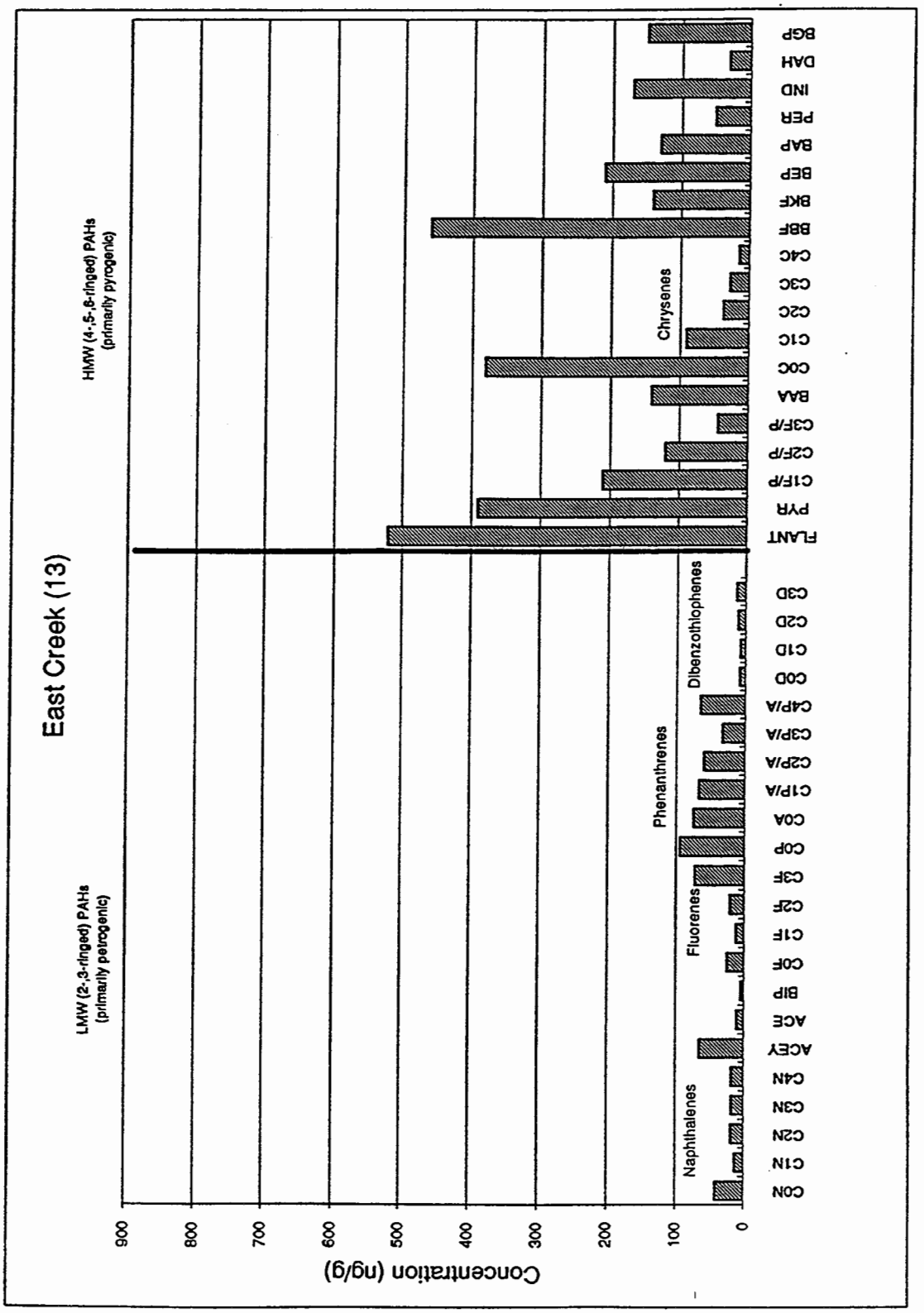


Figure ES-4: Sediment PAH Composition at East Creek (Station 13). Similar Concentrations and Compositions Measured at Mouth of Peconic River (Station 14) and Meetinghouse Creek (Station 16).

Pesticides

Based on historical agricultural land use along the north portion of the estuary and other historical data, pesticide residues were predicted to be found in sediments. In addition to organochlorine pesticides targeted in NOAA's National Status and Trends Program and EPA's EMAP, aldicarb and several of its metabolites were targeted in split sample analyses performed by the Suffolk County Department of Health Services Laboratory, but not detected at detection limits of 8 ng/g. DDT concentrations exceeded ER-L at Upper Sag Harbor Cove, East Creek, and Meetinghouse Creek. Although influenced by TOC and grain size distributions, these elevations are very likely due to continuous drainage of agricultural areas containing persisting residues of DDT, which has been banned from use in the United States since the 1970s.

Metals

Sediments deposited in coastal areas adjacent to urban and industrial development commonly have elevated concentrations of a variety of heavy metals. Metals concentrations are usually categorized as "elevated" by comparing metal concentrations or metal-to-aluminum concentration ratios in the sediments of interest with values for average continental crust, "clean" sediments, or pre-industrial (sub-surface) sediments from the same area. When metal values or metal/Al ratios for a given sample exceed the 95 percent prediction interval for "clean" or "natural" sediments, then the samples most likely reflect an anthropogenic influence. However, the presence of elevated metal concentrations is not necessarily directly linked with adverse effects to organisms living in or feeding from the sediments, although guidelines are being evaluated for their suitability in predicting this contaminant-effects linkage (e.g., Long et al., 1995).

In our evaluation of the metals data, we have followed a two-prong approach wherein we first identify "elevated" metal concentrations in the sediment and then predict the likelihood of adverse effects. We have measured total concentrations of Al and 13 other metals (Ag, As, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, Tl, and Zn) in the samples. Sediments from the Peconic Estuary analyzed for this study are from a variety of locations and represent a range of sediment types. Based on Al values, along with visible texture and composition, sediment samples from the Peconic River (Station 13, 0.42 percent Al) and Flanders Bay (Station 3, 0.44 percent Al) are sandy. The samples from Upper Sag Harbor Cove (Station 15, 2.18 percent Al) and the mouth of the Peconic River (Station 14, 3.58 percent Al) are intermediate in apparent grain-size and clay content. The remaining samples are relatively fine-grained, clay-rich samples (6.6 ± 0.7 percent Al). Metal concentrations are naturally higher in finer-grained, more clay-rich (higher Al) samples due to the minerals associated with them and the greater surface area for adsorption. Contaminant loadings of metals also show up most readily in fine-grained sediments because of the greater availability of surface uptake sites.

None of the samples from any station in this study exhibited metal concentrations that exceed the higher ER-M values (Table ES-2). Thus, the estuary is not in a situation where adverse effects due to metals would be expected to frequently occur. However, the metal concentrations listed as ER-M levels are very high and are not commonly observed.

Overall, about 17 percent of the metal concentrations (18) exceed ER-L values, based on 12 stations and nine metals with available ER-L values. Two metals, As and Pb, account for 56 percent (10) of the high values. An anthropogenic source is likely for both metals. Lead has been introduced into the environment from Pb additives in gasoline for many years. However, Trefry et al. (1985) showed that inputs of Pb to the environment have declined since regulations restricting use of Pb additives in gasoline were introduced during the 1970s. The history of pollutant inputs to sediments in the Peconic Estuary could also be evaluated by studying age-dated sediment cores. Sources of As include fertilizers, pesticides, smelters, and stormwater runoff.

From the perspective of location, East Creek (Station 13) and Meetinghouse Creek (Station 16) each have five metals that exceed the ER-L (Table 2) and are the most metal-enriched sites from this study. Further investigations at these sites would be helpful to determine likely sources of metals to the system.

By using the more sensitive metal/Al ratios, 24 data points (22 percent of total) likely reflect anthropogenic inputs (Table 2). Four metals, As, Cd, Pb, and Zn, account for 82 percent of the high values. These four metals are frequently among those metals that show the first signs of pollutant inputs to coastal sediments.

No ER-L or ER-M values have been established for Be, Sb, Se, or Tl. All values for these metals in the Peconic Estuary are in the broad boundaries for typical sediments with no obvious anthropogenic contribution at this time.

Overall, the Peconic Estuary has several clear instances of elevated metal concentrations, especially in East Creek and Meetinghouse Creek. Occasional adverse biological effects can be expected due to metals and management plans should consider reducing future metal inputs that are most likely related to stormwater and urban runoff.

Condition of the Sediment Environment as Indicator of Ecosystem Health

Although ER-L and ER-M values (and other sediment-effects criteria) may be useful predictors of contaminant-induced degradation, they are most effectively used as a component of an assessment strategy that includes complementary indicators of ecosystem conditions. Sediment profile imaging was used in this study as the complementary indicator of ecosystem conditions.

With the exception of the fine sand and shells found at Flanders Bay (Station 3) and Upper Sag Harbor Cove (Station 15), the grain size major mode at all the stations sampled were silt-clay, indicative of a relatively quiescent, depositional environment. Station 12 within the Peconic River could not be surveyed by SPI. Station 3, located in Flanders Bay, had a significant surface shell-hash layer, indicative of persistent strong currents at this location capable of washing away any surface fine sediments.

The fine sand area at Upper Sag Harbor Cove is quite consolidated with little evidence of biogenic reworking; as one moves away from shore on to the muddier bottoms, there is evidence of a surface sand layer over a mud facies before quickly transitioning into a fine-grained, soft bottom environment.

Table ES-2: Summary of Stations in Peconic Estuary where sediment metal levels show the following: (1) Elevated levels based on metal/Al ratios, (2) Values above biological effects range low (ER-L), and (3) Values above biological effects range medium (ER-M).

Element	ER-L	ER-M	Elevated Levels	>ER-L	>ER-M
Ag	1.0	3.7	13, 14, 16	14, 16	None
As	8.2	70	11, 13, 14, 15, 16	6, 9, 11, 13, 14, 16	None
Cd	1.2	9.6	11, 13, 14, 16	13	None
Cr	81	370	None	None	None
Cu	34	270	13, 16	13, 16	None
Hg	0.15	0.71	16	9, 16	None
Ni	20.9	51.6	None	(Some)	None
Pb	46.7	218	9, 12, 13, 15, 16	9, 13, 15, 16	None
Zn	150	410	12, 13, 14, 16	13	None

Most stations showed highly reduced muds with low reflectance at depth, indicative of relatively high sediment oxygen demand (SOD). Noyac Bay (Station 8) exhibited the most stressed habitat characteristics, with no apparent redox potential discontinuity depth and high SOD, indicating that this location most likely experiences prolonged periods of low dissolved oxygen stress.

Most stations showed evidence of only early successional assemblages; only two locations (Station 10 in Gardiners Bay, the eastern most station sampled closest to the open Sound, and Station 16, Meetinghouse Creek at the opposite end of the estuary) had evidence of mature Stage III communities (indicating low disturbance habitats with relatively high sediment quality); no stations were azoic. Dense *Ampelisca* tube mats were found at Station 9. All stations sampled showed evidence of infaunal communities present, although determinations at some locations were difficult due to the presence of dense layers of *Ulva* that were dragged below the sediment-water interface by the camera's prism during bottom penetration (Figure ES-5).

For the most part, the fine-grained stations sampled in April 1995 showed evidence of relatively low flushing rates, high organic loading, and relatively high SOD at many locations. We would predict that as the season progressed and temperatures increased, high SOD coupled with warmer water and low oxygen levels would exacerbate existing conditions at those stations with low organism-sediment indices values, degrading habitat quality even further. Conditions at Noyac Bay (Station 8) should be particularly stressed in late summer/early fall when water temperatures are at their maximum.

The SPI survey and subsequent analyses provide important perspective on the most likely causes of poor benthic community and habitat conditions in this ecosystem. Given the broad expanse and relatively shallow nature of the Peconic estuary, many areas of bottom will experience low or modest flushing rates, so they will be particularly susceptible to ecological stress from nutrient and excess organic loading. Few of the locations sampled showed evidence of mature, deposit-feeding infaunal communities. As macrophytes such as the sea lettuce, *Ulva*, die and start to decompose on the bottom as the season progresses, low dissolved oxygen conditions and high sediment oxygen demand will contribute to further habitat degradation in shallow areas with low circulation rates.

Conclusions

Toxic Contaminant Effects

The results of this study lead us to conclude that toxic chemical contaminants do not pose considerable risk to biological resources on an estuary-wide basis. Although difficult to quantify terms such as "considerable risk," we can conservatively conclude that toxic contaminants do not pose as great a risk to resources as the stress resulting from excessive nutrient and organic carbon loading. We must, however, note that one of the problems associated with high organic carbon concentrations found in this study is the favorable accumulation of predominantly background contaminants to concentrations that could adversely affect biological resources on a local basis. The key distinction in these statements are the aspect of spatial scales implied by "estuary-wide" versus "local." The factors that will determine the extent to which resources may be affected by localized accumulations of contaminants include the response of potentially affected biological communities to the stresses of the organic carbon loading.

Based on the suite of assessment tools employed in this study, there did not appear to be any stations for which poor habitat quality could be attributed to toxic chemical contamination. However, there remains the potential for localized problems associated with toxic chemicals that may accumulate in fine-grained, organic-rich muds that are found in many of the sheltered embayments, particularly in the western portion of the estuary. In addressing this important study objective, we conclude that the following toxic chemical contaminants may pose potential risk given the necessary circumstances:

- PCBs
- DDTs and pesticides/herbicides identified in future studies
- Arsenic
- Lead

Although lower in priority, cadmium, zinc, and high-molecular-weight PAHs (i.e., the 4- through 6-ringed priority pollutant PAHs), may also be considered for targeting in future studies.

Figure ES-5: East Creek (Station 13). The dense layers of the sea lettuce *Ulva* contribute to high organic loading in areas with low flushing rates, causing buildup of methane gas at depths in the sediment (bubbles at depth with glassy appearance).

Contaminant Sources

The physical dynamics of this estuary, with respect to limited source inputs, circulation, and flushing, greatly influence chemical contaminant distributions. Such strong parallels between physical and chemical contaminant dynamics suggest that nonpoint sources (e.g., atmospheric deposition, surface runoff, groundwater underflow), which make up the chemical contaminant background or baseline for this system, exceed the influence of localized point sources throughout the estuary. This general conclusion is strongly supported by two lines of evidence: 1) the general correspondence of contaminant concentrations with TOC and silt + clay content and 2) constancy of alkylated PAH compositions throughout all study stations.

It appears that there may be some localized point source(s) for PCBs influencing Meetinghouse Creek. This conclusion is based on the elevation in total PCB at that station beyond what we would predict based on the TOC and silt + clay content.

Additional Research Needs

As we have concluded that organic carbon is the greatest single factor driving distributions of toxic contaminants in the Peconic Estuary, it is crucial to accurately understand the dynamics of organic carbon on an estuary-wide basis. This includes characterizing the major sources of organic carbon and modeling its transport and fate. Additional surveys to better map benthic conditions throughout the estuary, perhaps using sediment profile imaging, can provide direct evidence of the extent to which benthic resources are stressed and indirectly indicate (using SPI parameters) offshore locations that may be vulnerable to contaminant accumulations.

Despite the limited sampling for this study, we were able to identify locations with elevations of toxic contaminants. These locations combined high organic carbon and fine-grained sediments to produce accumulations of background contaminants, and in some cases localized sources of contaminants, to concentrations that may adversely affect resources. Not surprisingly, these locations are typically in shallow, protected embayments or creeks. More thorough sampling of sediments from some of these areas for a subset of the chemical contaminants targeted in this study should confirm or clarify the conclusions stated herein regarding potential contaminants of concern and their likely point sources. For any further study, organic carbon concentrations should be measured as a screen, with selected samples analyzed for selected target contaminants.

Management Recommendations

The direct observation of benthic habitat conditions and infaunal succession through sediment profile imaging revealed considerable evidence of a stressed system as indicated by complementary measures of sediment quality. However, as a reviewer of the draft of this report insightfully commented: "The continuum of habitats from disturbed to stable provides a mosaic on varying scales that is extremely important to the overall health and biodiversity of the system." As Rhoads and Germano (1986) addressed in their discussion of "Stage I" versus "Stage III" assemblages in an ecosystem, both have their overall functions and are needed. But what is the critical loading rate of natural organics or contaminants that would cause an equilibrium (Stage III) community retrograde to a

Stage I? Further, what is a "healthy balance" of Stage III versus Stage I on a regional scale? These are first-order resource management questions without known answers.

While nature will, no doubt, always have a balance of the successional continuum, clearly there are extreme pulses of disturbance (or stability) when the "ecological pendulum" is too far at either end and the system is "out of balance" so something will happen to cause change. Applying this analogy to the Peconic Estuary, yes, there probably are natural areas of an estuary where flushing rates are low and organic loadings are high, which is part of the normal ecosystem and probably of value for some species with respect to feeding or protected nursery areas. What requires vigilant resource management is when the number of these quiescent, depositional (high sediment oxygen demand, high TOC, low DO) areas start to increase due to anthropogenic stress (e.g., coastline development, leaking septic systems, excessive lawn fertilization along the shoreline) and the estuary reverts to a stagnant swamp. Although, it also follows that there are benefits to a swamp also, from a larger scale ecosystem perspective.

Thus, while we caution that the terms "disturbed" or "poor quality" are indeed subjective when applied to benthic environments, we acknowledge that any resource management perspective is somewhat subjective. It will inherently be biased according to the current societal or scientific beliefs of the day (or from the perspective of the species or group for which the habitat is trying to be managed or maximized). What is needed is a balance, or moderation of all extremes. As to what defines a proper or improper balance as far as ecosystem community types unfortunately remains a subjective, or personal, argument at this point--there are no commonly accepted standards.

With respect to toxic contaminants, management objectives should focus on (1) addressing organic carbon loading, (2) better characterizing the contaminant distributions in the vicinity of East Creek, Meetinghouse Creek, and other potentially contaminated embayments and creeks/rivers, and (3) addressing potentially elevated loadings of heavy metals.

1.0 Introduction

1.1 Background

In seeking to assure the protection of our nation's estuaries, the National Estuary Program (NEP) requires Comprehensive Conservation and Management Plans (CCMPs) to be developed for estuaries of national significance. CCMPs assure the protection of the designated estuaries by recommending priority corrective actions and compliance schedules that address point and nonpoint sources of pollution to restore and maintain the chemical, physical, and biological integrity of the estuaries.

The Peconic Estuary, which consists of more than 100 distinct bays, harbors, embayments, and tributaries covering an area of over 100,000 acres on Long Island, was added by the U.S. Congress to the list of nationally significant estuaries in 1988. The Peconic Estuary was accepted by the U.S. Environmental Protection Agency (EPA) into the NEP in September 1992; the Peconic Estuary Program (PEP) was initiated in April 1993. The PEP is funded by EPA, the Suffolk County Department of Health Services (SCDHS), and the New York State Department of Environmental Conservation (NYSDEC), with the SCDHS serving as the Program Office.

1.2 Study Objectives

In order to develop meaningful and effective management strategies, the physical, biological, and chemical dynamics of the estuary must be understood. The focus of this study has been toxic chemical contaminants. The overall objective has been to further the understanding of the chemical contaminant dynamics of the Peconic Estuary ecosystem through a survey of sediment quality in non-randomly selected locations. Several specific objectives related to PEP management objectives that this study has tried to address are as follows:

- Review available data on toxic chemical contaminant distributions in sediments and biota to identify (1) contaminants that may pose risk and (2) critical data gaps
- Examine spatial distributions of toxic chemical contaminants in estuarine sediments through chemical analyses of field samples
- Characterize sediment properties that may influence accumulation of toxic contaminants, such as grain size distribution and organic carbon content
- Identify chemical contaminants that may adversely affect biological resources of the Peconic Estuary
- Determine, to a general level, potential sources of chemical contaminants
- Compare concentrations of toxic contaminants in the Peconic Estuary to concentrations that have been shown to cause adverse effects to estuarine organisms
- Identify additional needs for research regarding sources, transport, and fate of toxic contaminants and impacts on living resources, human health, and the ecosystem

These objectives have guided the data collection framework developed for this study.

1.3 Study Design

The study design focuses on the benthic, or sediment environment, as an indicator of water quality, chemical contaminant loadings, and ecosystem health. The value of using the benthic environmental condition as an integrative indicator of ecosystem health has been demonstrated through the successful application of the Sediment Quality Triad method (e.g., Long and Chapman, 1985; Chapman, 1986; Chapman et al., 1987; Long and Morgan, 1990; Chapman et al., 1991; Carr, 1993; Hyland and Costa, 1995) and other investigative approaches that utilize complementary indicators of ecosystem health/stress (e.g., Costa and Sauer, 1994).

The study objectives were addressed primarily through a measurement program providing chemical characterization of sediments (sampled in September 1994). Consistent with the "initial reconnaissance" nature of this study, a relatively small number of samples (12 stations) were collected and analyzed for a broad range of contaminants. The chemical characterization provided measurements of contaminant concentrations for comparison with levels that have been shown to adversely affect benthic organisms (Long and Morgan, 1990; MacDonald, 1992; Long et al., 1995). These data were supplemented with a review of sediment chemistry data that were available for the Peconic Estuary. The data sets from several previous studies are briefly discussed in Section 2 of this report.

In order to address data gaps with respect to sediment toxicity, benthic infaunal communities, and general sediment quality, an additional measurement component was added to the study design. A Sediment Profile Imaging (SPI) survey was subsequently performed (April 1995) to provide physical and biological measures of benthic conditions at the same locations that had been sampled in the sediment chemistry survey.

For the measurement components of this study, 12 stations were sampled for surface sediments, one which could not be accessed for the SPI survey. The stations were selected from among the 16 stations established for the Peconic Estuary Program's Sediment Flux and Toxics Monitoring Program. Section 3 of this report describes the field sampling portion of the study. Station locations are represented on a map of the study area and documented in a table. Additional documentation (Site Logs) of sediment sampling locations is provided in Appendix A to this report. Field sampling methods and quality control measures are also described in Section 3.

The chemical analyses used for the sediment characterization followed the analytical strategy developed by the National Oceanic and Atmospheric Administration (NOAA) for the National Status and Trends (NS&T) Program. This analytical design, adopted by the EPA for the Environmental Monitoring and Assessment Program (EMAP), has been successfully applied in similar studies for the Delaware Estuary Program (Costa and Sauer, 1994) and Massachusetts Bays Program (Hyland and Costa, 1995). The analytical strategy features ultra-trace level measurements (i.e., low parts per billion, ng/g, detection limits) for organic compound classes that have been shown to be nearly ubiquitous in coastal sediments in highly populated regions. These chemicals have also been shown to adversely affect aquatic organisms at concentrations that are often below reporting limits provided by conventional analytical methods (e.g., EPA Solid Waste 846 series methods and Contract Laboratory Program).

Target analytes consist of priority pollutant and alkylated polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) measured as individual congeners, and organochlorine pesticides. Priority pollutant metals were also targeted, but at detection limits lower than those achievable using conventional methods. Sediment grain size and total organic carbon content were also measured to assess their influence on contaminant distributions. Section 4 of this report describes the methods used for the sediment analyses and the image analyses from the SPI survey.

Section 5 summarizes the data quality objectives (DQOs) and assessments established in the Quality Assurance Project Plan (QAPjP). DQOs were established for the quality control (QC) measures that were implemented as part of our quality assurance (QA) program. DQOs specify measures of data quality that are used to assess accuracy, precision, validity, and quality of sample analytical results. Results of the QC analyses are reported along with their respective sample results in the data appendices.

Results of this study are discussed in Section 6. All newly generated data are reported in Appendices to this report. Data used to support the discussion are presented graphically and in summary tables throughout Section 6. The primary conclusions with respect to the study objectives are summarized in Section 7 of this report. These conclusions may serve as starting points for future studies directed at characterizing the distributions of selected contaminants on an estuarine-wide basis or in selected creeks and embayments. Literature references cited throughout the report are listed in Section 8.

2.0 Historical Data

The review of historical data focused on studies that (1) targeted similar chemical contaminants as this study, (2) measured contaminant concentrations in sediments or biota, (3) documented data quality through valid assessments, and (4) provided biological or toxicological indicators of contaminant-induced degradation. The following studies and sources of data met one or more of these four criteria:

- EPA Environmental Monitoring and Assessment Program (EMAP)
- North Sea Landfill/Fish Cove Study
- Rowe Industries/Sag Harbor Remedial Investigation
- Several 1970's published reports of measurements of PCBs and pesticides in biota
- A Food and Drug Administration (FDA) memorandum (1984) reporting measurements of PCBs, lead (Pb), cadmium (Cd), and chromium (Cr) in oysters
- Peconic Estuary Program Submerged Aquatic Vegetation Study

2.1 Environmental Monitoring and Assessment Program

Two stations within EMAP's Virginian Province fall within the Peconic Estuary Program study area: a station within Great Peconic Bay (sampled in 1990) and a station within Little Peconic Bay (sampled in 1990 and 1991). The data set includes most of the same analytes targeted in this study, including PAHs, PCBs (quantified as individual congeners), organochlorine pesticides, and trace metals in sediments. Additionally, the results of 10-day static acute toxicity tests with amphipods (*Ampelisca abdita*) were also reported.

The Peconic Estuary station results are summarized in Table 2-1. The Effects Range-Low (ER-L) values in Table 2-1 are intended to indicate concentrations at which contaminant concentrations may begin to cause adverse effects to aquatic organisms (Long et al., 1995). Thus, contaminant concentrations below these ER-Ls presumably should not pose ecological risk. Both stations sampled during the 1990 EMAP survey had statistically significant toxicity relative to controls. However, for the data that were available, only nickel (Ni) exceeded the ER-L (Great Peconic Bay station; 1990 data set). As discussed in Section 6.2 (Figure 6-10), the reported concentration of Ni from the EMAP data set is comparable with concentrations measured in this study and within the range of concentrations found in pristine sediments, suggesting unlikely ecological risk due to Ni.

Encountering sediment toxicity without apparent toxic concentrations of contaminants suggest other conditions or factors causing acute toxicity to amphipods in the bioassays. This observation will prove to be consistent with results of this study presented in Section 6, where likely causes are discussed.

Table 2-1: Summary of EMAP Data for Peconic Estuary Stations

Parameter	Conc. Units	ER-L Conc.	Great Peconic Bay--1990	Little Peconic Bay--1990	Little Peconic Bay--1991
LMW-PAH	ng/g	552	41	95	67
HMW-PAH	ng/g	1700	82	29	370
Total PAH	ng/g	4022	123	124	440
Total PCB	ng/g	22.7	ND	ND	3.1
Total DDT	ng/g	1.58	ND	ND	0.85
Ag	µg/g	1.0	ND	ND	NA
Al	%	-	6.18	5.22	NA
As	µg/g	8.2	7.91	6.32	NA
Cd	µg/g	1.2	0.139	0.215	NA
Cr	µg/g	81	53.5	49.7	NA
Cu	µg/g	34	23.1	20.4	NA
Fe	%	-	3.66	2.72	NA
Hg	µg/g	0.15	0.04	0.064	NA
Mn	µg/g	-	887	837	NA
Ni	µg/g	20.9	22.3	17.8	NA
Pb	µg/g	46.7	31.5	29.2	NA
Sb	µg/g	-	0.03	0.021	NA
Se	µg/g	-	0.557	0.431	NA
Sn	µg/g	-	3.37	2.87	NA
Zn	µg/g	150	109	92.9	NA
TOC	%	-	2.38	1.71	1.75
Silt+Clay	%	-	92.2	73.6	46.6
Amphipod Survival (Toxicity)	%	-	67 (Yes)	52 (Yes)	96.3 (No)

ND - Not Detected; NA - Not Available; ER-L - Effects Range-Low
LMW-PAH - Low-Molecular-Weight (2- and 3-ringed) Polynuclear Aromatic Hydrocarbons
HMW-PAH - High-Molecular-Weight (4- through 6-ringed) PAH
PCB - Polychlorinated Biphenyls
Total DDT - 2,4'-DDT + 4,4'-DDT
TOC - Total Organic Carbon

2.2 North Sea Landfill/Fish Cove Study

The objectives of the North Sea Landfill/Fish Cove study were to evaluate (1) potential impacts from the North Sea Landfill on water quality, (2) the flux of leachate solutes across the sediment-water interface, and (3) tissue residue concentrations and mortality of *Mercenaria mercenaria* in the southeast area of Fish Cove. Although not actually in Peconic Bay, Fish Cove is connected tidally to North Sea Harbor, which is an inlet off Little Peconic Bay situated adjacent to the North Sea Landfill. This study, conducted 1989 through 1990, included measurements of ammonia (NH^{4+}), iron (Fe^{++}), manganese (Mn^{++}), phosphate (HPO_4^{3-}) (by colorimetric analyses) and chloride (Cl^{-}) (by titrimetry) in surface water (conducted by J. Mackin, SUNY Stony Brook Marine Science Research Center). Additionally, the study measured volatile organic compound and trace metal priority pollutants in water, sediment, and tissue of hard clams (H2M GROUP, 1992). Results of these measurements found the highest manganese concentration (2.22 mg/L) at Station C in the southeast portion of the cove. This site also had the highest porewater concentrations of ammonia (40 mg/L) and iron (4 mg/L). Flux calculations of these solutes from the sediments were highest at Station C and decreased farther away from this location. The elevated concentrations of ammonia, iron, and manganese were attributed to several contributing sources, including landfill leachate, stormwater runoff, and natural sources.

Bioassays with hard clam (*Mercenaria mercenaria*) larvae were performed. The investigators concluded from the bioassay results that larvae transported to the southeast portion of Fish Cove--the identified "impacted zone"--would not survive. However, subsequent field surveys revealed a population hard clams with varying ages and comparable with populations found in healthy near-shore habitats that support commercial fisheries. In addition, field survey results reported a diversity of other fauna and flora species, some of which are more environmentally sensitive than *Mercenaria mercenaria*. Thus, in the context of the entire estuary, there appears to be little or no ecological risk posed by contaminants leaching from the North Sea landfill, with any influences from toxic contaminants likely to be very localized.

2.3 Rowe Industries/Sag Harbor Remedial Investigation

A public health assessment was performed by the New York State Department of Health (1993) in response to contamination of ground water from the Rowe Industries site in Sag Harbor. The site, which has been placed on the National Priorities List, contains a facility that operated as a small tool and motor manufacturing plant from 1961 through 1974. The facility was subsequently purchased by Aurora Industries and then Nabisco, Inc. The primary pollution issue is contamination of ground water by volatile organic compounds. Surface water (16 samples from five locations) and sediments (19 samples from five locations corresponding to surface water stations) were collected in Ligonee Brook, which drains into Sag Harbor Cove. Concentrations up to 30 parts per billion (ppb or µg/L) of 12 volatile organic compounds were detected in water samples. These compounds were also identified as constituents of the Rowe Industries site plume. Sediment concentrations of volatile organic compounds up to 0.34 parts per million (ppm or µg/g) were reported.

2.4 Miscellaneous Reports

Several investigators have reported measurements of semivolatile organic compounds and metals in tissues of fish and shellfish from the Peconic Estuary. Because these reports date from the 1970s and 1984, they are of limited value in assessing the current contaminant dynamics in the estuary. However, these reports serve to provide some context for the historical influence of these chemical contaminants in this system.

As part of a national monitoring program for organochlorine residues in estuarine mollusks, concentrations of dichlorodiphenyl trichloroethene (DDT) (0.2 ppm) and dieldrin (0.1 ppm) were reported in *Mercenaria mercenaria* collected from Flanders Bay between 1966 and 1972 (Butler, 1973). DDT residues were measured in shellfish collected between 1968 and 1970 from Flanders Bay at concentrations ranging up to 0.14 ppm (Foehrenbach, 1972). Pesticides (DDT and its metabolites, and dieldrin) and PCBs (as Arochlor 1254) were reported in mummichog collected from the Peconic River and Orient Harbor in the Fall of 1977 (Foehrenbach and Sullivan, 1978). Arochlor 1254 concentrations were reported at 0.14 and 0.15 ppm for Orient Harbor and Peconic River fish, respectively; total DDTs were 0.05 and 0.2 ppm, respectively, in the same samples. In a 1984 study, oysters from Orient Harbor and Sag Harbor contained measurable concentrations of chromium (0.03 ppm), cadmium (0.62 ppm), and lead (0.14 ppm); PCBs and pesticides were not detected (detection limits not stated) (Leone, 1984).

2.5 Peconic Estuary Program Submerged Aquatic Vegetation Study

A comprehensive survey of submerged aquatic vegetation (SAV) has been performed as part of the PEP (Cashin Associates, 1995). Important conclusions regarding current conditions in the Peconic and ecosystem health are reported. Those will be discussed in Section 7 of this report in the context of conclusions pertaining to contaminant dynamics resulting from this study.

3.0 Field Sampling

Sediment samples were collected at 12 stations throughout the Peconic Estuary during a survey conducted September 20 and 21, 1994. Sediments were sampled for chemical characterization, including semivolatile organic compounds, metals, total organic carbon (TOC), and grain size analyses. A second survey was conducted April 21, 1995 to obtain additional information about the condition of the sedimentary environment using Sediment Profile Imaging (SPI). Sediment photographic images were successfully obtained at all stations with the exception of Station 12 within the Peconic River.

The following sections describe the station locations, sediment sampling methods, and SPI methods.

3.1 Station Locations

A non-random sampling design was chosen for this program consisting of both bay and nearshore stations. The 12 station locations (Figure 3-1) were selected to coincide with the Sediment Flux Monitoring stations. The six bay stations consisted of the following locations:

- Station 3 - **Flanders Bay**
- Station 6 - **Great Peconic Bay** (central basin/deep)
- Station 7 - **Little Peconic Bay**
- Station 8 - **Noyac Bay**
- Station 9 - **West Neck Bay**
- Station 10 - **Gardiners Bay**

In addition to the bay stations, six nearshore stations were sampled:

- Station 11 - **Fish Cove**; chosen because of suspected landfill leachate and stormwater runoff
- Station 12 - **Peconic River**; downstream of the Grumman and Brookhaven National Laboratory sewage treatment plant discharge and the Swan Lake golf course
- Station 13 - **East Creek**; suspected pesticide influence
- Station 14 - **Mouth of the Peconic River**
- Station 15 - **Upper Sag Harbor Cove**; chosen to incorporate potential influence from the Rowe Industries Site
- Station 16 - **Meetinghouse Creek**

3.2 Station Documentation

Based on the targeted sampling locations described in this section, the field sampling team established suitable and safe sampling stations as close as possible to the target locations. The sampling vessel, provided and operated by Suffolk County Department of Health Services staff, was maneuvered onto each station and was maintained on site by the boat captain. The position of each sampling station was documented using three methods: (1) visual positioning by bearings, (2) photodocumentation, and (3) a LORAN-C electronic navigational system. The sampling station coordinates provided in Table 3-1 were verified using NOAA nautical charts to confirm LORAN-C coordinates.

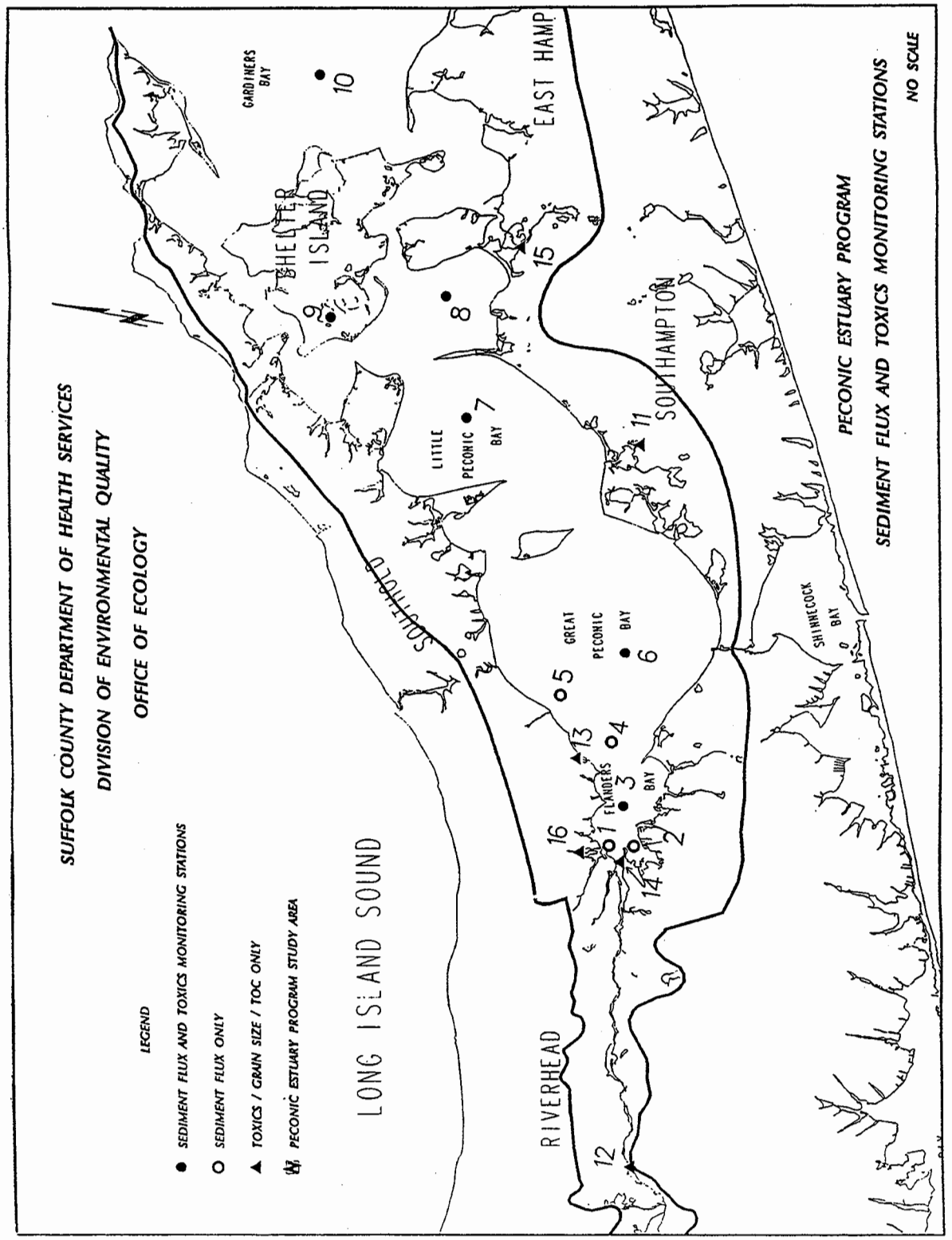


Figure 3-1: Peconic Estuary Program Study Area

Table 3-1 Sampling Locations

Station	Location Description	Latitude	Longitude
3	Flanders Bay	40°55'20"N	72°35'32"W
6	Great Peconic Bay (central basin/deep)	40°56'00"N	72°30'30"W
7	Little Peconic Bay	40°59'62"N	72°25'06"W
8	Noyac Bay	41°00'79"N	72°20'54"W
9	West Neck Bay	41°03'70"N	72°21'41"W
10	Gardiners Bay	41°05'87"N	72°12'21"W
11	Fish Cove		
12	Peconic River		
13	East Creek	40°56'53"N	72°33'98"W
14	Mouth of the Peconic River	40°55'22"N	72°36'85"W
15	Upper Sag Harbor Cove	40°59'29"N	72°18'09"W
16	Meetinghouse Creek	40°56'20"N	72°36'87"W

Site Logs were prepared by the field sampling team at each station documenting the sampling date, time, location, and sediment collection.

3.3 Sediment Sampling Methods

Sediment samples were collected from at least four different points within each station boundary (as defined by a 100-m radius from the station center). A Petite Ponar grab sampler was used to collect sediment. Prior to deployment, the grab sampler was decontaminated by sequential solvent rinsing with acetone, dichloromethane, and deionized water.

At each station, surface sediment (approximately the upper 2 cm) was composited from four casts of the grab. Upon retrieval of the grab sampler, sediment was subsampled with a decontaminated Teflon®-coated scoop. Care was taken to remove sediment from the internal portion of the grab, leaving behind any of the sediment that came into contact with the sides or bottom of the grab sampler. The sediment subsampled from each of the grabs was placed into a stainless-steel bowl and homogenized. Subsamples were aliquoted from each homogenized station composite for chemical characterization. At Station 3, five casts were required to obtain a sufficient amount of sediment. The grab sampler was not used at the Peconic River Station 12. Teflon®-coated scoops were used to collect the top 2 cm of sediment at this station. Subsamples for chemical analyses were stored in 500-mL I-CHEM® jars for organic analyses, 250-mL I-CHEM® jars for both metals and TOC analyses, and plastic freezer bags for grain size measurement.

3.4 Sediment Profile Imaging (SPI)

SPI is a formal and standardized technique (Rhoads and Germano, 1982). The method of acquiring SPI data is described below together with QA/QC procedures. Methods for the subsequent image analysis, interpretation, and synthesis are described in Section 4 of this report.

The sediment profile camera used in this survey was a Hulcher sediment profile camera. The camera assembly is mounted horizontally inside a watertight housing on top of a wedge-shaped prism. The prism has a Plexiglass® faceplate at the front with a mirror placed at a 45° angle at the back. The camera lens looks down at the mirror, which reflects the image from the faceplate. The prism has an internal strobe mounted inside at the back of the wedge to provide illumination for the image; this chamber is filled with distilled water, so the camera always has an optically clear path through which to photograph. This wedge assembly is mounted on a moveable carriage within a stainless-steel frame. The frame is lowered to the seafloor on a winch wire. Tension on the wire keeps the prism in its "up" position. When the frame comes to rest on the seafloor, the winch wire goes slack (Figure 3-2) and the camera prism descends into the sediment at a slow rate, controlled by the dampening action of a hydraulic piston so as not to disturb the sediment-water interface. On the way down, it trips a trigger that activates a time-delay circuit to allow the camera to reach maximum penetration into the seafloor before the picture is taken.

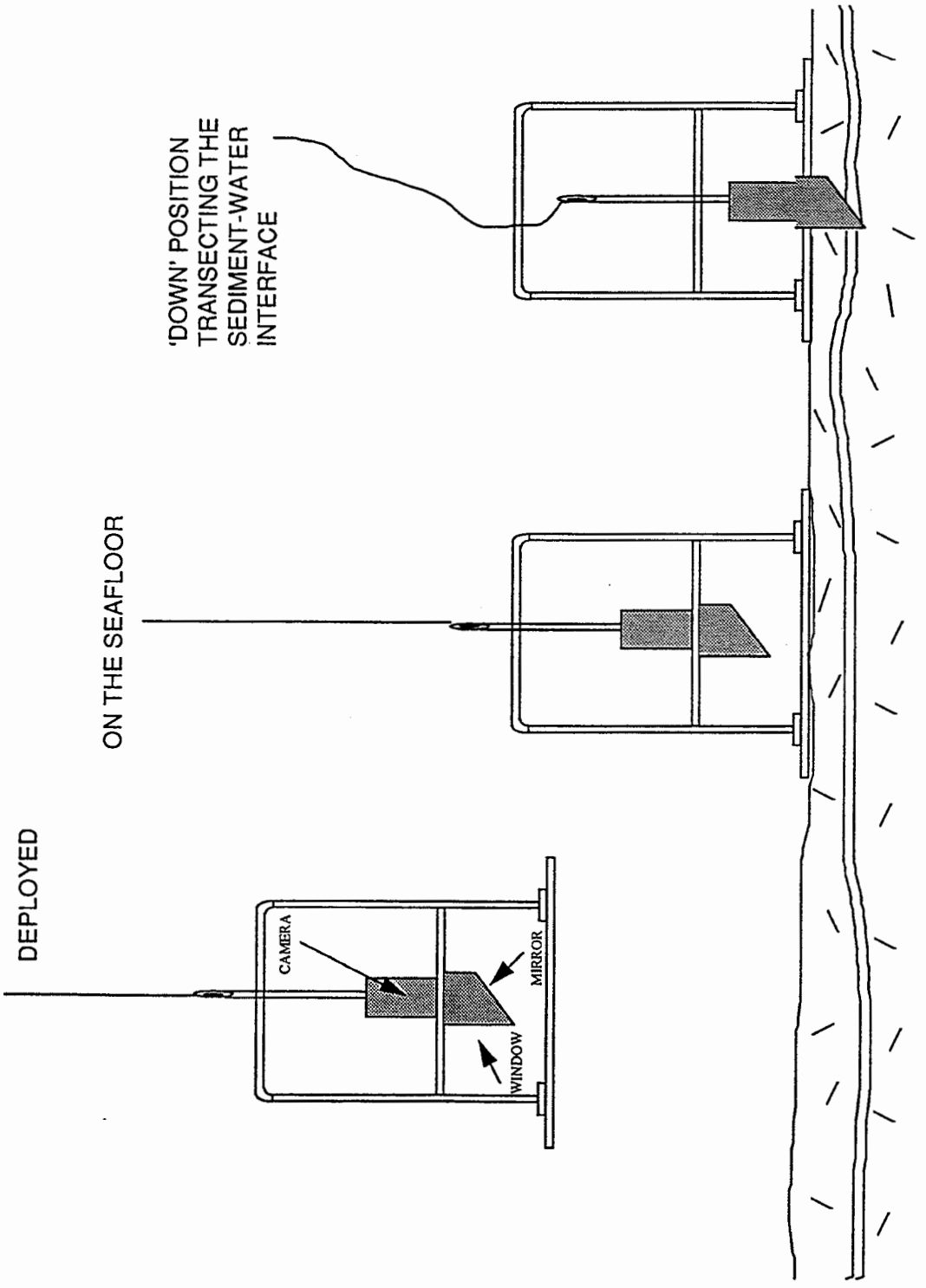


Figure 3-2: The central cradle of the camera is held in the "up" position by tension on the winch wire as it is being lowered to the seafloor (left); once the frame base hits the bottom (center), the prism is then free to penetrate the bottom (right) and take the photograph.

The knife-sharp edge of the prism transects the sediment and the prism penetrates the bottom. The strobe is discharged to obtain a cross-sectional image of the upper 20 cm of the sediment column. The camera is then raised approximately 2 to 3 meters off the bottom while an internal motor drive advances the film. The strobe recharges within 5 seconds and the camera is ready to be lowered again for another image. Surveys can be accomplished rapidly by "pogo-sticking" the camera across an area of seafloor while recording positional fixes on the surface vessel. The resulting images give the viewer the same perspective as looking through the side of an aquarium half-filled with sediment.

3.5 Field Quality Control

Appropriate QC measures were implemented to prevent contamination of samples during collection, to ensure proper documentation for all samples collected, to maintain proper storage of sediments during transportation, and to establish formal chain-of-custody (COC) from collection and shipment in the field, to receipt in the laboratory.

3.5.1 Sampling Equipment. All sampling equipment was cleaned prior to use at each station. The sampling jars (I-CHEM®) used for chemistry samples were purchased precleaned by the supplier.

3.5.2 Labeling and Documentation. All samples were assigned unique laboratory sample identification numbers. Field notes (e.g., sampling date, time, location, personnel, deviations from the sampling plan, observations) for each station were recorded on a Site Log. Each Site Log was signed and dated by the sampling personnel. COC forms were completed for all samples collected. The COC forms included the following information: sample ID, sampling date, sampling time, and analyses to be performed. COC forms were signed by personnel relinquishing and accepting custody. Copies of all COC forms are maintained at Arthur D. Little's Environmental Monitoring and Analysis Laboratory.

3.5.3 Shipment and Storage. Original COC forms remained with their associated samples during transportation/shipment. Samples were refrigerated from the time of collection by storing them in coolers packed with ice. Samples received from the field were examined and any pertinent observations noted when the samples were logged into the laboratory. COC and controlled storage procedures were used to ensure that samples and sample extracts were traceable in the laboratory. Following receipt in the laboratory, samples for grain size analyses were refrigerated. Samples for all other analyses were stored frozen.

3.5.4 Sediment Profile Imaging. During the Peconic Estuary survey, the frame counter was checked after the camera was deployed at each station to make sure that the requisite number of replicates had been photographed. In addition, a prism-penetration-depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth to acquire a profile image. If images were missed (frame counter indicator) or the penetration depth was insufficient (penetration indicator), additional replicates were photographed. Strict controls were maintained for film development temperatures, times, and chemicals to ensure consistent

density on the film emulsion and minimize potential interpretive error by the computer-image analysis system.

The chemical contaminants targeted in this study were selected because of their potential to degrade benthic environments and adversely affect biological resources. PAHs, PCBs, targeted as individual congeners, and chlorinated pesticides were the organic compound classes targeted. Aldicarb, a carbamate pesticide, was targeted because of its known historical use in the Peconic Estuary. Priority pollutant trace metals were also analyzed. Chemical analyses were performed on 12 field sediment samples and associated QC samples. TOC and sediment grain size (gravel, sand, silt, and clay fractions) were measured as auxiliary parameters. An additional 12 sediments samples, from the study of vegetation distributions performed by Cashin Associates (G. Greene, Principal Investigator), were analyzed for TOC and grain size.

Homogenized sediment samples for all chemical analyses, with the exception of grain size, were stored frozen in the dark in 500-mL or 250-mL I-CHEM® wide-mouth jars. Storage in frozen condition extends the effective holding time for sediments, which is typically 14 days for refrigerated sediments for most analyses, to an indefinite period. The Quality Assurance/Project Plan (QAPjP) recommended 60 days for extraction holding times. Sediment samples for grain size analysis (no holding time requirement) were stored refrigerated, not frozen, in plastic freezer bags.

In the laboratory, sediment samples were aliquoted as follows:

- 30 g for extraction of organic compounds
- 5 g for determination of moisture content
- 10 g for analysis of metals
- 50 g for sediment grain size determination
- 5 g for TOC measurement
- 100 g for aldicarb
- The remaining sample material (and all extracts) were archived in a sample freezer until completion of the study

4.1 Organic Compound Analyses

4.1.1 Sediment Extraction. Sediment samples were extracted for organic compounds using the Arthur D. Little standard operating procedures (SOP) ADL-2819 "Extraction of Polychlorinated Biphenyls (PCBs) and Chlorinated Pesticides from Sediment or Shoreline Soil Samples," with the addition of PAH surrogates, as discussed below. The sediments to be extracted were placed in a 500-mL Teflon® jar, mixed with sodium sulfate, and spiked with the appropriate amount of pesticide surrogate compound 4,4'-dibromooctafluorobiphenyl (DBOFB) and PCB congeners (103 and 198) and PAH surrogate compounds (d_8-naphthalene, d_{10}-acenaphthene, d_{10}-phenanthrene, and d_{12}-benzo(a)pyrene). Each sample was spiked with 0.1 µg PCB/pesticide surrogates, and 0.4 µg PAH surrogates.

Each sample was vigorously shaken for approximately 30 seconds, then underwent three sequential solvent extractions using sonication to promote solvent/matrix contact and phase partitioning. Resulting whole extracts were centrifuged and combined for each sample. Each sample was then dried over Na_2SO_4, concentrated by Kuderna-Danish

evaporation to less than 10 mL, and then transferred to a 25-mL vial and further concentrated by nitrogen evaporation to approximately 1 mL. The total extract weight of each sample was determined prior to cleaning extracts using alumina column chromatography.

4.1.2 Extract Fractionation/Cleanup. Sample extracts underwent size-exclusion chromatography by high performance liquid chromatography (HPLC), following Arthur D. Little SOP ADL-2821 "Fractionation/Cleanup of Sample Extracts for Semivolatile Hydrocarbons, Polychlorinated Biphenyl, and Chlorinated Pesticide Analyses." This chromatography method was developed by Arthur D. Little specifically to isolate an extract fraction that contains PCBs, pesticides, and PAHs. The automated HPLC sample delivery system splits (50:50) the extract, so that a one-half split of each extract was fractionated by HPLC. The other one-half split was archived. The resulting extract was then concentrated to 500 µL, and spiked with an appropriate amount of internal standards. The internal standard used for PCB/pesticide quantification, tetrachloro-m-xylene (TCMX), was spiked into the samples at 50 ng. The PAH internal standards, d_{10}-fluorene and d_{12}-chrysene, were added at 0.2 µg.

4.1.3 GC/MS Instrumental Analysis. An aliquot of the extract fraction was analyzed for the target PAHs listed in Table 4-1 following Arthur D. Little SOP ADL-2827 "Determination of Polynuclear Aromatic Hydrocarbons and Selected Heterocyclic Compounds by Gas Chromatography/Mass Spectrometry in the Selected Ion Monitoring Mode." An initial calibration was analyzed using standards with concentrations of approximately 25, 75, 250, 1,250, and 5,000 ng/mL. In order to be deemed acceptable, the percent relative standard deviation (%RSD) of the average relative response factors (RRF) for each of the analytes was ≤ 35 percent. A mid-level calibration solution was analyzed for approximately every 12 to 18 hours of instrument run time, and also met the criteria set in SOP ADL-2827 for acceptability. It should be noted that the PAH analyte list in Table 4-1 exceeds those compounds currently designated as EPA priority pollutants. The importance of quantifying alkylated PAHs (e.g., C_1- through C_4-naphthalenes) in addition to the parent compounds is based on the environmental importance of these alkyl homologues, which are generally toxic and frequently are present in far greater abundance than the parent compounds (Neff, 1979).

Table 4-1 designates each analyte and its corresponding surrogate used for quantification. It is important to note that although the alkyl homologues are listed as target analytes, the relative response factor of the corresponding parent compound was used for quantification. Analyte quantifications were based on responses relative to the appropriate surrogate compounds resulting in concentrations that were adjusted for surrogate compound recovery. Concentrations were reported as ng/g dry weight of sediment.

4.1.4 Gas Chromatography-Electron Capture Detection Instrumental Analysis. The extract fraction was also analyzed for the PCB congeners and chlorinated pesticides listed in Table 4-2 by dual-column gas chromatography-electron capture detection (GC-ECD) following Arthur D. Little SOP ADL-2818, "Determination of Chlorinated Pesticides and PCB Congeners by Gas Chromatography-Electron Capture Detection

Table 4-1. PAH and Alkyl Homologue PAH Target Analyte List

Compound	Surrogate Reference	Compound	Surrogate Reference
Naphthalene (C0N)	1	Benzo[a]anthracene (BAA)	3
C_1-Naphthalenes (C1N)	2		
C_2-Naphthalenes (C2N)	2	Chrysene (C0C)	3
C_3-Naphthalenes (C3N)	2	C_1-Chrysenes (C1C)	3
C_4-Naphthalenes (C4N)	2	C_2-Chrysenes (C2C)	3
		C_3-Chrysenes (C3C)	3
Acenaphthylene (ACEY)	2	C_4-Chrysenes (C4C)	3
Acenaphthene (ACE)	2	Benzo[b]fluoranthene (BBF)	4
Biphenyl (BIP)	2	Benzo[k]fluoranthene (BKF)	4
Fluorene (C0F)	2	Benzo[a]pyrene (BAP)	4
C_1-Fluorenes (C1F)	2		
C_2-Fluorenes (C2F)	2	Benzo[e]pyrene (BEP)	4
C_3-Fluorenes (C3F)	2		
		Perylene (PER)	4
Phenanthrene (C0P)	3		
Anthracene (COA)	3	Indeno[1,2,3-c,d]pyrene (IND)	4
C_1-Phenanthrenes/Anthracenes (C1P/A)	3		
C_2-Phenanthrenes/Anthracenes (C2P/A)	3	Dibenz[a,h]anthracene (DAH)	4
C_3-Phenanthrenes/Anthracenes (C3P/A)	3		
C_4-Phenanthrenes/Anthracenes (C4P/A)	3	Benzo[g,h,i]perylene (BGP)	4
Dibenzothiophene (C0D)	3		
C_1-Dibenzothiophenes (C1D)	3		
C_2-Dibenzothiophenes (C2D)	3		
C_3-Dibenzothiophenes (C3D)	3		
Fluoranthene (FLANT)	3		
Pyrene (PYR)	3		
C_1-Fluoranthenes/Pyrenes (C1F/P)	3		
C_2-Fluoranthenes/Pyrenes (C2F/P)	3		
C_3-Fluoranthenes/Pyrenes (C3F/P)	3		
Surrogate Compounds			
Naphthalene-d_8	1,A		
Acenaphthene-d_{10}	2,A		
Phenanthrene-d_{10}	3,A		
Benzo(a)pyrene-d_{12}	4,B		
Recovery Internal Standards			
Fluorene-d_{10}	A		
Chrysene-d_{12}	B		

Note: Alkylated phenanthrenes and anthracenes, and alkylated fluoranthenes and pyrenes are quantified together as total alkylated phenanthrene/anthracenes and total fluoranthenes/pyrenes

Table 4-2. Chlorinated Pesticide/PCB Congener Target Analyte List

Compound	Surrogate Reference	Compound	Surrogate Reference
Aldrin	3	**Surrogate Compounds**	
Endrin	3	DBOFB Dibromo-octafluoro-biphenyl	1,A
Dieldrin	3	PCB 103	2,A
alpha-Chlordane	3	PCB 198	3,A
trans-Nonachlor	3		
gamma-Chlordane	3	**Recovery Internal Standard**	
Heptachlor	3	TCMX Tetrachloro-m-xylene	A
Heptachlor Epoxide	3		
Hexachlorobenzene	3		
alpha-BHC	3		
Mirex	3		
beta-BHC	3		
gamma-BHC (Lindane)	3		
Endosulfan sulfate	3		
delta-BHC	3		
Endrin ketone	3		
Methoxychlor	3		
2,4'-DDD	3		
4,4'-DDD	3		
2,4'-DDE	3		
4,4-DDE	3		
2,4'-DDT	3		
4,4'-DDT	3		
PCB-8(2,4')	3		
PCB-18(2,2',5)	3		
PCB-28(2,4,4')	3		
PCB-44(2,2',3,5')	3		
PCB-52(2,2',5,5')	3		
PCB-66(2,3',4,4')	3		
PCB-77(3,3',4,4')	3		
PCB-101(2,2',3,5,5')	3		
PCB-105(2,3,3',4,4')	3		
PCB-118(2,3',4,4',5)	3		
PCB-126(3,3',4,4',5)	3		
PCB-128(2,2'3,3',4,4')	3		
PCB-138(2,2',3,4,4'5')	3		
PCB-153(2,2'4,4',5,5')	3		
PCB-170(2,2',3,3',4,4',5)	3		
PCB-180(2,2',3,4,4',5,5')	3		
PCB-187(2,2',3,4',5,5')	3		
PCB-195(2,2',3,3',4,4'5,6)	3		
PCB-206(2,2',3,3',4,4',5,5',6)	3		
PCB-209(2,2'3,3'4,4'5,5'6,6')	3		

(GC-ECD)." This dual-column method, which uses quantification from a RTX-5 column (equivalent to a DB-5 column) with confirmation using a DB-17 column, provides for more confident identification of PCB congeners than a single-column analysis. The DB-17 column was used to quantify analytes that coelute on the RTX-5 column but are resolved on the DB-17 column. An initial calibration was analyzed using standards with concentrations of approximately 5, 10, 50, 100, and 200 ng/mL. Quantification was based on the recovery internal standard, TCMX. Resulting concentrations were adjusted for the recovery of the surrogate compounds for reporting. Concentrations were reported as ng/g dry weight of sediment.

4.1.5 Aldicarb. Aldicarb, a carbamate pesticide, and several of its metabolites were targeted in this study because of its known historical use in the Peconic Estuary. Aldicarb was analyzed in separate aliquots of field-collected samples. The Suffolk County Public and Environmental Health Laboratory performed the analysis following EPA Method 531.

4.2 Trace Metals Analyses

Sediment aliquots were shipped by overnight delivery to the Marine & Environmental Chemistry Laboratories at the Florida Institute of Technology (FIT). To ensure adequate homogenization, whole wet sediment from each site was carefully mixed with a Teflon® rod and freeze-dried, except for the portion to be analyzed for mercury (Hg). The metals analytes are listed in Table 4-3.

Prior to analysis, 0.4-g aliquots of dried sediment and standard reference sediment were totally digested in Teflon® beakers using concentrated, high-purity HF-HNO_3-$HClO_4$. Total digestion of the sediments is preferred because then no doubt remains about the absolute amount of metal associated with a sample. In the digestion process, 0.5 mL of $HClO_4$, 1 mL of HNO_3 and 3 mL of HF were added to the sediment in a Teflon® beaker and heated at 50°C with a watch cover in place until a moist paste formed. The mixture was heated for another 3 h at 80°C with an additional 2 mL of HNO_3 and 3 mL of HF before being heated to dryness. Finally, 1 mL of HNO_3 and about 30 mL of distilled, deionized water (DDW) were added to the sample and heated strongly to dissolve perchlorate salts and reduce the volume. The completely dissolved and clear samples were then diluted to 20 mL with DDW. This technique ensures complete digestion with no appreciable loss of the target metals. This method has been used successfully in FIT's Marine AND Environmental Chemistry Laboratory for many years with a variety of sediment types.

Sediment Hg concentrations were determined by heating separate aliquots of wet sediment in acid-washed, sealed polypropylene centrifuge tubes with 3 mL of HNO_3 and 2 mL of H_2SO_4. Sample tubes were heated for 1 h in a 65°C water bath and allowed to cool overnight. Each tube was then centrifuged at 2,000 rpm and the supernatant decanted into a 25-mL graduated cylinder. The sediment pellet was rinsed twice with 5 mL of DDW each time, centrifuged and decanted into the graduated cylinder before diluting to a final volume of 20 mL with DDW. Final Hg concentrations were calculated on a dry weight basis using water content data from a subsample taken at the same time as the Hg sample.

Table 4-3: Metals Target Analyte List and Methods

Element	Method
Silver (Ag)	ICP-MS
Aluminum (Al)	FAAS
Arsenic (As)	AAS
Beryllium (Be)	ICP-MS
Cadmium (Cd)	ICP-MS
Chromium (Cr)	FAAS
Copper (Cu)	FAAS, ICP-MS
Mercury (Hg)	CVAAS
Nickel (Ni)	FAAS, ICP-MS
Lead (Pb)	ICP-MS
Antimony (Sb)	ICP-MS
Selenium (Se)	ICP-MS
Thallium (Tl)	ICP-MS
Zinc (Zn)	FAAS

Notes: FAAS - flame atomic absorption spectroscopy
AAS - flameless atomic absorption spectroscopy
CVAAS - cold vapor atomic absorption spectroscopy
ICP-MS - inductively coupled plasma mass spectrometry

Labware used in the digestion process was acid-washed and rinsed with DDW. Procedural blanks and triplicate sample analyses were prepared with each set of samples. Standard Reference Material (SRM) #1646, an estuarine sediment, and SRM #2704, a river sediment, both provided by the U.S. National Institute of Standards and Technology, and a marine sediment sample, BCSS-1, prepared by the National Research Council of Canada, were also digested by the method described herein to document analytical accuracy.

Samples, reference standards, and procedural and reagent blanks were analyzed by either AAS or ICP-MS. Concentrations of Al, Cr, Cu, Ni, and Zn were determined by flame AAS using a Perkin-Elmer Model 4000 AAS. Concentrations of As were determined by flameless AAS using a Perkin-Elmer Model 5100PC instrument. Values for Ag, Be, Cd, Cu, Ni, Pb, Sb, Se, and Tl were determined by ICP-MS using a Perkin-Elmer ELAN 5000 instrument. Mercury analyses were carried out by cold-vapor AAS using a

Laboratory Data Control Mercury Monitor. Matrix interferences were carefully monitored during all analyses for all elements using the method of standard additions.

4.3 Grain Size

Sediment grain size, represented in the general size ranges of gravel, sand, silt, and clay, is often used to normalize chemical concentration data that are being used to assess trends. Grain size analysis was performed by Applied Marine Sciences, Inc., under subcontract to Arthur D. Little following SOP ADL-2833 "Determination of Particle Size Distribution (Phi Size Classification) in Sediment Samples" modified to report gravel, sand, silt, and clay size distributions.

4.4 Total Organic Carbon

TOC is a measure of the total amount of oxidizable material in a sample. Sediment samples were analyzed by Applied Marine Sciences, under subcontract to Arthur D. Little, following the procedures in Applied Marine Sciences SOP AMS-TOC94, "Determination of Total Organic and Carbonate Content of Sediment Samples by Coulometric Detection."

4.5 Sediment Profile Image Analysis

Thorough measurements of all physical parameters and some biological parameters were subsequently measured directly from the color film positives using a video digitizer and computer-image analysis system. The actual film slides were used for analysis instead of positive prints in order to avoid changes in image density that can accompany the printing of a positive image. The full color image analysis system can discriminate up to 16.7 million different shades of color, so subtle features can be accurately digitized and measured. All data stored on disks were printed out on data sheets for editing by the principal investigator and as a hard-copy backup. All data sheets were edited and verified by a senior-level scientist before being approved for final data synthesis, statistical analyses, and interpretation. Automatic disk storage of all parameters measured allows data from any variables of interest to be compiled, sorted, displayed graphically, contoured, or compared statistically. Specific measurement techniques for the SPI parameters measured are described in the following sections.

4.5.1 Sediment Type Determination. The sediment grain-size major mode and range are visually estimated from the photographs by overlaying a grain-size comparator that is at the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes) through the SPI camera. Seven grain-size classes are on this comparator: ≥ 4 phi, 4 to 3 phi, 3 to 2 phi, 2 to 1 phi, 1 to 0 phi, 0 to -1 phi, < -1 phi. The lower limit of optical resolution of the photographic system is about 62 microns, allowing recognition of grain sizes equal to or greater than coarse silt. The accuracy of this method has been documented by comparing our SPI estimates with grain-size statistics determined from laboratory sieve analyses. Also, near-surface stratigraphy such as sand-over-mud or mud-

over-sand can be mapped. This information can provide information as to transport directions when mapped on a local scale near facies boundaries.

4.5.2 Prism Penetration Depth. The SPI prism penetration depth is determined by measuring both the largest and smallest linear distance between the sediment-water interface and the bottom of the film frame. The SPI analysis software automatically averages these maximum and minimum values to determine the average penetration depth. All three values, (maximum, minimum, and average penetration depth) are included on the data sheets. Prism penetration is potentially a noteworthy parameter; if the number of weights used in the camera is held constant throughout a survey, the camera functions as a static-load penetrometer. Comparative penetration values from sites of similar grain-size give an indication of the relative sediment water content.

The depth of the camera's penetration into the bottom reflects the bearing capacity and shear strength of local sediments. Over-consolidated or relic sediments and shell-bearing sands resist camera penetration. Highly bioturbated, sulphidic, or methanogenic muds are the least consolidated, and deep penetration is typical. Seasonal changes in camera prism penetration are typically observed at the same station related to the control of sediment geotechnical properties by bioturbation (Rhoads and Boyer, 1982). The effect of water temperature on bioturbation rates appears to be important in controlling both biogenic surface relief and prism penetration depth (Rhoads and Germano, 1982).

4.5.3 Surface Boundary Roughness. Surface boundary roughness is determined by measuring the vertical distance (parallel to the film border) between the highest and lowest points of the sediment-water interface. In addition, the origin of this small-scale topographic relief is indicated when it is evident (physical or biogenic). Boundary roughness is only accurately measured when the camera is level. In sandy sediments, boundary roughness can be a measure of sand wave height. On silt-clay bottoms, boundary roughness values often reflect biogenic features such as fecal mounds or surface burrows.

The surface boundary roughness (i.e., sediment surface relief) measured over a horizontal distance of 15 cm can typically range from 0.02 to 3.8 cm and may be related to either physical structures (ripples, rip-up structures, mud clasts) or biogenic features (burrow openings, fecal mounds, foraging depressions). Biogenic roughness typically changes seasonally and is related to the interaction of bottom turbulence and bioturbational activities.

4.5.4 Mud Clasts. When fine-grained, cohesive sediments are disturbed, either by physical bottom scour or faunal activity (e.g., decapod foraging), intact clumps of sediment are often scattered about the seafloor. These mud clasts can be seen at the sediment-water interface in SPI images. During analysis, the number of clasts is counted, the diameter of a typical clast is measured, and their oxidation state is assessed. Depending on their place of origin and the depth of disturbance of the sediment column, mud clasts can be reduced or oxidized (in SPI images, the oxidation state is apparent from their reflectance value; see discussion of Apparent Redox Potential Discontinuity Depth). Also, once at the sediment-water interface, these sediment clumps are subject to bottom-

water oxygen levels and bottom currents. Based on laboratory microcosm observations of reduced sediments placed within an aerobic environment, oxidation of reduced surface layers by diffusion alone is quite rapid, occurring within 6 to 12 h (Germano, 1983). Consequently, the detection of reduced mud clasts in an obviously aerobic setting suggests a recent origin. The size and shape of mud clasts, e.g. angular versus rounded, is also considered. Mud clasts may be moved about and broken by bottom currents and/or animals (macro- or meiofauna; Germano, 1983). Over time, large angular clasts become small and rounded. Overall, the abundance, distribution, oxidation state, and angularity of mud clasts are used to make inferences about the recent pattern of seafloor disturbance in an area.

4.5.5 Apparent Redox Potential Discontinuity (RPD) Depth. Aerobic near-surface marine sediments typically have higher reflectance values relative to underlying hypoxic or anoxic sediments. Surface sands washed free of mud also have higher optical reflectance than underlying muddy sands. These differences in optical reflectance are readily apparent in SPI images. The oxidized surface sediment contains particles coated with ferric hydroxide (an olive color when associated with particles), while reduced and muddy sediments below this oxygenated layer are darker, generally grey to black. The boundary between the colored ferric hydroxide surface sediment and underlying grey to black sediment is called the apparent redox potential discontinuity (abbreviated as the RPD).

The depth of the apparent RPD in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment pore waters. In the absence of bioturbating organisms, this high reflectance layer (in muds) will typically reach a thickness of 2 mm (Rhoads, 1974). This depth is related to the supply rate of molecular oxygen by diffusion into the bottom and the consumption of that oxygen by the sediment and associated microflora. In sediments that have very high sediment-oxygen demand, the sediment may lack a high reflectance layer even when the overlying water column is aerobic.

In the presence of bioturbating macrofauna, the thickness of the high reflectance layer may be several centimeters. The relationship between the thickness of this high reflectance layer and the presence or absence of free molecular oxygen in the associated pore waters must be made with caution. The boundary (or horizon) that separates the positive E_h region of the sediment column from the underlying negative E_h region is called the Redox Potential Discontinuity or RPD. The exact location of this $E_h = 0$ potential can only be determined accurately with microelectrodes; hence, the relationship between the change in optical reflectance, as imaged with the SPI camera, and the actual RPD can only be determined by making the appropriate *in situ* E_h measurements. For this reason, we describe the optical reflectance boundary, as imaged, as the "apparent" RPD, and it is mapped as a mean value. In general, the depth of the actual $E_h = 0$ horizon will be either equal or slightly shallower than the depth of the optical reflectance boundary. This is because bioturbating organisms can mix ferric hydroxide-coated particles downward into the bottom below the $E_h = 0$ horizon. As a result, the apparent mean RPD depth can be used as an estimate of the depth of pore water exchange, usually through pore water irrigation (bioturbation).

The depression of the apparent RPD within the sediment is relatively slow in organic-rich muds (on the order of 200 to 300 micrometers per day); therefore this parameter has a long time constant (Germano and Rhoads, 1984). The rebound in the apparent RPD is also slow (Germano, 1983). Measurable changes in the apparent RPD depth using the SPI optical technique can be detected over periods of one or two months. This parameter is used effectively to document changes (or gradients) that develop over a seasonal or yearly cycle related to water temperature effects on bioturbation rates, seasonal hypoxia, sediment oxygen demand, and infaunal recruitment. Sediment-profile surveys of ocean disposal sites sampled seasonally or on an annual basis throughout the New England region performed under the DAMOS program for the U.S. Army Corps of Engineers, New England Division, have repeatedly documented a drastic reduction in apparent RPD depths at disposal sites immediately after dredged material disposal, followed by a progressive post-disposal apparent RPD deepening (barring further physical disturbance). Consequently, time-series RPD measurements can be a critical diagnostic element in monitoring the degree of recolonization in an area by the ambient benthos.

The depth of the mean apparent RPD also can be affected by local erosion. The peaks of disposal mounds commonly are scoured by divergent flow over the mound. This can result in washing away of fines, development of shell or gravel lag deposits, and very thin apparent RPD depths. During storm periods, erosion may completely remove any evidence of the apparent RPD (Fredette et al., 1988).

Another important characteristic of the apparent RPD is the contrast in reflectance values at this boundary. This contrast is related to the interactions among the degree of organic-loading, bioturbational activity in the sediment, and the levels of bottom-water dissolved oxygen in an area. High inputs of labile organic material increase sediment oxygen demand and, subsequently, sulfate reduction rates (and the abundance of sulfide end-products). This results in more highly reduced (lower-reflectance) sediments at depth and higher RPD contrasts. In a region of generally low RPD contrasts, images with high RPD contrasts indicate localized sites of relatively high past inputs of organic-rich material (e.g., organic or phytoplankton detritus, dredged material, sewage sludge, etc.).

4.5.6 Sedimentary Methane. At extreme levels of organic-loading, pore-water sulphate is depleted, and methanogenesis occurs. The process of methanogenesis is detected by the appearance of methane bubbles in the sediment column. These gas-filled voids are readily discernable in SPI images because of their irregular, generally circular aspect and glassy texture (due to the reflection of the strobe off the gas). If present, the number and total areal coverage of all methane pockets are measured.

4.5.7 Infaunal Successional Stage. The mapping of successional stages is possible with SPI technology and is based on the theory that organism-sediment interactions follow a predictable sequence after a major seafloor perturbation. This theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest, our definition does not demand a sequential appearance of particular

invertebrate species or genera" (Rhoads and Boyer, 1982). This theory is formally developed in Rhoads and Germano (1982, 1986) and Rhoads and Boyer (1982).

Infaunal successional stages or series are recognized in SPI images by the presence of dense assemblages of near-surface polychaetes (Stage I) and/or the presence of subsurface feeding voids produced by head-down deposit feeders (Stage III); both types of assemblages may be present in the same image.

4.5.8 Organism-Sediment Index. The Organism-Sediment Index (OSI) is a summary mapping statistic that is calculated on the basis of four independently measured SPI parameters: mean apparent RPD depth, presence of methane gas, low/no oxygen at the sediment water interface, and successional status. Table 4-4 shows how these sub-indices are summed to derive the OSI. The calculation and use of the OSI are explained in considerable detail in Revelas et al. (1987).

The highest possible OSI value is +11, which reflects a mature benthic community in relatively undisturbed conditions (generally a good yardstick for high benthic habitat quality): deeply oxidized sediment with a low inventory of anaerobic metabolites and low sediment oxygen demand, populated by a climax (Stage III) community. The lowest OSI value is -10, indicating that the sediment has a high inventory of anaerobic metabolites, has a high oxygen demand, and is azoic. In our mapping experience with this parameter over the past 15 years, we have found that OSI values of +6 or less indicate that the benthic habitat has experienced physical disturbance, eutrophication, or excessive, bioavailable contamination in the recent past.

Table 4-4: Calculation of the SPI Organism-Sediment Index Value

A. CHOOSE ONE VALUE:

Mean RPD Depth	Index Value
0.00 cm	0
> 0 - 0.75 cm	1
0.76 -1.50 cm	2
1.51 - 2.25 cm	3
2.26 - 3.00 cm	4
3.01 - 3.75 cm	5
>3.75 cm	6

B. CHOOSE ONE VALUE:

Successional Stage	Index Value
Azoic	-4
Stage I	1
Stage I → II	2
Stage II	3
Stage II → III	4
Stage III	5
Stage I on III	5
Stage II on III	5

C. CHOOSE ONE OR BOTH IF APPROPRIATE:

Chemical Parameters	Index Value
Methane Present	-2
No/Low Dissolved Oxygen**	-4

SPI ORGANISM-SEDIMENT INDEX = Total of above subset indices (A+B+C)

RANGE: -10 to +11

* Note: DO based on the imaged evidence of reduced, low reflectance (i.e., high oxygen demand) sediment at the sediment-water interface, rather than a Winkler or polarigraphic electrode measurement.

5.0 Data Quality Objectives and Assessments

Data quality was assured for this study by (1) selecting appropriate measurement methods for the study objectives, (2) developing a study-specific QAPjP that was reviewed by the study sponsor prior to performing any measurements, (3) implementing the suite of quality control measures specified in the QAPjP, and (4) using the data quality objectives (DQOs) therein to guide any necessary corrective actions.

5.1 Quality Control Measures

DQOs were established for laboratory QC measures in the QAPjP prior to the initiation of this study. The DQOs (Table 5-1) provided guidelines and acceptance criteria for laboratory QC measures including initial calibration and continuing calibration checks, procedural blank analyses, surrogate compound recoveries, and percent differences for replicate analyses.

These DQOs were intended to ensure a high quality data set documented through measures of accuracy and precision. Accuracy was assessed through the monitoring of surrogate compound recoveries and the analysis of standard reference materials (SRMs). Precision was assessed through the analysis of duplicate SRMs. Surrogate compounds were spiked into field and QC samples prior to extraction for semivolatile organic compounds. Recovery internal standards were spiked into extracts prior to instrumental analyses and were used to calculate the recovery of the surrogate compounds.

Potential analytical interference/contamination was monitored through the processing and analysis of laboratory procedural blanks as part of each batch of field samples.

Method detection limits (MDLs), listed in Tables 5-2, 5-3, and 5-4, are typically determined at Arthur D. Little annually for the analyses used in this study. MDLs are determined based on the standard deviation obtained from the analysis of replicate (usually seven) matrix samples spiked at three to ten times the expected MDL. This approach follows guidance provided by EPA (*Federal Register*, 1984).

5.2 Quality Assurance

Quality assurance was implemented through the development of and adherence to the QAPjP. In the laboratory, all reagents and solvents used were logged into a record book. Lot number, purity, and chemical descriptions were recorded. Standards preparation was documented and the records maintained in separate 3-ring binders. Laboratory notebooks or log sheets for all sample preparation activities were maintained. Access to all chemicals, calibration solutions, and reference materials was controlled as part of routine laboratory practice. Balances used to weigh materials were calibrated according to standard procedures.

Table 5-1: Data Quality Objectives and Criteria

Element or Sample Type	Minimum Frequency	Data Quality Objective/ Acceptance Criteria
Polynuclear Aromatic Hydrocarbons		
Initial Calibration	Prior to every batch sequence	5 point curve. % RSD ≤ 35%
Continuing Calibration	Must end analytical sequence and every 12 field samples or 16 hours, whichever is more frequent	%D ≤ 25% for 90% of analytes. %D ≤ 35% for remaining analytes.
Sediment SRM 1941a	Two per batch	Values must be within ± 30% of true value on average for all analytes; not to exceed ± 35% of true value for more than 30% of individual analytes.
Procedural Blank	One per batch	No more than 2 analytes to exceed 5x target MDL unless analyte not detected in associated sample(s) or analyte concentration > 10x blank.
Duplicate SRM	Every batch	Mean RPD ≤ 30% for all target analytes.
Internal Standards/Surrogates	Every Sample	%R 50-125% for quantification surrogates and %R 35-125% for non-quantification surrogates.
Matrix Spike/Spike Duplicate (Advisory only)	One per batch	%R 50-125% RPD ± 25%
Polychlorinated Biphenyls and Pesticides		
Initial Calibration	Prior to every batch sequence	5 point curve. %RSD ≤ 35% for all analytes and ≤ 25% for 90%.
Continuing Calibration	Must end analytical sequence and every 12 field samples or 16 hours, whichever is more frequent	%D ≤ 25% for 90% of analytes. %D ≤ 35% for remaining analytes.
Sediment SRM 1941a	Two per batch	Values must be within ± 30% of true value on average for all analytes; not to exceed ± 35% of true value for more than 30% of analytes.
Procedural Blank	One per batch	No more than 2 analytes to exceed 3x MDL unless analyte not detected in associated sample(s) or analyte concentration > 10x blank value.
Duplicate SRM	Every batch	Mean RPD ≤ 30% for all targets.
Internal Standards/Surrogates	Every sample	%R 50-125% for quantification surrogates and %R 35-125% for non-quantification surrogates.
Matrix Spike/Spike Duplicate (Advisory only)	One per batch	%R 50-125% RPD ± 25%

Table 5-1: Data Quality Objectives and Criteria (continued)

Element or Sample Type	Minimum Frequency	Data Quality Objective/ Acceptance Criteria
Metals		
Initial Calibration	Prior to every batch of samples	3 point curve and a blank. Standard curve correlation coefficient $r^2 >$ 0.990 for all analytes.
Continuing Calibration	Must end analytical sequence and every 10 samples	%D ≤ 5% for all analytes
NIST/NBS 3100 Series SRM	Every 50 field samples	Values must be within ± 15% of accepted values for all certified analytes
NIST/NBS Sediment SRM 1646 and/or 98-A NRC Sediment SRM MESS-1 and/or BCSS-1	One per batch	Values must be within ± 15% of accepted values for all certified analytes
Method Blank	One per batch	No more than 2 analytes to exceed 3x MDL unless analyte not detected in associated sample(s)
Spike Method Blanks	One per batch	%R 90-110%
Target MDLs	Sediment	0.1 - 10 mg/kg
Total Organic Carbon		
Initial Calibration	Prior to every batch of samples	3 point curve. Standard curve correlation coefficient (r) > 0.995
Continuing Calibration	Every batch/every 10 field samples	≤ 15% D
Duplicates	Every batch/every 20 field samples	RPD ≤ 25% or ± MDL if the sample result < 5x MDL
Sediment SRM 1941a	One per batch	≤ 15% D
Reagent/Method Blank	Every batch/every 20 field samples	1/10 sample concentration.
Grain Size		
Duplicates	Every 20 field samples	RPD ≤ 25%

Table 5-2. Arthur D. Little PAH and Alkyl Homologue Method Detection Limits

Analyte	Sediment (ng/g)
Naphthalene	0.26
C_1-Naphthalenes	0.26
C_2-Naphthalenes	0.26
C_3-Naphthalenes	0.26
C_4-Naphthalenes	0.26
Acenaphthylene	0.19
Acenaphthene	0.19
Biphenyl	0.20
Fluorene	0.25
C_1-Fluorenes	0.25
C_2-Fluorenes	0.25
C_3-Fluorenes	0.25
Phenanthrene	0.31
Anthracene	0.18
C_1-Phenanthrenes/anthracenes	0.31
C_2-Phenanthrenes/anthracenes	0.31
C_3-Phenanthrenes/anthracenes	0.31
C_4-Phenanthrenes/anthracenes	0.31
Dibenzothiophene	0.18
C_1-Dibenzothiophenes	0.18
C_2-Dibenzothiophenes	0.18
C_3-Dibenzothiophenes	0.18
Fluoranthene	0.23
Pyrene	0.23
C_1-Fluoranthenes/Pyrenes	0.23
C_2-Fluoranthenes/Pyrenes	0.23
C_3-Fluoranthenes/Pyrenes	0.23
Benzo[a]anthracene	0.22
Chrysene	0.29
C_1-Chrysenes	0.29
C_2-Chrysenes	0.29
C_3-Chrysenes	0.29
C_4-Chrysenes	0.29
Benzo[b]fluoranthene	0.30
Benzo[k]fluoranthene	0.26
Benzo[a]pyrene	0.14
Benzo[e]pyrene	0.25
Perylene	0.10
Indeno[1,2,3-cd]pyrene	0.22
Dibenz[a,h]anthracene	0.33
Benzo[g,h,i]perylene	0.30

Note: MDLs determined as recommended by EPA (40 CFR, Ch. 1, Part 136, Appendix B). MDLs for alkyl PA are assigned the MDL for the parent PAH compound. Based on the following sample size and pre-injection volume (PIV): 50 g dry weight and 0.5 mL PIV for sediments.

Table 5-3. Arthur D. Little PCB Congener Method Detection Limits

Analyte	Sediment (ng/g)
PCB-8(2,4')	0.021
PCB-18(2,2',5)	0.044
PCB-28(2,4,4')	0.030
PCB-44(2,2',3,5')	0.015
PCB-52(2,2',5,5')	0.013
PCB-66(2,3',4,4')	0.016
PCB-77(3,3',4,4')	0.024
PCB-101(2,2',3,5,5')	0.012
PCB-105(2,3,3',4,4')	0.014
PCB-118(2,3',4,4',5)	0.019
PCB-126(3,3',4,4',5)	0.037
PCB-128(2,2'3,3',4,4')	0.016
PCB-138(2,2',3,4,4'5')	0.018
PCB-153(2,2'4,4',5,5')	0.016
PCB-170(2,2',3,3',4,4',5)	0.063
PCB-180(2,2',3,4,4',5,5')	0.018
PCB-187(2,2',3,4',5,5')	0.028
PCB-195(2,2',3,3',4,4'5,6)	0.013
PCB-206(2,2',3,3',4,4',5,5',6)	0.011
PCB-209(2,2'3,3'4,4'5,5'6,6')	0.013

Note: MDLs determined as recommended by EPA (40 CFR, Ch. 1, Part 136, Appendix B). MDLs based on the following sample size and pre-injection volume (PIV): 50 g dry weight and 0.5 mL PIV for sediments.

Table 5-4. Arthur D. Little Chlorinated Pesticide Method Detection Limits

Analyte	Sediment (ng/g)
Aldrin	0.018
Endrin	0.0061
Dieldrin	0.022
alpha-Chlordane	0.017
trans-Nonachlor	0.010
gamma-Chlordane	0.018
Heptachlor	0.019
Heptachlor Epoxide	0.023
Hexachlorobenzene	0.020
alpha-BHC	0.013
Mirex	0.020
beta-BHC	0.024
gamma-BHC (Lindane)	0.017
Endosulfan sulfate	0.026
delta-BHC	0.014
Endrin ketone	0.014
Methoxychlor	0.087
2,4'-DDD	0.017
4,4'-DDD	0.029
2,4'-DDE	0.020
4,4-DDE	0.016
2,4'-DDT	0.026
4,4'-DDT	0.023

Note: MDLs determined as recommended by EPA (40 CFR, Ch. 1, Part 136, Appendix B). MDLs based on the following sample size and pre-injection volume (PIV): 50 g dry weight and 0.5 mL PIV for sediments.

All laboratory data were reviewed to ensure accuracy of all transcribed data by an analyst not involved in performing the analyses. Data were also reviewed by the Project Manager/Principal Investigator from the perspective of internal consistency and comparability.

Upon completion of analyses, a data package was prepared containing all documentation and instrumental analytical outputs necessary to validate the data set. A data audit was performed using the DQOs established for this study. The results of the audit was reported to the Project Manager for response. Corrective actions were applied as deemed necessary by the Project Manager.

5.3 Conformance with DQOs

All QC measures were implemented in accordance with the QAPjP. Project DQOs were met with the exceptions discussed herein. Assessment of precision for metals analyses were determined from analysis of triplicate samples and are expressed as average coefficient of variance [(std. deviation/mean) x 100%] as follows: Ag (16%), Al (2%), As (3%), Cd (9%), Cr (3%), Cu (1%), Hg (5%), Ni (1%), Pb (2%), Tl (1%), and Zn (3%). Precision values typically vary as a function of total metal content and the homogeneity of the sample.

The 60-day holding time for sample extraction as stated in the QAPjP was originally met. However, several sample extract vials did not seal properly and several of the sample extracts went dry prior to analysis, necessitating re-extraction past holding time as a corrective action. Because the samples were kept frozen and holding times for frozen sediments are typically considered indefinite, and also because sediments were analyzed for semivolatile rather than volatile compounds, we have not qualified data because of the holding time exceedance.

The MS and MSD analyses did not meet the advisory data quality objectives for recovery for PAH analytes. However, because MS/MSD recoveries are susceptible to interferences from target analytes in the native sample, no further corrective action or data qualification was deemed necessary. For two samples for which all surrogates failed to meet the target range we consider reported PAH concentrations for Little Peconic Bay (Lab ID 07PEORG) and Meetinghouse Creek (Lab ID 16PEORG) as estimated values. However, from the compositional analysis of PAHs, the data remain usable for the data interpretations for which they were intended.

One of the two SRM analyses did not meet DQOs for the pesticide/PCB analysis. The Project Manager reviewed the data and assessed that the sample results should be reported without qualification.

6.0 Results and Discussion

Several sets of criteria have been developed for evaluating chemically contaminated sediments. Some of the most widely used include Apparent Effects Threshold (AET) concentrations, EPA's Sediment Quality Criteria (SQC), No-Observed Effects Levels/Probable Effects Levels (NOELs/PELs), and Effects Range-Low/Effects Range-Median (ER-L/ER-M) concentrations. All of these are intended to help predict adverse biological effects to aquatic organisms based on measurements of chemical contaminant concentrations in sediments.

In this study, contaminant concentrations are compared to ER-L/ER-M values, which were developed from the National Status and Trends Program database (Long and Morgan, 1990) and recently updated (Long et al., 1995). The "low" and "median" concentrations derive from statistical analyses of chemical measurements and effects endpoints, but essentially correspond to concentration ranges below which contaminant-induced adverse effects are unlikely (ER-L) and above which contaminant-induced effects are likely (ER-M). Concentrations between ER-L and ER-M values fall into a "grey area" of potential effects. In studies similar to this one, which examined linkages between chemical contaminants and sediment quality/degradation in the Delaware Estuary (Costa and Sauer, 1994) and Massachusetts and Cape Cod Bays harbors (Hyland and Costa, 1995), ER-L and ER-M values proved to be effective predictors of reduced sediment quality as indicated by measures of biological effects. Because of the similarities in objectives and analytical methods between this study and these other NEP studies, ER-L/ER-M values are used with this data set to evaluate whether contaminant concentrations in sediments are likely to adversely affect benthic organisms and habitats.

Measurements of TOC and fine-grained sediment content (specifically the "silt + clay" fractions) are used to evaluate the data as well. Organic-carbon-rich muds provide a favorable matrix for the accumulation of organic contaminants. Fine-grained sediments likewise influence the degree to which contaminants are sorbed and accumulated in low-energy, depositional areas. Measurements of these sediment characteristics are used to evaluate whether observed elevations in contaminant concentrations reflect localized contaminant influences (e.g., point sources) or an integration of chronic background contaminants (e.g., nonpoint sources). The distinction between these general types of contaminant sources is important to the management objectives of a CCMP. Point-source influences typically indicate a specific activity or release of pollutants that, upon identification, can be abated or remediated. Nonpoint-source influences typically indicate atmospheric deposition, surface water runoff, groundwater underflow, and other processes that require a more long-term approach to resource management.

Although ER-L and ER-M values (and other sediment-effects criteria) have proven to be useful predictors of contaminant-induced degradation, they are most effectively used as a component of a sediment assessment approach that includes complementary indicators of benthic conditions. This philosophy has been most effectively illustrated through application of the Sediment Quality Triad (e.g., Long and Chapman, 1985; Chapman et al., 1987; Carr, 1993; Hyland and Costa, 1995). The Sediment Quality Triad features complementary measures of 1) biological effects, such as acute and sublethal toxicity, 2) benthic conditions, such as community structure and diversity, and 3) chemical contaminant concentrations.

Sediment profile imaging was used in this study as the complementary indicator of benthic conditions and biological effects attributable to chemical contaminants. The results of the SPI survey and subsequent image analyses provide valuable information regarding background conditions of the sediment environment within the estuary. In trying to understand the pollutant dynamics of an estuarine system with respect to potential effects of chemical contaminant inputs, it is important to characterize conditions where chemical contaminants are not a problem. The SPI documentation of benthic conditions within the estuary also provides a useful link with observations and conclusions derived from the Peconic Estuary Program's other studies.

6.1 Organic Contaminant Distributions

In order to summarize the results of the organic chemical characterization of sediments, several chemical compound classes are presented as summed parameters. The following summations have been used for discussion purposes (individual analyte concentrations are reported in the appendices):

- Total PAHs (TPAH), reported in ng/g dry weight (parts per billion or ppb), consists of the sum of the 2- through 6-ringed PAHs targeted in this study.
- High-molecular-weight (HMW) PAHs, reported in ng/g dry weight, consists of the 4-, 5-, and 6-ringed PAHs targeted in this study and represent the PAHs primarily attributable to combustion of fossil fuel, forest fires, and other pyrogenic sources.
- Low-molecular-weight (LMW) PAHs, reported in ng/g dry weight, consists of the sum of the 2- and 3-ringed PAHs targeted in this study and represent the PAHs primarily attributable to petroleum spills, discharges, and other petrogenic sources.
- Total PCBs, reported in ng/g dry weight, consists of the sum of the PCB congeners targeted in this study multiplied by two, a validated estimate of total PCB concentration that has been derived by NOAA from its National Status and Trends Program database.
- Total DDTs, reported in ng/g dry weight, consists of the sum of 2,4'-DDT and 4,4'-DDT.

Table 6-1 summarizes the concentrations of these summed organic compound classes, their respective ER-L and ER-M concentrations, TOC concentrations, and combined silt + clay content. The additional organochlorine pesticides measured in this study are reported in Appendix C; they are not highlighted in Table 6-1 because none of the measured concentrations exceeded ER-L concentrations.

Table 6-1: Summary of Organic Compound Distributions

	% TOC	% Silt+Clay	Concentrations (ng/g dry wt) LMW PAHs	HMW PAHs	TPAH	TPCBs	Total DDTs
ER-L			552	1700	4022	22.7	1.58
ER-M			3160	9600	44792	180	46.1
Flanders Bay (Station 3)	0.18	2.85	7.13	19.5	26.6	0.072	ND
Great Peconic Bay (Station 6)	2.04	96.86	114	467	581	4.26	ND
Little Peconic Bay (Station 7)	1.67	91.76	235	1011	1246	14.8	ND
Noyac Bay (Station 8)	2.09	88.66	269	1107	1376	11.5	0.54
West Neck Bay (Station 9)	3.21	96.41	200	754	954	24.8	ND
Gardiners Bay (Station 10)	1.43	86.97	376	1332	1708	23.7	ND
Fish Cove (Station 11)	3.98	89.53	321	1365	1686	23.6	1.2
Peconic River (Station 12)	0.67	1.82	214	1356	1570	6.57	0.68
East Creek (Station 13)	6.56	98.1	735	3310	4045	10.7	31.8
Mouth of Peconic River (Station 14)	3.11	50.42	915	2997	3912	12.4	0.63
Upper Sag Harbor Cove (Station 15)	4.06	26.72	594	2279	2873	19.6	10.9
Meetinghouse Creek (Station 16)	9.48	97.9	1296	5625	6921	87.2	20.4

Note: Underlined values exceed applicable ER-L concentrations
LMW PAHs- Low Molecule Weight (2-, 3-ringed) PAHs
HMW PAHs - High Molecule Weight (4-, 5-, 6-ringed) PAHs
TPAH - Total PAHs
DDT - Dichlorodiphenyltrichloroethene
ND - Not Detected

6.1.1 Total Organic Carbon. The role of organic carbon in enhancing the bioavailability of contaminants sorbed to sediments is the focus of considerable research and debate among scientists. EPA's development of SQC for nonionic chemicals, which is based on equilibrium partitioning models, relies heavily on organic carbon to the point that the SQC values are stated as organic-carbon-based concentrations. For this study, TOC results are used to evaluate the degree to which organic carbon has influenced contaminant accumulations.

Measured TOC concentrations ranged from less than 1 percent at Flanders Bay and Peconic River stations to greater than 5 percent at East Creek and Meetinghouse Creek stations (Table 6-1). TOC concentrations of up to 3 or 4 percent are not unusual for

estuarine sediments; similar studies included three out of 16 Delaware estuary stations with TOC concentrations greater than 4 percent (Costa and Sauer, 1994) and one out of 12 Massachusetts and Cape Cod Bays stations at greater than 4 percent TOC (Hyland and Costa, 1995). In addition to generally high concentrations of TOC, eight of the 12 Peconic estuary stations contained greater than 80 percent silt + clay. Both the TOC and silt + clay trends are consistent with the physical and biogeochemical dynamics of the Peconic estuary. With considerable agricultural land-use along the north and south forks of eastern Long Island, numerous embayments, shallow waters, and other restrictions to flushing, the predominance of fine-grained organic-rich muds at most of the stations sampled for this study is to be expected. Direct observation of sediment characteristics from the subsequent SPI survey, discussed in Section 6.3, were generally consistent with the measurements from the sediment chemistry survey.

6.1.2 Polynuclear Aromatic Hydrocarbons. Figure 6-1 summarizes total PAH concentrations at all study stations. Concentrations exceeding the ER-L were measured at East Creek (Station 13) and Meetinghouse Creek (Station 16). These two stations also had the highest concentrations of organic carbon, indicating organic-rich, fine-grained sediments (note high silt + clay content). Normalizing total PAH to TOC and silt + clay (shown in Figure 6-1) suggest that the elevated PAH concentrations at the East Creek and Meetinghouse Creek stations are driven by the nature of the substrate (very favorable for contaminant accumulations) rather than a local point-source influence.

In looking at distributions of PAHs, it can be useful to look at the high-molecular-weight PAHs (primarily pyrogenic sources) and low-molecular-weight PAHs (primarily petrogenic sources) separately. This separation of PAHs into subclasses can help identify the relative importance of PAH point sources, which are typically responsible for elevations of petrogenic PAHs (Costa and Sauer, 1994), versus PAH nonpoint sources, which are typically responsible for elevations of pyrogenic PAHs. Additionally, the primary modes of toxicity differ somewhat between the low- and high-molecular-weight PAHs with the 2- and 3-ringed PAHs (LMW) more likely to cause mortality and the 4-, 5-, and 6-ringed PAHs more likely to induce sublethal effects.

The use of the terms "petrogenic" and "pyrogenic" refers to sources from which the different subclasses of PAHs in sediment residues typically derive. Although crude oil contains all of the PAHs targeted in this study, the low-molecular-weight compounds are typically much greater in abundance in petroleum products than the high-molecular-weight compounds. This "petrogenic" composition also applies to environmental residues. Conversely, combustion of petroleum products produces residues in which the low-molecular-weight PAHs are depleted and the high-molecular-weight PAHs predominate. These "pyrogenic" PAHs are found globally in urban/industrial areas, finding their way into coastal sediments through atmospheric fallout of soot particles into bays and rivers, surface water runoff of PAH-containing particles, and underflow of residues that percolate through soil and into groundwater.

As shown in Figures 6-2 and 6-3, both subclasses of PAHs exhibit similar spatial trends. Again, elevations are primarily attributable to favorable conditions for deposition and contaminant accumulation in organic-rich fine-grained sediments. In comparing sediment effects levels, ER-Ls were exceeded at East Creek, the Mouth of the Peconic River, Upper Sag Cove Harbor, and Meetinghouse Creek. ER-M values were not exceeded at

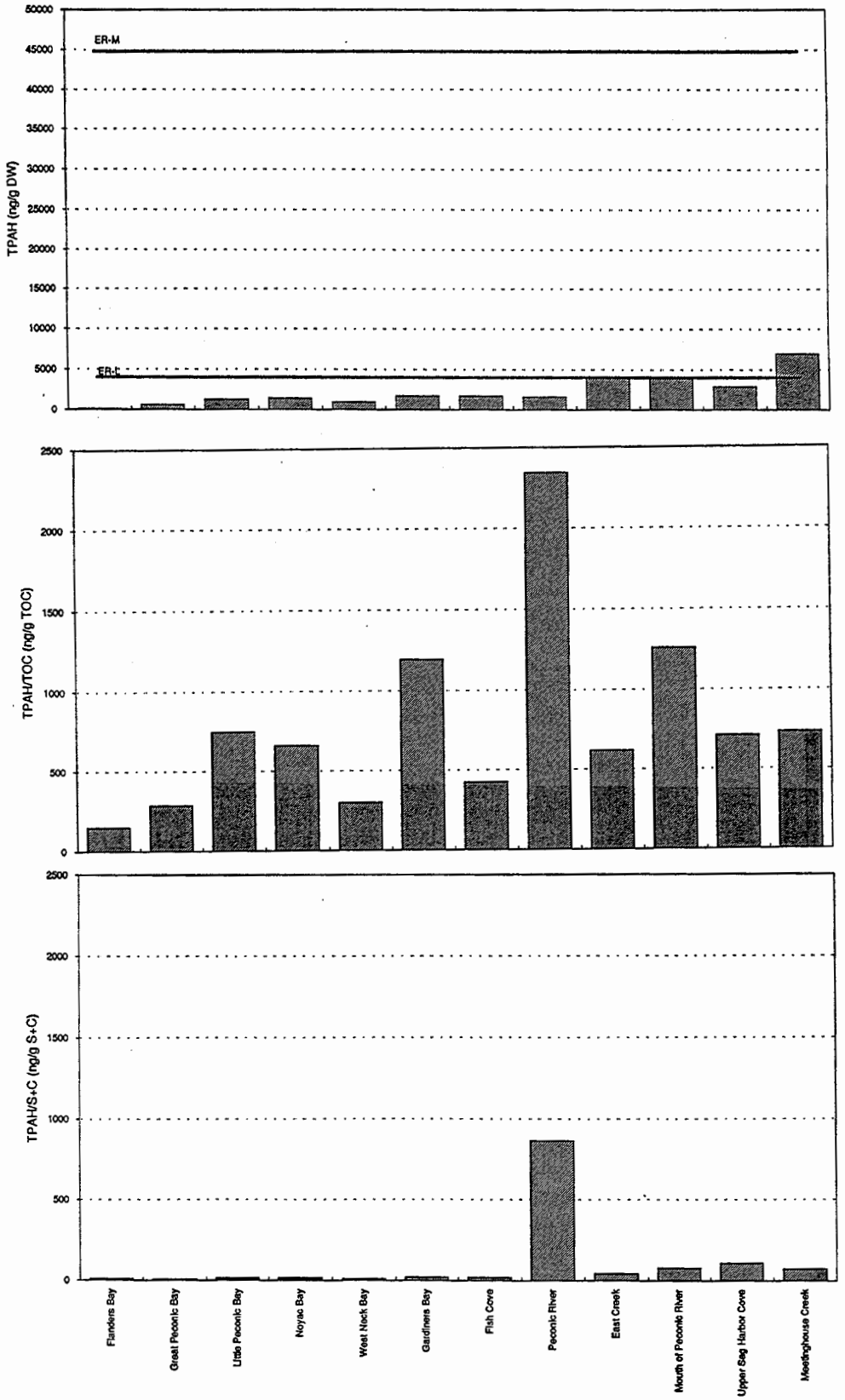


Figure 6-1: Sediment Total PAH Concentrations (ng/g dry weight) (a). Normalized to TOC (b) and Silt+Clay (c).

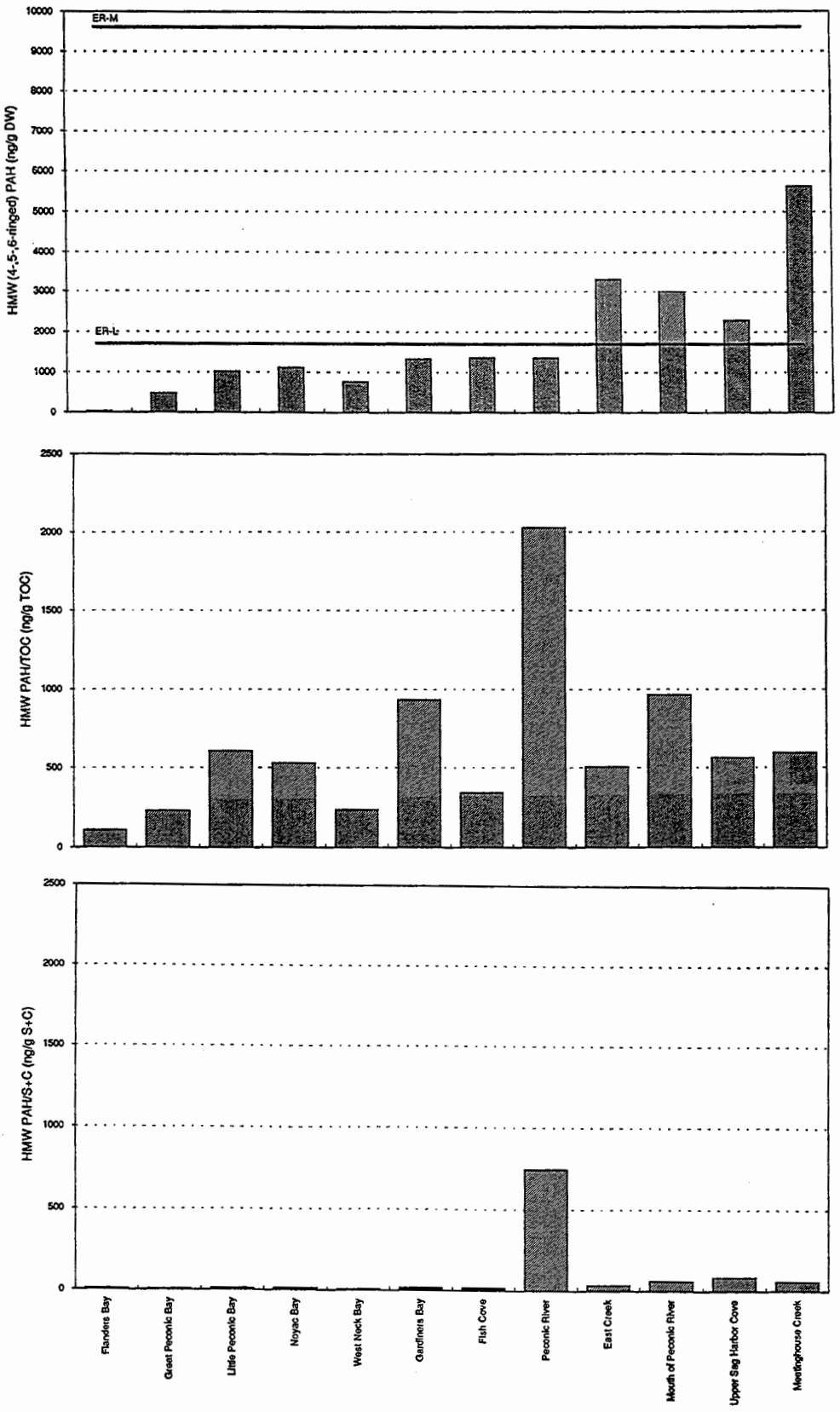


Figure 6-2: Sediment HMW PAH Concentrations (ng/g dry weight) (a). Normalized to TOC (b) and Silt+Clay (c).

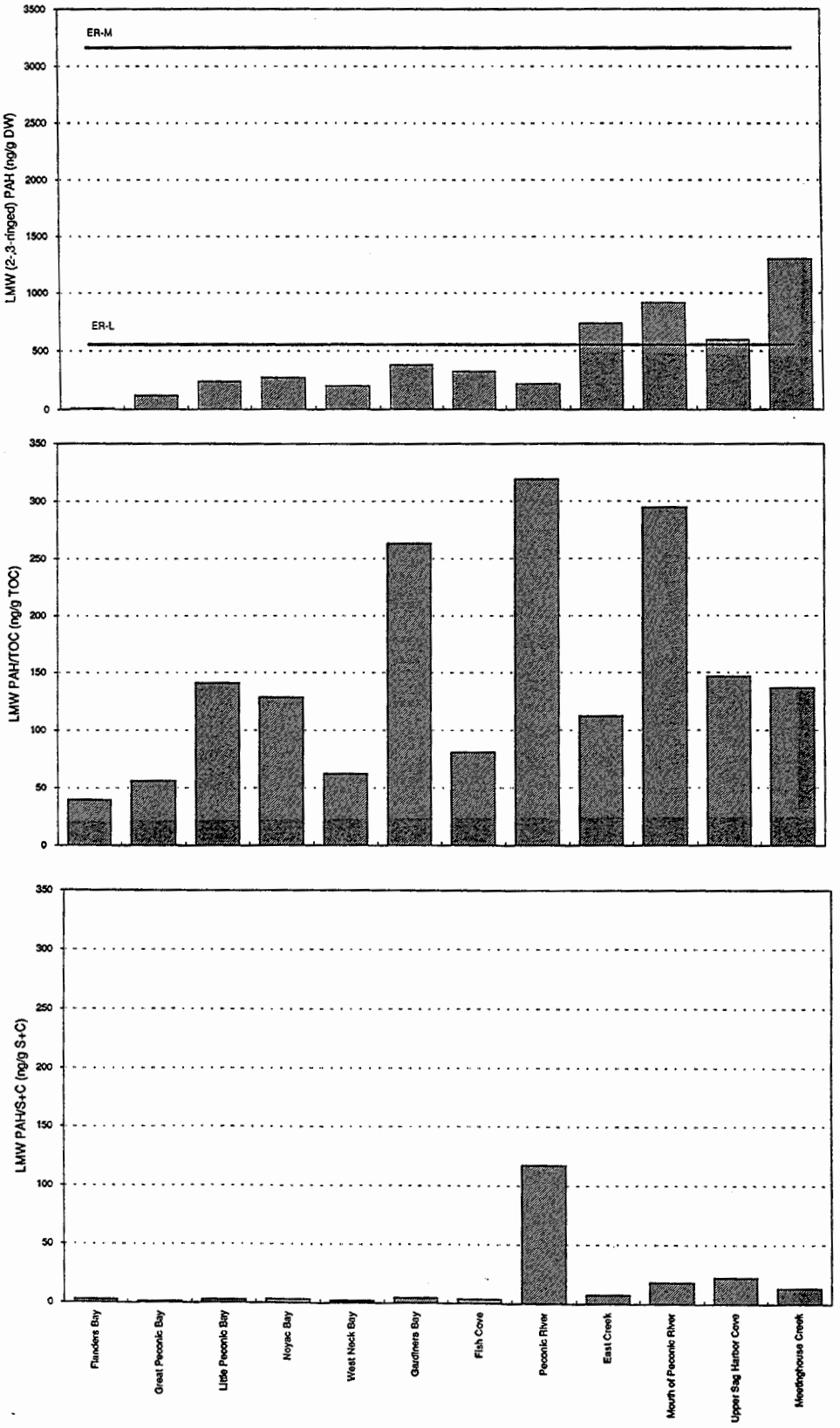


Figure 6-3: Sediment LMW PAH Concentrations (ng/g dry weight) (a). Normalized to TOC (b) and Silt+Clay (c).

any study stations. Concentrations of the HMW PAHs are consistently three to five times higher than LMW PAH concentrations (Table 6-1). This consistency suggests a predominant influence driving PAH distributions throughout the estuary.

PAH compositions were examined for patterns of the alkylated PAHs, which provide clues regarding the nature of PAH sources. Figures 6-4 through 6-6 show PAH compositions for stations representing low, medium, and high relative concentration ranges within the Peconic estuary. The relative abundances of the individual PAH compounds and alkylated homologue groups to each other are nearly identical in these three figures. This similarity in the PAH composition, or fingerprint, extends to the nine additional stations. This single PAH fingerprint, seen in all samples analyzed for this study, strongly suggests that PAH distributions throughout the estuary derive from nonpoint sources of primarily pyrogenic PAHs. Airborne pyrogenic PAHs can be introduced into the estuary by fallout during rain, freshwater flow from rivers, runoff through municipal sewer/stormwater discharges, and watershed drainage through groundwater flow. Although individual rivers and municipal discharges may be considered point sources, they are categorized "nonpoint" in this discussion because they integrate multiple individual sources.

6.1.3 Polychlorinated Biphenyls. Figure 6-7 shows total PCB concentrations at all stations. Total PCB concentration at Meetinghouse Creek exceeded the ER-L (Table 6-1). Although the influence of TOC and fine-grained sediments affects PCB accumulations the same as with PAH accumulations, it is notable that East Creek (Station 13), with similar TOC and silt + clay content to Meetinghouse Creek, is nearly an order of magnitude lower in total PCB concentration than the composite sample from Meetinghouse Creek. Thus, factoring in some attenuation for varying levels of organic carbon and fine-grained sediment content, Meetinghouse Creek PCB concentrations were greater than those at the other stations, indicating accumulations above "background" for the Peconic estuary. This empirical result suggests a localized source of PCBs influencing Meetinghouse Creek, whereas all other stations appear to be influenced primarily, if not exclusively, by nonpoint or background sources.

6.1.4 Pesticides. Based on the agricultural land use along the north portion of the estuary and historical data (see Section 2), pesticide residues were predicted to be found in sediments. In addition to organochlorine pesticides targeted in NOAA's National Status and Trends Program and EPA's EMAP, aldicarb and several of its metabolites were targeted but not detected at detection limits of 8 ng/g (split samples were analyzed by the Suffolk County Public and Environmental Health Laboratory). DDT concentrations exceeded ER-L at Upper Sag Harbor Cove, East Creek, and Meetinghouse Creek (Figure 6-8 and Table 6-1). Although influenced by TOC and grain size distributions, these elevations are very likely due to continuous drainage of agricultural areas containing persisting residues of DDT, which has been banned from use in the United States since the 1970s.

The pesticides targeted in this study do not appear likely to pose risk to benthic resources on an estuary-wide scale. However, very high concentrations of organic carbon in some shallow, nearshore areas may result in problematic accumulations of pesticides/ herbicides and/or their metabolites that have escaped detection in studies to date.

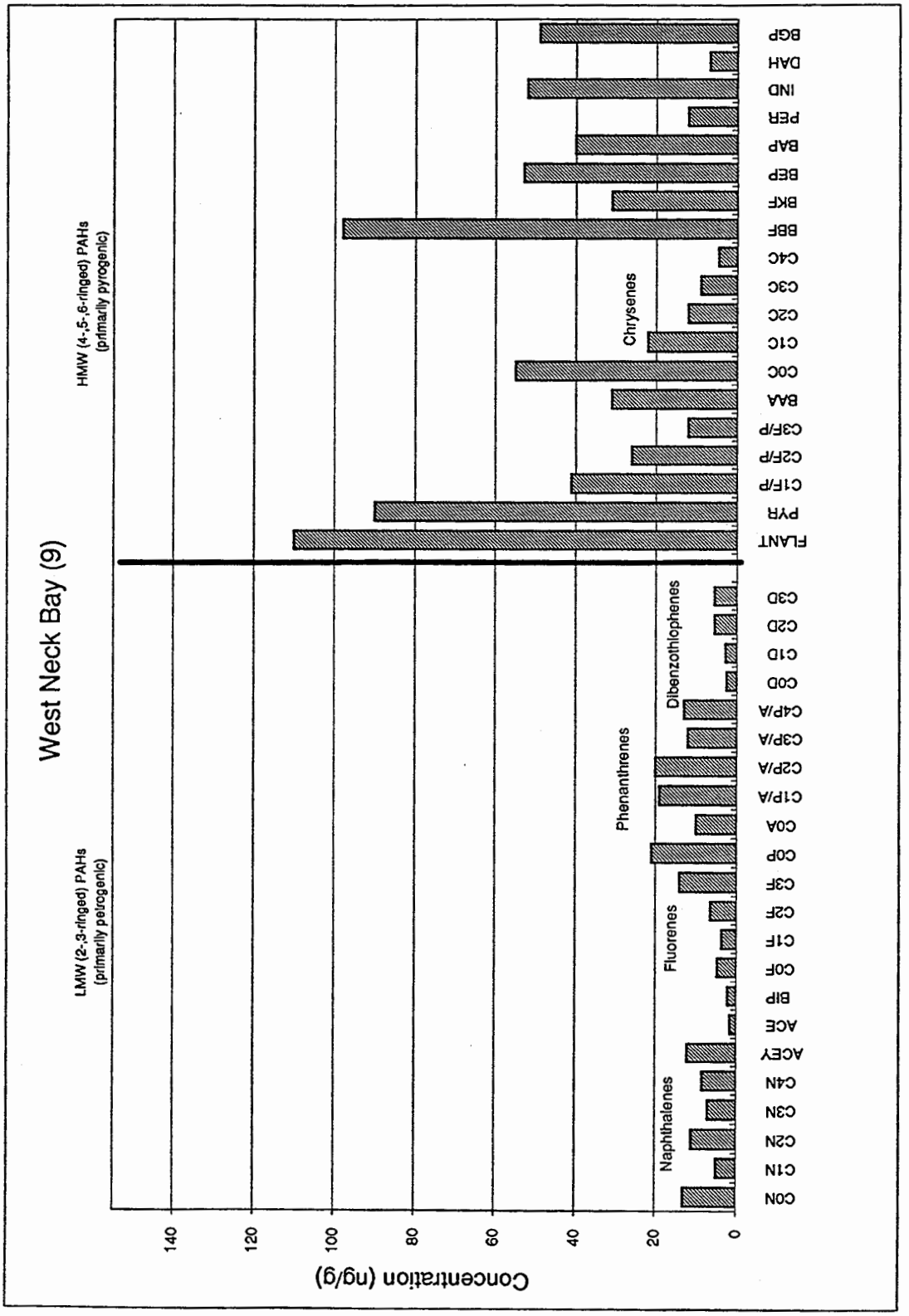


Figure 6-4: Sediment PAH Distribution for West Neck Bay (Station 9). Similar Concentrations and Distributions seen in Great Peconic Bay (Station 6), Little Peconic Bay (Station 7), and Noyac Bay (Station 8).

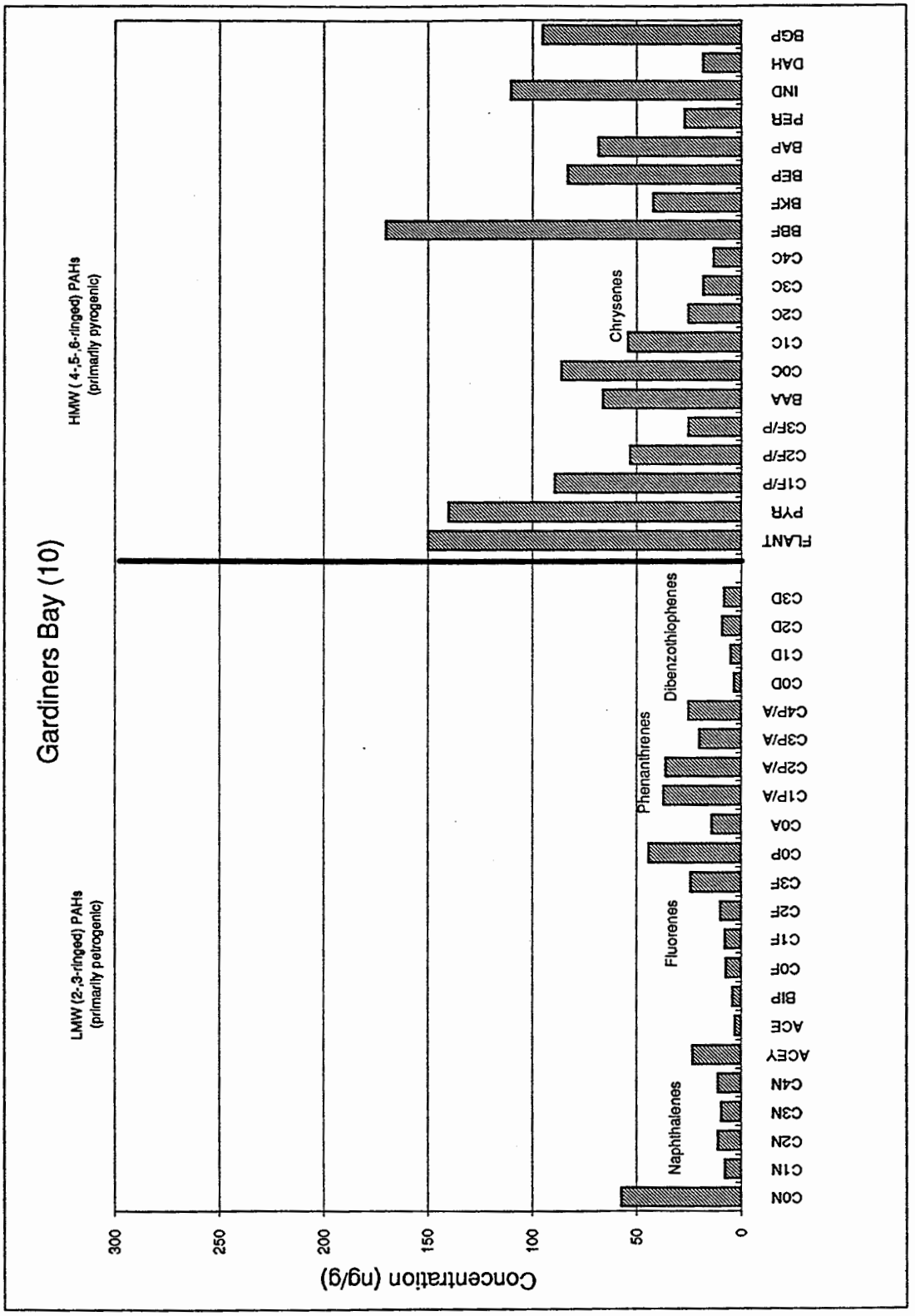


Figure 6-5: Sediment PAH Distribution for Gardiners Bay (Station 10). Similar Concentrations and Distributions seen in Fish Cove (Station 11), Peconic River (Station 12), and Upper Sag Harbor Cove (Station 15).

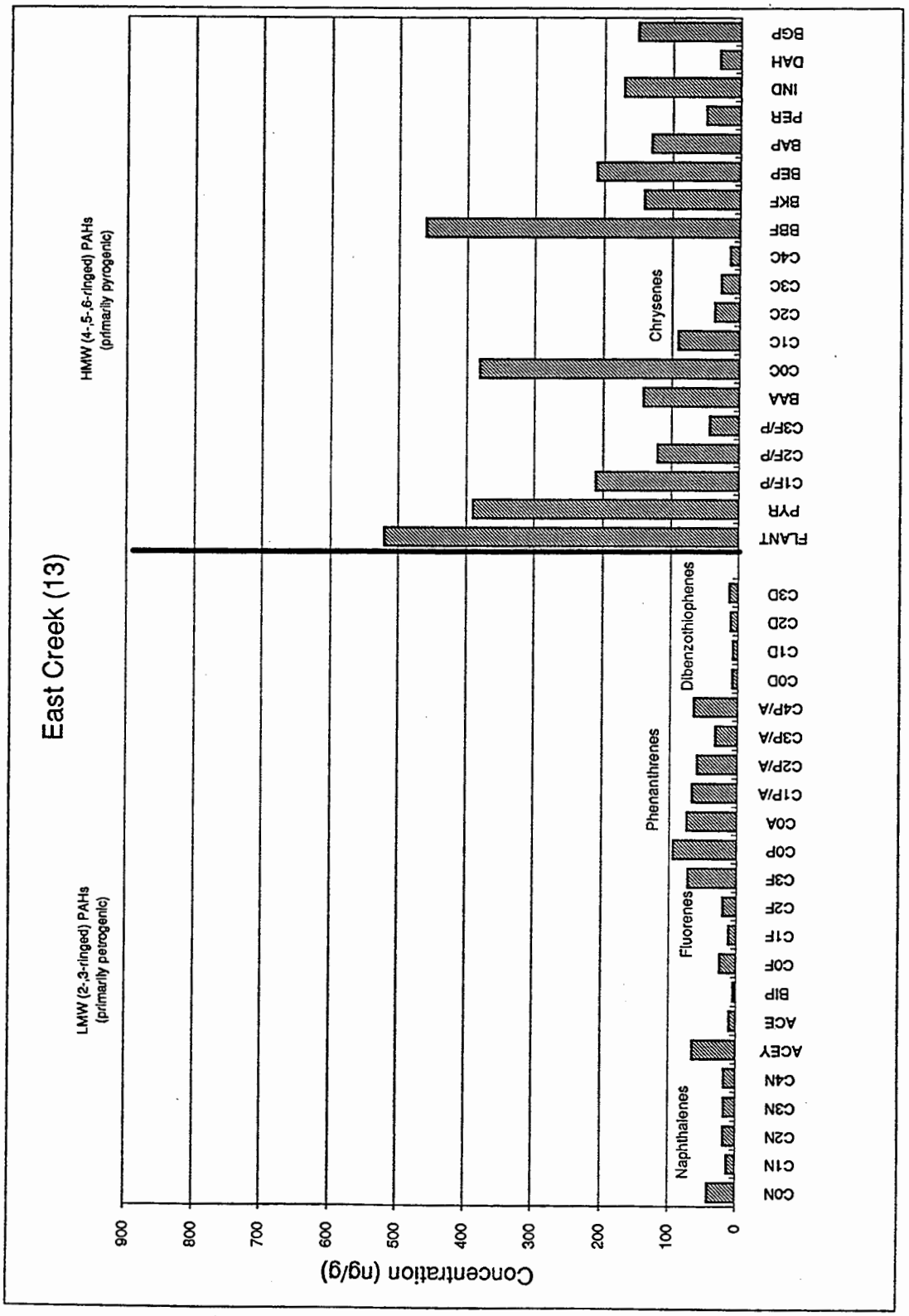


Figure 6-6: Sediment PAH Distribution for East Creek (Station 13). Similar Concentrations and Distributions seen in Mouth of Peconic River (Station 14) and Meetinghouse Creek (Station 16).

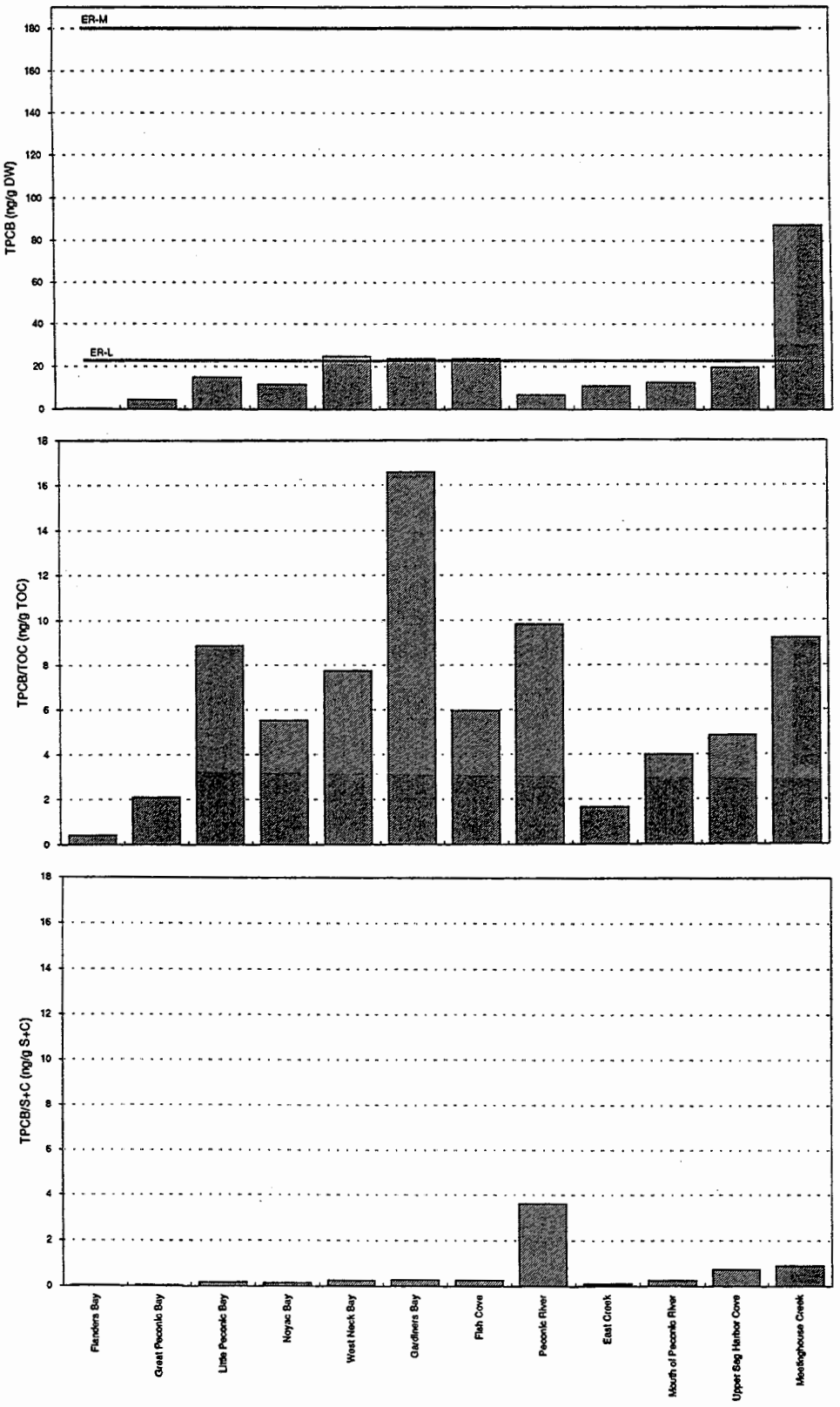


Figure 6-7: Sediment Total PCB Concentrations (ng/g dry weight) (a). Normalized to TOC (b) and Silt+Clay (c).

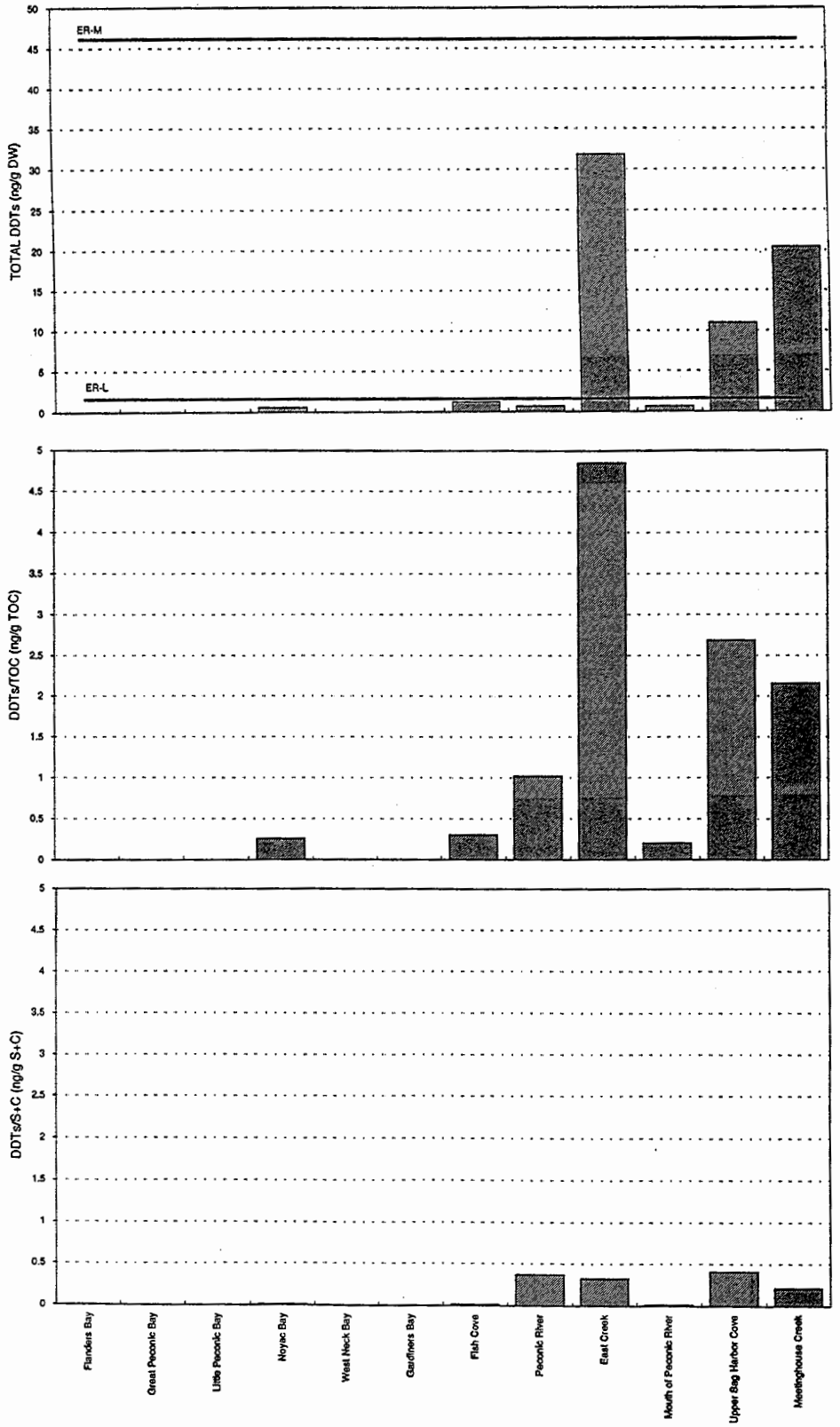


Figure 6-8: Sediment Total DDT Concentrations (ng/g dry weight) (a). Normalized to TOC (b) and Silt+Clay (c).

6.2 Metal Contaminant Distributions

Sediments deposited in coastal areas adjacent to urban and industrial development commonly have elevated concentrations of a variety of heavy metals. Metals concentrations are usually categorized as "elevated" by comparing metal concentrations or metal-to-aluminum concentration ratios in the sediments of interest with values for average continental crust, "clean" sediments, or pre-industrial (sub-surface) sediments from the same area. When metal values or metal/Al ratios for a given sample exceed the 95 percent prediction interval for "clean" or "natural" sediments, then the samples most likely reflect an anthropogenic influence. However, the presence of elevated metal concentrations is not necessarily directly linked with adverse effects to organisms living in or feeding from the sediments, although guidelines are being evaluated for their suitability in predicting this contaminant-effects linkage (e.g., Long et al., 1995).

In our evaluation of the metals data, we have followed a two-prong approach wherein we first identify "elevated" metal concentrations in the sediment and then predict the likelihood of adverse effects. We have measured total concentrations of Al and 13 other metals (Ag, As, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, Tl, and Zn) in the samples. Sediments from the Peconic Estuary analyzed for this study are from a variety of locations and represent a range of sediment types. Based on Al values, along with visible texture and composition, sediment samples from the Peconic River (Station 13, 0.42 percent Al) and Flanders Bay (Station 3, 0.44 percent Al) are sandy. The samples from Upper Sag Harbor Cove (Station 15, 2.18 percent Al) and the mouth of the Peconic River (Station 14, 3.58 percent Al) are intermediate in apparent grain-size and clay content. The remaining samples are relatively fine-grained, clay-rich samples (6.6 ± 0.7 percent Al). Metal concentrations are naturally higher in finer-grained, more clay-rich (higher Al) samples due to the minerals associated with them and the greater surface area for adsorption. Contaminant loadings of metals also show up most readily in fine-grained sediments because of the greater availability of surface uptake sites.

The distribution of Cr in the Peconic Estuary is a good starting point for this discussion because all samples seem to have natural levels of Cr with no indication of contamination. Figure 6-9a shows a plot of Cr versus Al for the Peconic Estuary samples on a log-log grid used by the State of Florida to identify metal contamination (Schropp et al., 1990). The solid line represents mean values for Cr and Al in "clean" sediments from Florida. The same broad relationship and similar metal values are observed in most "clean" sedimentary environments. The two dotted lines on Figure 6-9a show 95-percent prediction intervals around the mean. When points lie above the upper dotted line, they have most likely had an anthropogenic contribution of Cr. The same approach can be more closely scrutinized on linear scales where the line shown on Figure 6-9b represents the trend based on the Cr/Al ratio of average continental crust. In both cases (Figures 6-9a and 6-9b), no evidence of elevated levels of Cr are observed.

Sediment Cr concentrations can also be evaluated based on the biological effects database developed by Long et al. (1995) (Figure 6-9c). All samples from the Peconic Estuary do not have elevated concentrations of Cr. Furthermore, Cr concentrations at all sites are below the ER-L values and thus biological effects due to Cr would be unlikely.

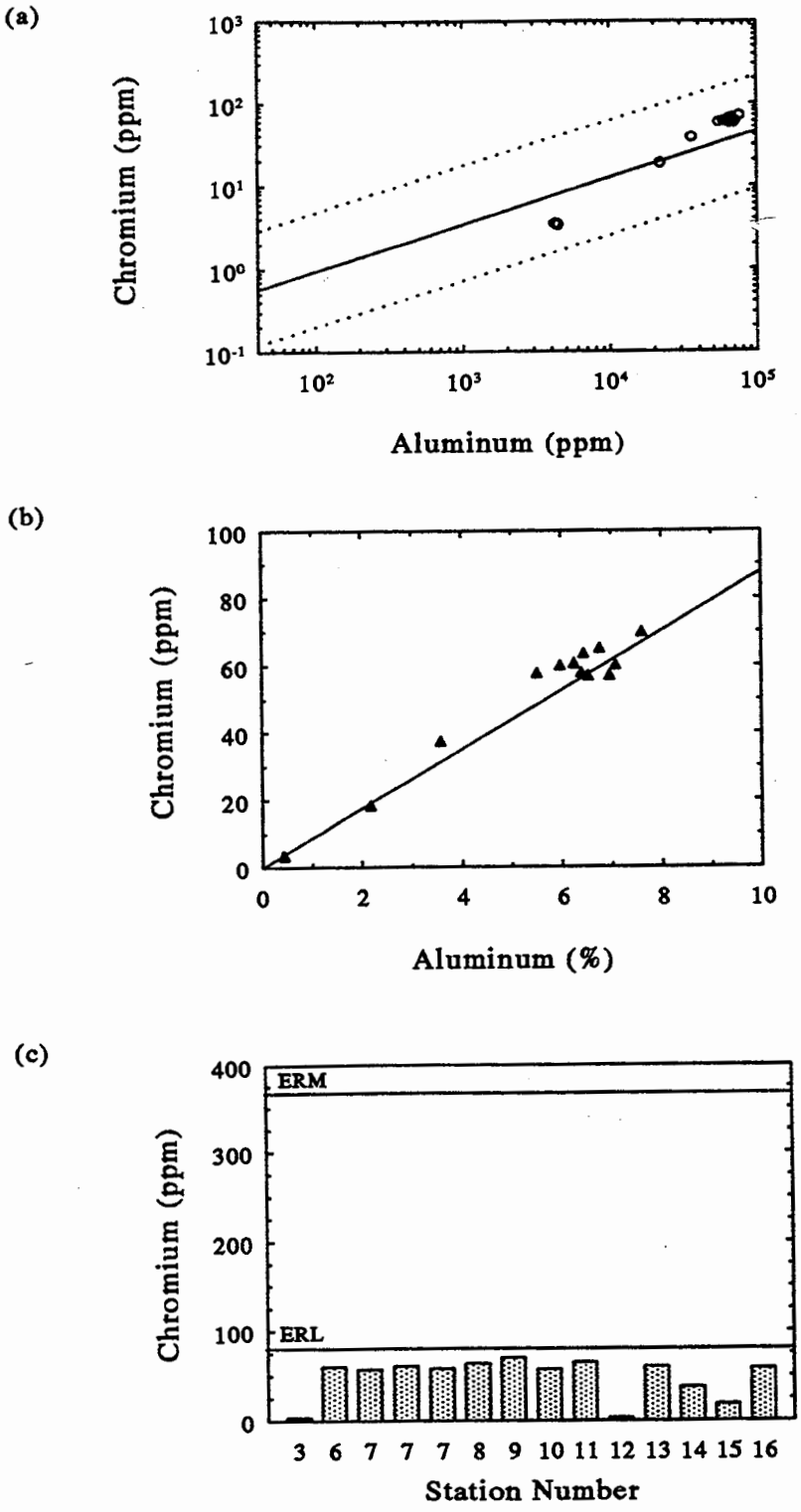


Figure 6-9: Plots showing Cr levels in sediments from the Peconic Estuary. (a) Cr versus Al (log scale) with regression line for clean sediment and dotted line for 95% prediction interval, (b) Cr versus Al (linear scale) with line for average continental crust, and (c) Cr levels relative to values for effects range low (ERL) and effects range median (ERM).

Results for Ni are essentially the same as observed for Cr. All samples have Ni concentrations that show a strong correlation with Al ($r = 0.97$) and have a Ni/Al ratio that is actually below that found for average continental crust (Figure 6-10). This lower trend for sediments from the Peconic Estuary is within the range of Ni/Al variations that can be expected for soils and rocks globally. Based on the Ni/Al ratios shown in Figure 6-10a, one would predict that all samples would plot below an ER-L value. From Figure 6-10b, Ni levels in most samples are just above the ER-L level and occasional effects may be expected. However, the ER-L value for Ni seems unrealistic because the sediments from this study merely appear to reflect natural concentrations of Ni.

Concentrations of Cu in sediments from East Creek (Station 13) and Meetinghouse Creek (Station 16) are above the upper prediction limit shown in Figure 6-11a and the Cu/Al line for average continental crust (Figure 6-11b). Thus, these two sites most likely have an anthropogenic Cu contribution. Likewise, these two sites have Cu levels that are well above the ER-L values and biological effects could be expected. As was discussed for Ni, the remaining samples reflect natural Cu levels based on their Al content and effects would not be predicted as a result of Cu.

The discussion provided above for Cr, Ni, and Cu provides a framework for first identifying elevated metal concentrations and then determining whether any biological effects may be expected. This same approach is used for Cd (Figure 6-12), Ag (Figure 6-13), As (Figure 6-14), Hg (Figure 6-15), Pb (Figure 6-16), and Zn (Figure 6-17) and summarized in Table 6-2.

None of the samples from any station in this study have metal concentrations that exceed the higher ER-M values (Table 6-2). Thus, the estuary is not in a situation where adverse effects due to metals would be expected to frequently occur. However, the metal concentrations listed as ER-M levels are very high and are not commonly observed.

Overall, about 17 percent of the metal concentrations (18) exceed ER-L values, based on 12 stations and nine metals with available ER-L values. Two metals, As and Pb, account for 56 percent (10) of the high values. An anthropogenic source is likely for both metals. Lead has been introduced into the environment from Pb additives in gasoline for many years. However, Trefry et al. (1985) showed that inputs of Pb to the environment have declined since regulations restricting use of Pb additives in gasoline were introduced during the 1970s. The history of pollutant inputs to sediments in the Peconic Estuary could also be evaluated by studying age-dated sediment cores. Sources of As include fertilizers, pesticides, smelters, and stormwater runoff.

From the perspective of location, East Creek (Station 13) and Meetinghouse Creek (Station 16) each have five metals that exceed the ER-L (Table 6-2) and are the most metal-enriched sites from this study. Further investigations at these sites would be helpful to determine likely sources of metals to the system.

By using the more sensitive metal/Al ratios, 24 data points (22 percent of total) likely reflect anthropogenic inputs (Table 6-2). Four metals, As, Cd, Pb, and Zn, account for 82 percent of the high values. These four metals are frequently among those metals that show the first signs of pollutant inputs to coastal sediments.

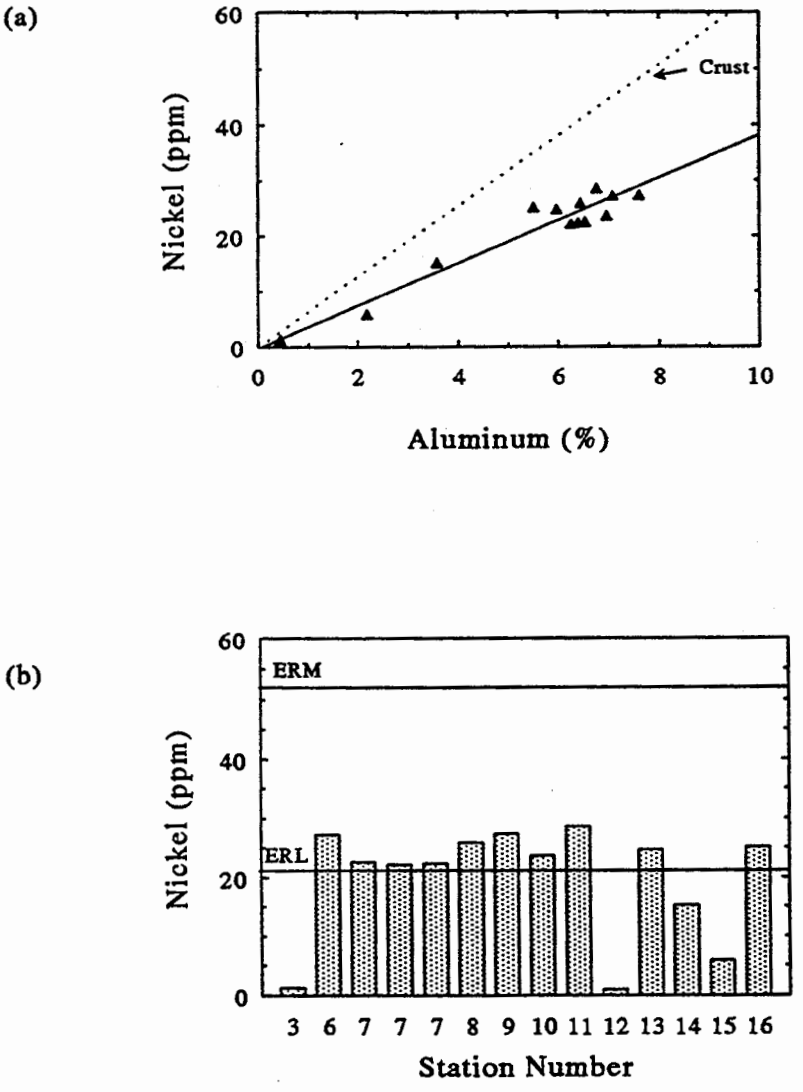


Figure 6-10: Plots showing Ni levels in sediments from the Peconic Estuary. (a) Ni versus Al (linear scale) with regression line for samples from the Peconic Estuary and dotted line for average continental crust, and (b) Ni levels relative to values for effects range low (ERL) and effects range median (ERM).

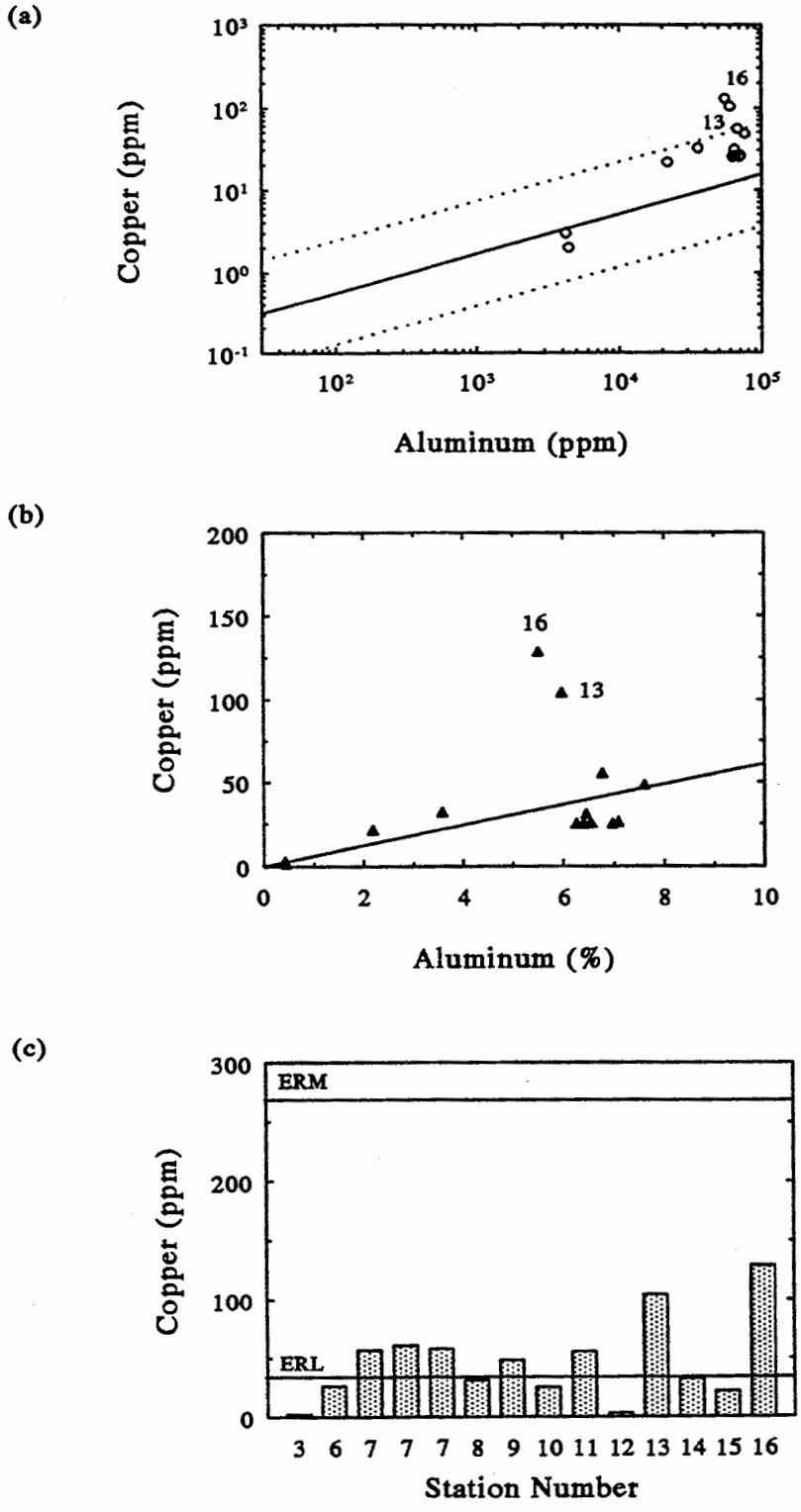


Figure 6-11 Plots showing Cu levels in sediments from the Peconic Estuary. (a) Cu versus Al (log scale) with regression line for clean sediment and dotted line for 95% prediction interval, (b) Cu versus Al (linear scale) with line for average continental crust and (c) Cu levels relative to values for effects range low (ERL) and effects range median (ERM).

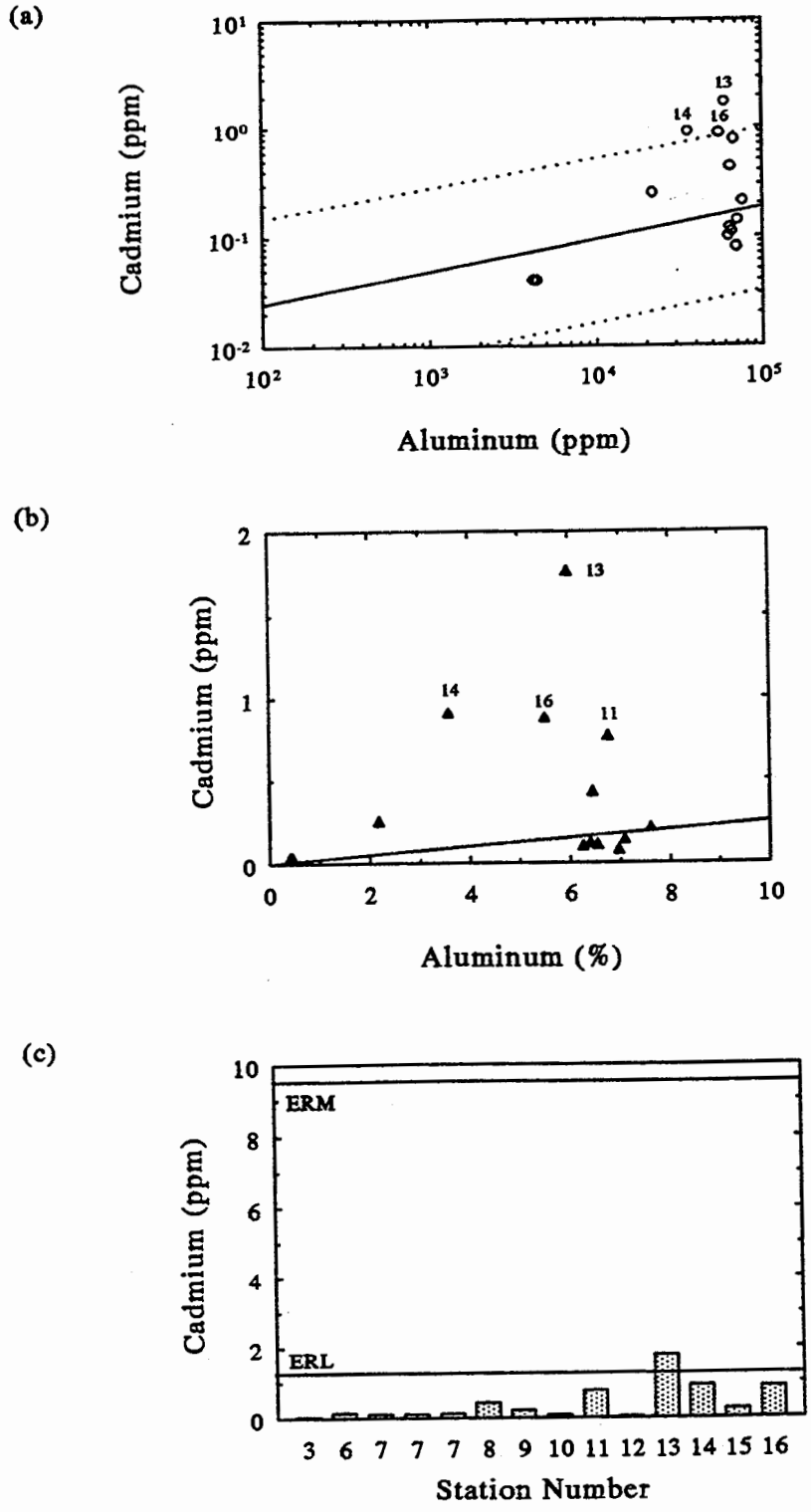


Figure 6-12: Plots showing Cd levels in sediments from the Peconic Estuary. (a) Cd versus Al (log scale) with regression line for clean sediment and dotted line for 95% prediction interval, (b) Cd versus Al (linear scale) with line for average continental crust and (c) Cd levels relative to values for effects range low (ERL) and effects range median (ERM).

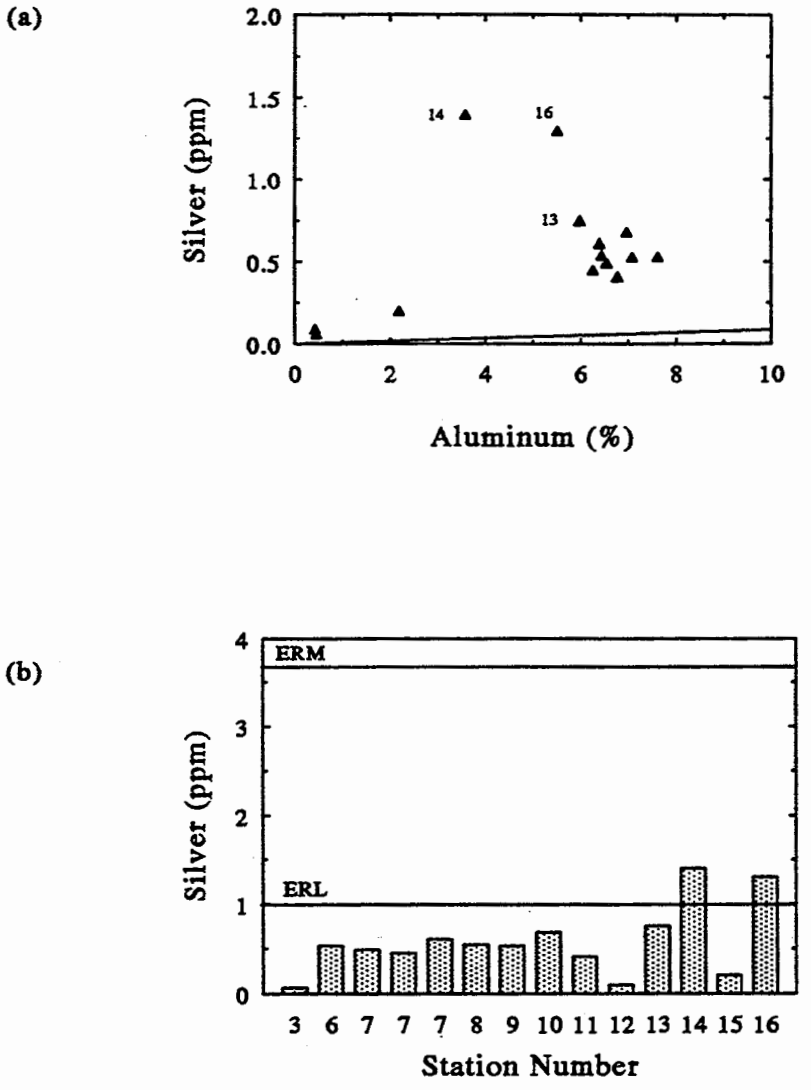


Figure 6-13: Plots showing Ag levels in sediments from the Peconic Estuary, (a) Ag versus Al (linear scale) with regression line for samples from the Peconic Estuary and dotted line for average continental crust, and (b) Ag levels relative to values for effects range low (ERL) and effects range median (ERM).

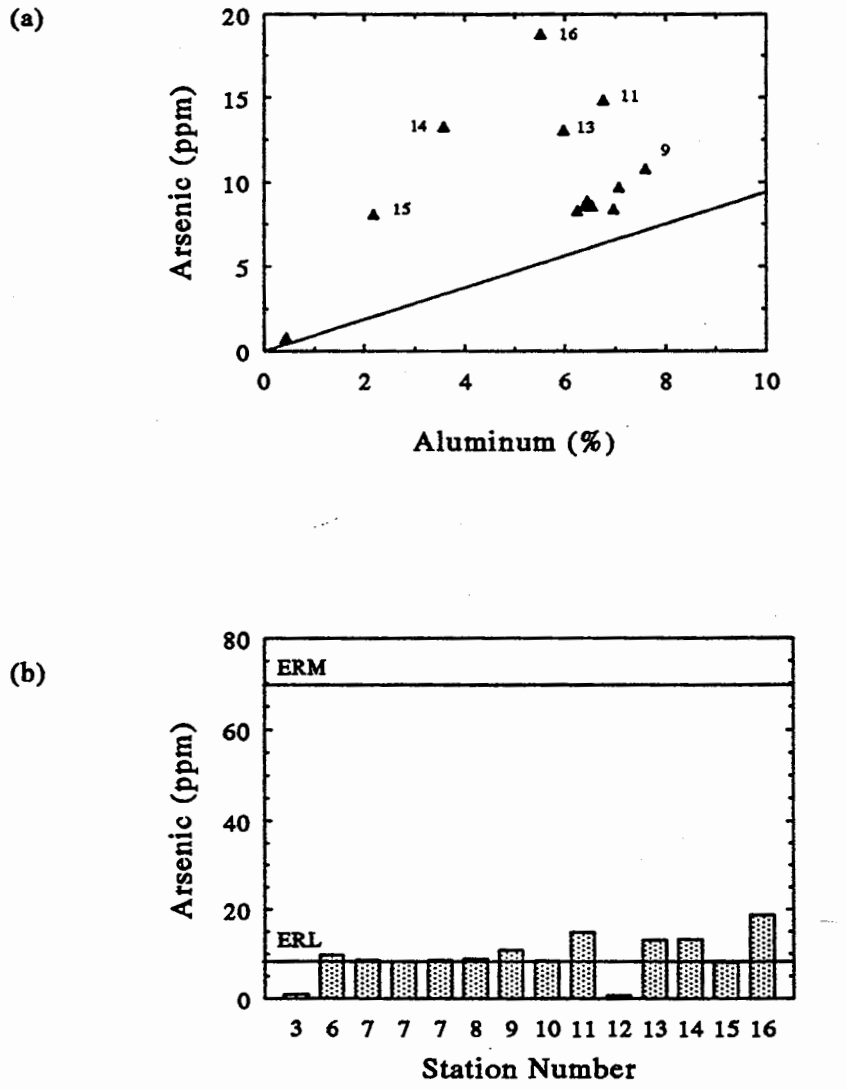


Figure 6-14: Plots showing As levels in sediments from the Peconic Estuary. (a) As versus Al (linear scale) with regression line for samples from the Peconic Estuary and dotted line for average continental crust, and (b) As levels relative to values for effects range low (ERL) and effects range median (ERM).

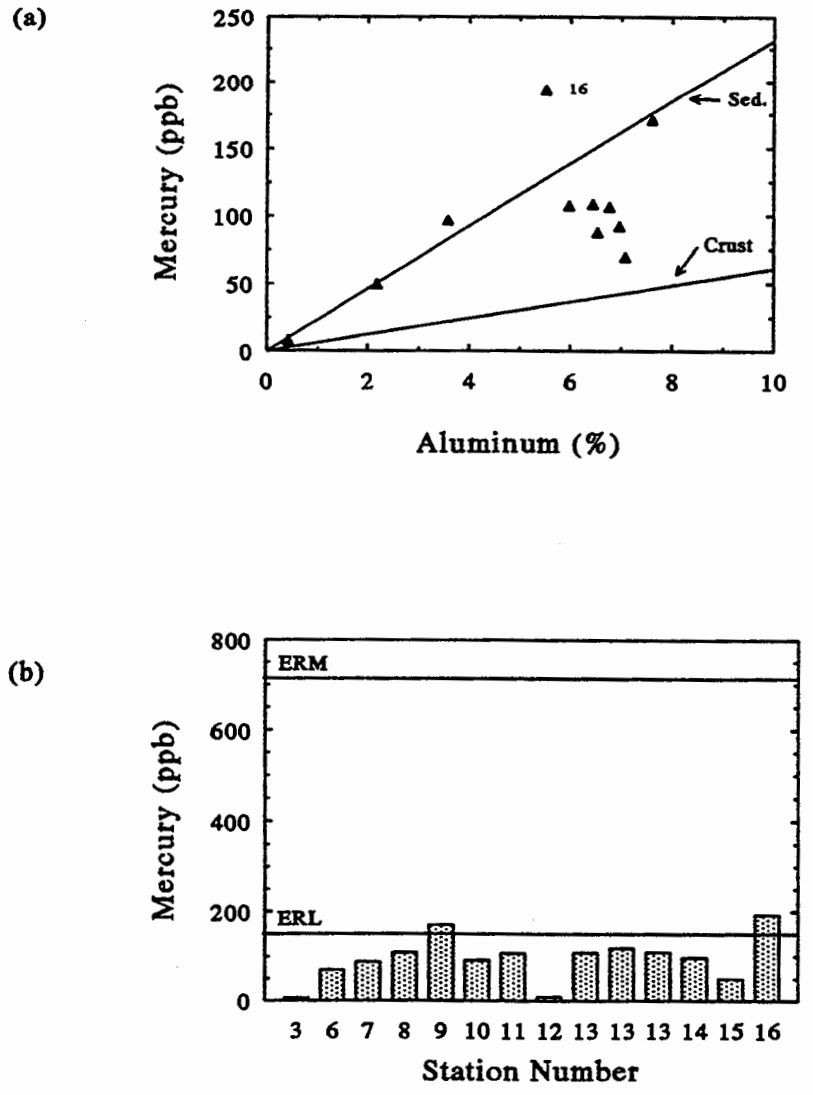


Figure 6-15: Plots showing Hg levels in sediments from the Peconic Estuary. (a) Hg versus Al (linear scale) with regression line for samples from the Peconic Estuary and dotted line for average continental crust, and (b) Hg levels relative to values for effects range low (ERL) and effects range median (ERM).

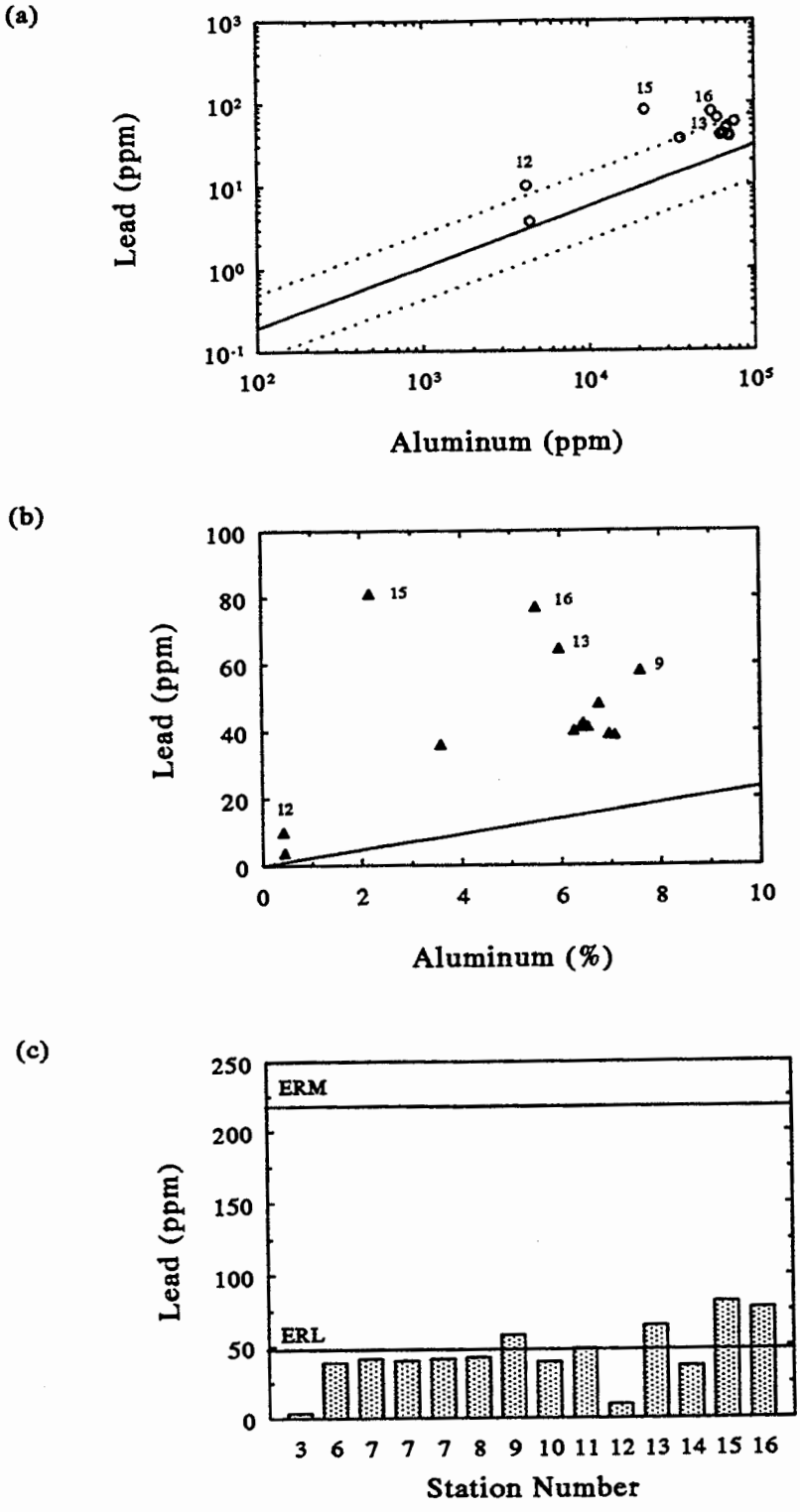


Figure 6-16: Plots showing Pb levels in sediments from the Peconic Estuary. (a) Pb versus Al (log scale) with regression line for clean sediment and dotted line for 95% prediction interval, (b) Pb versus Al (linear scale) with line for average continental crust and (c) Pb levels relative to values for effects range low (ERL) and effects range median (ERM).

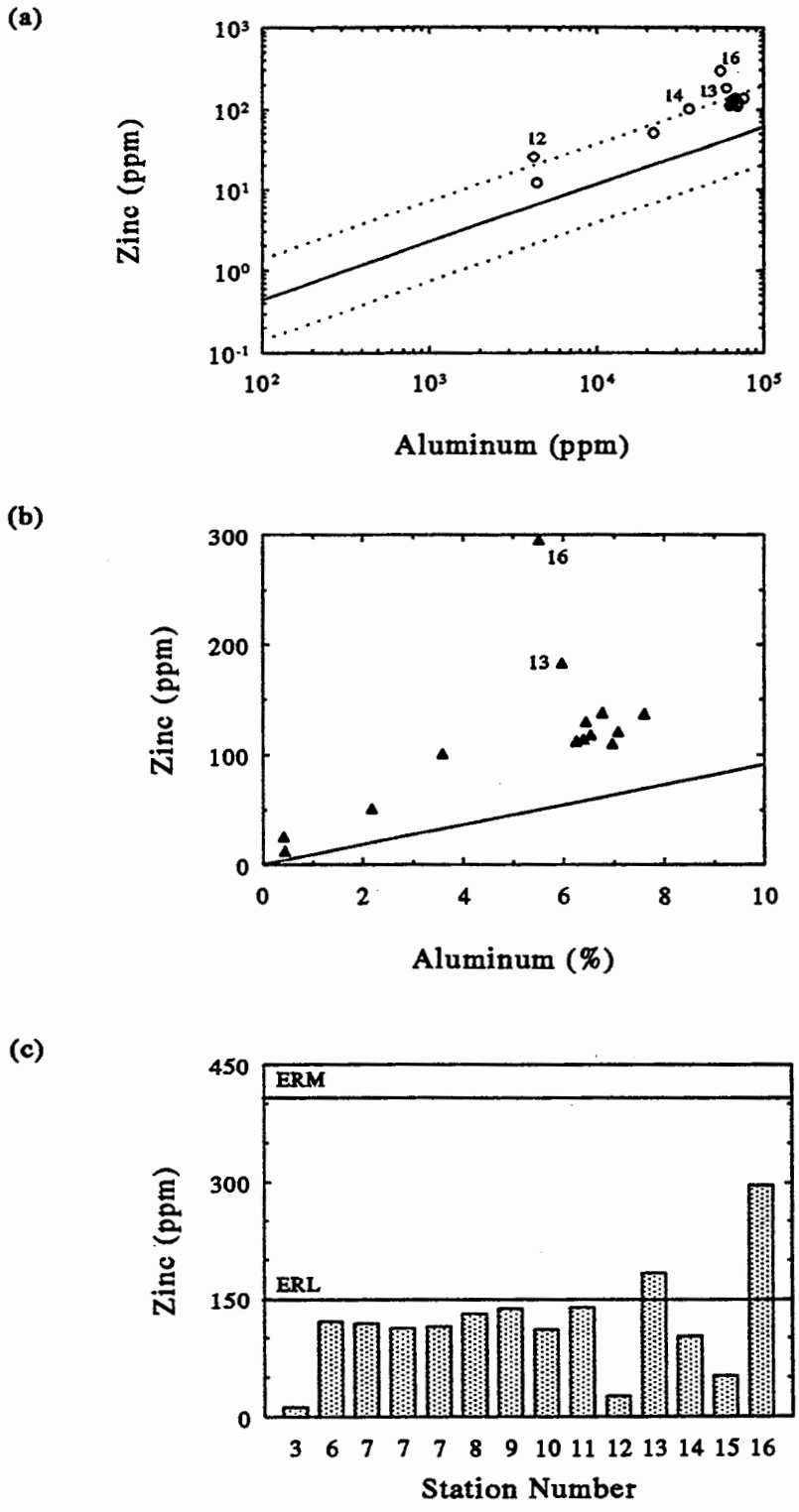


Figure 6-17: Plots showing Zn levels in sediments from the Peconic Estuary. (a) Zn versus Al (log scale) with regression line for clean sediment and dotted line for 95% prediction interval, (b) Zn versus Al (linear scale) with line for average continental crust and (c) Zn levels relative to values for effects range low (ERL) and effects range median (ERM).

No ER-L or ER-M values have been established for Be, Sb, Se, or Tl. All values for these metals in the Peconic Estuary are in the broad boundaries for typical sediments with no obvious anthropogenic contribution at this time.

Overall, the Peconic Estuary has several clear instances of elevated metal concentrations, especially in East Creek and Meetinghouse Creek. Occasional adverse biological effects can be expected due to metals and management plans should consider reducing future metal inputs that are most likely related to stormwater and urban runoff.

Table 6-2: Summary of Stations in Peconic Estuary where sediment metal levels show the following: (1) Elevated levels based on metal/Al ratios, (2) Values above biological effects range low (ER-L), and (3) Values above biological effects range medium (ER-M).

Element	ER-L	ER-M	Elevated Levels	>ER-L	>ER-M
Ag	1.0	3.7	13, 14, 16	14, 16	None
As	8.2	70	11, 13, 14, 15, 16	6, 9, 11, 13, 14, 16	None
Cd	1.2	9.6	11, 13, 14, 16	13	None
Cr	81	370	None	None	None
Cu	34	270	13, 16	13, 16	None
Hg	0.15	0.71	16	9, 16	None
Ni	20.9	51.6	None	(Some)	None
Pb	46.7	218	9, 12, 13, 15, 16	9, 13, 15, 16	None
Zn	150	410	12, 13, 14, 16	13	None

6.3 Condition of Benthic Communities

A minimum of three replicate images were collected at a total of 11 stations (the Peconic River station could not be surveyed) spread throughout the length of the estuary. Given the distance between individual sampling points, it is difficult to infer gradients or trends over large areas, so for the most part the results and discussion below will focus on individual sampling locations.

6.3.1 Physical Characteristics. With the exception of the fine sand and shells found at Flanders Bay (Station 3) and Upper Sag Harbor Cove (Station 15), the grain size major mode at all the stations sampled were silt-clay, indicative of a relatively quiescent, depositional environment. Station 3, located in Flanders Bay, had a significant surface shell-hash layer (Figure 6-18), indicative of persistent strong currents at this location capable of washing away any surface fine sediments.

Prism penetration was quite shallow at Flanders Bay (Station 3), Gardiners Bay (Station 10), and Upper Sag Harbor Cove (Station 15); a series of five replicates were collected at Station 15 located on a transitional facies between a fine sand and mud environment. The fine sand area at this location (Figure 6-19) is quite consolidated with little evidence of biogenic reworking; as one moves away from shore on to the muddier bottoms, there is evidence of a surface sand layer over a mud facies (Figure 6-20) before quickly transitioning into a fine-grained, soft bottom environment (Figure 6-21).

On the whole, the average apparent RPD depths at all stations sampled are relatively shallow (less than 2 cm; Table 6-3). Most stations show highly reduced muds with low reflectance at depth (Figure 6-22), indicative of relatively high sediment oxygen demand (SOD). Noyac Bay (Station 8) exhibited the most stressed habitat characteristics, with no apparent RPD and high SOD, indicating that this location most likely experiences prolonged periods of low dissolved oxygen stress.

6.3.2 Biological Conditions/Habitat Quality. Most stations showed evidence of only early successional assemblages. Only two locations (Station 10 in Gardiners Bay, the eastern most station sampled closest to the open Sound, and Station 16, Meetinghouse Creek at the opposite end of the estuary) had evidence of mature Stage III communities (indicating low disturbance habitats with relatively high sediment quality); no stations were azoic. Dense *Ampelisca* tube mats were found at Station 9 (Figure 6-23). All stations sampled showed evidence of infaunal communities present, although determinations at some locations were difficult due to the presence of dense layers of the sea lettuce, *Ulva*, that were dragged below the sediment-water interface by the camera's prism during bottom penetration (Figure 6-24).

OSI values (Table 6-3) for the most part were low; values less than +6 are typical of disturbed environments. Only three locations (Meetinghouse Creek, Gardiners Bay, and West Neck Creek) had OSI values above +6; Noyac Bay (Station 8) (median OSI value of -3) exhibited the worst habitat quality conditions. For the most part, the fine-grained stations sampled in April 1995 showed evidence of relatively low flushing rates, high organic loading, and relatively high SOD at many locations. We would predict that as the season progressed and temperatures increased, high SOD coupled with warmer water and low oxygen levels would exacerbate existing conditions at those stations with low OSI values, degrading habitat quality even further. Conditions at Noyac Bay (Station 8) should be particularly stressed in late summer/early fall when water temperatures are at their maximum.

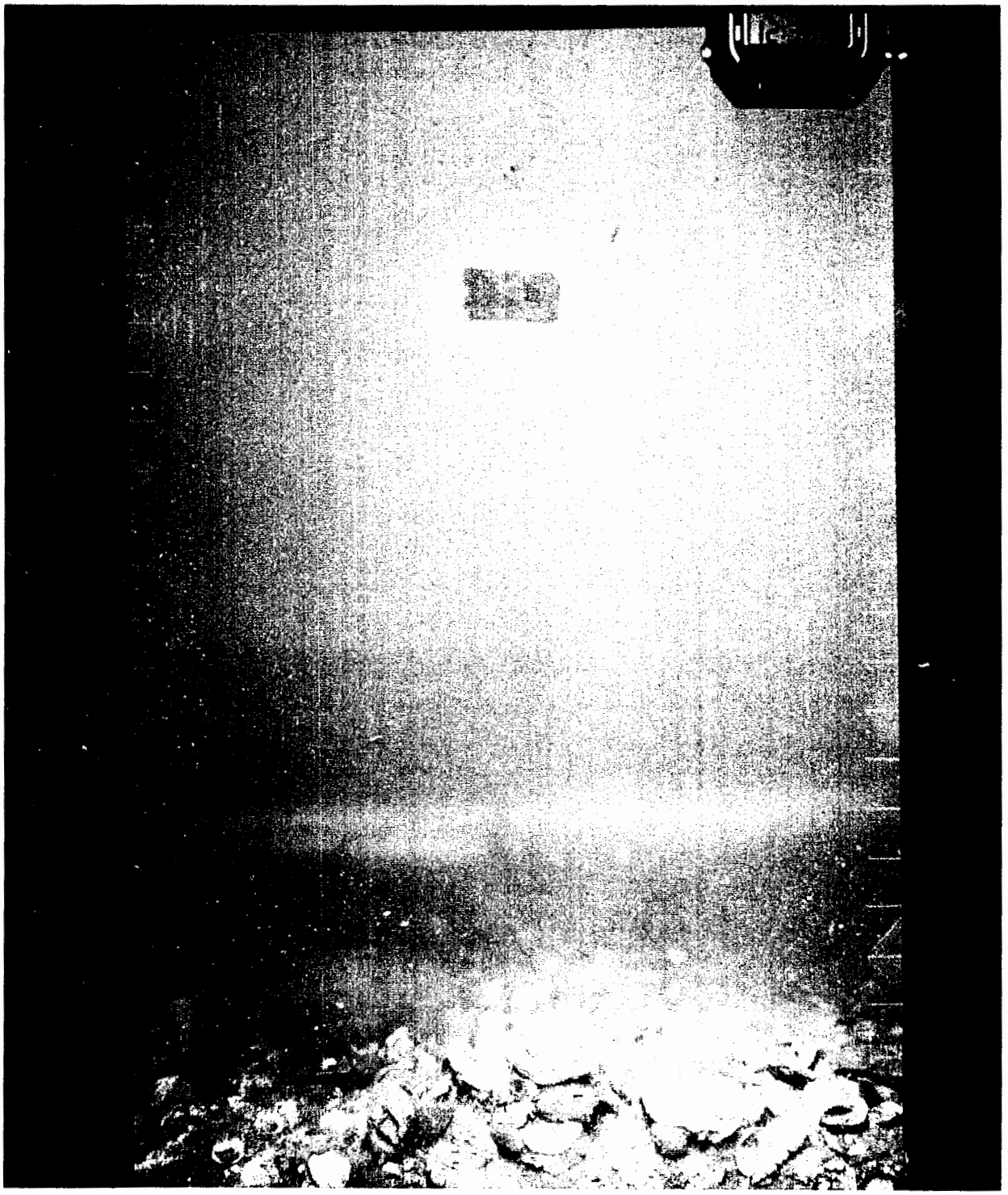


Figure 6-18: Flanders Bay (Station 3). Low prism penetration at Station 3 is caused by the dense shell hash layer at this location in the center of Flanders Bay. Image width is 15.5 cm.

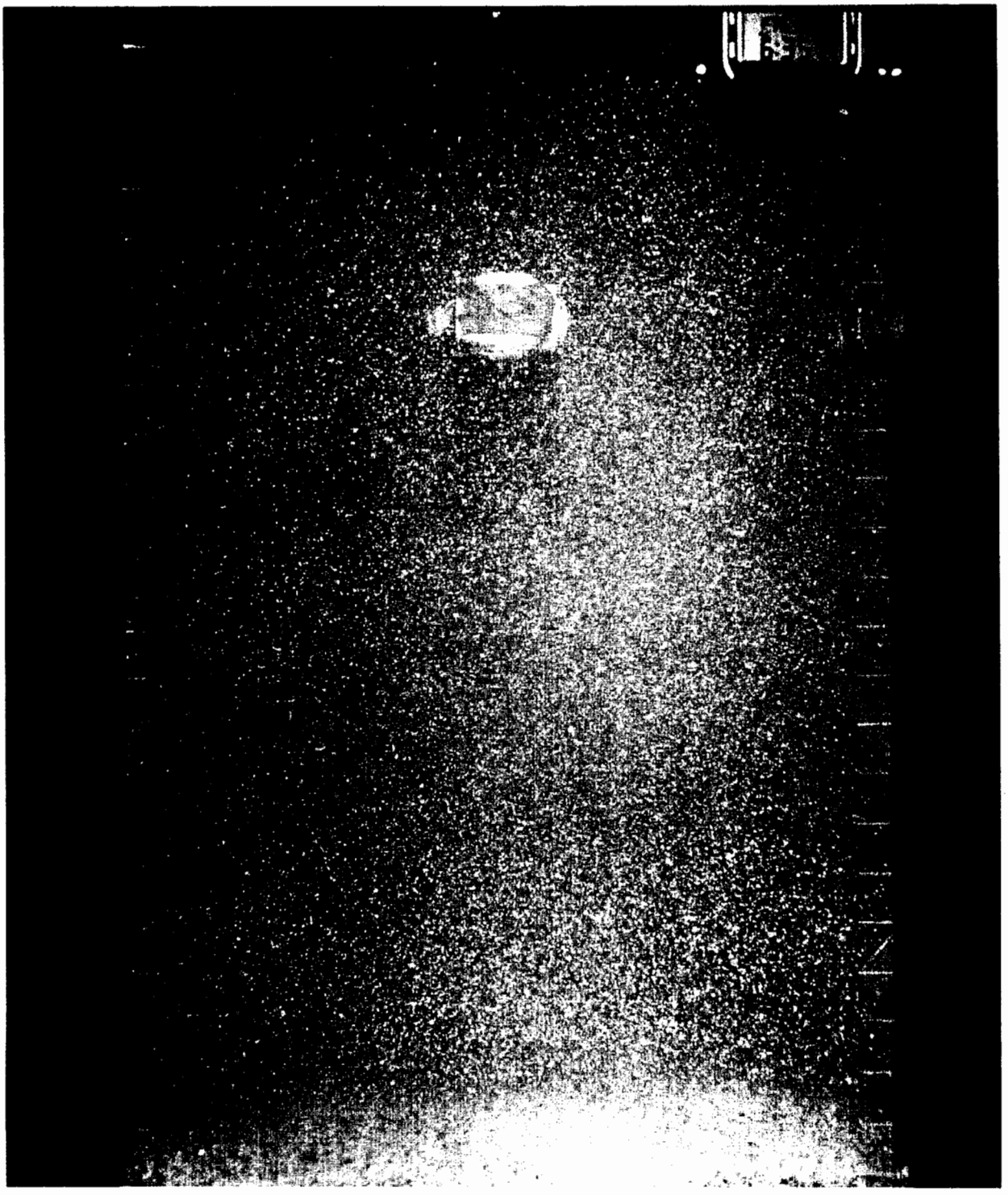


Figure 6-19: Upper Sag harbor Cove (Station 15). Fine sand facies at Station 15.

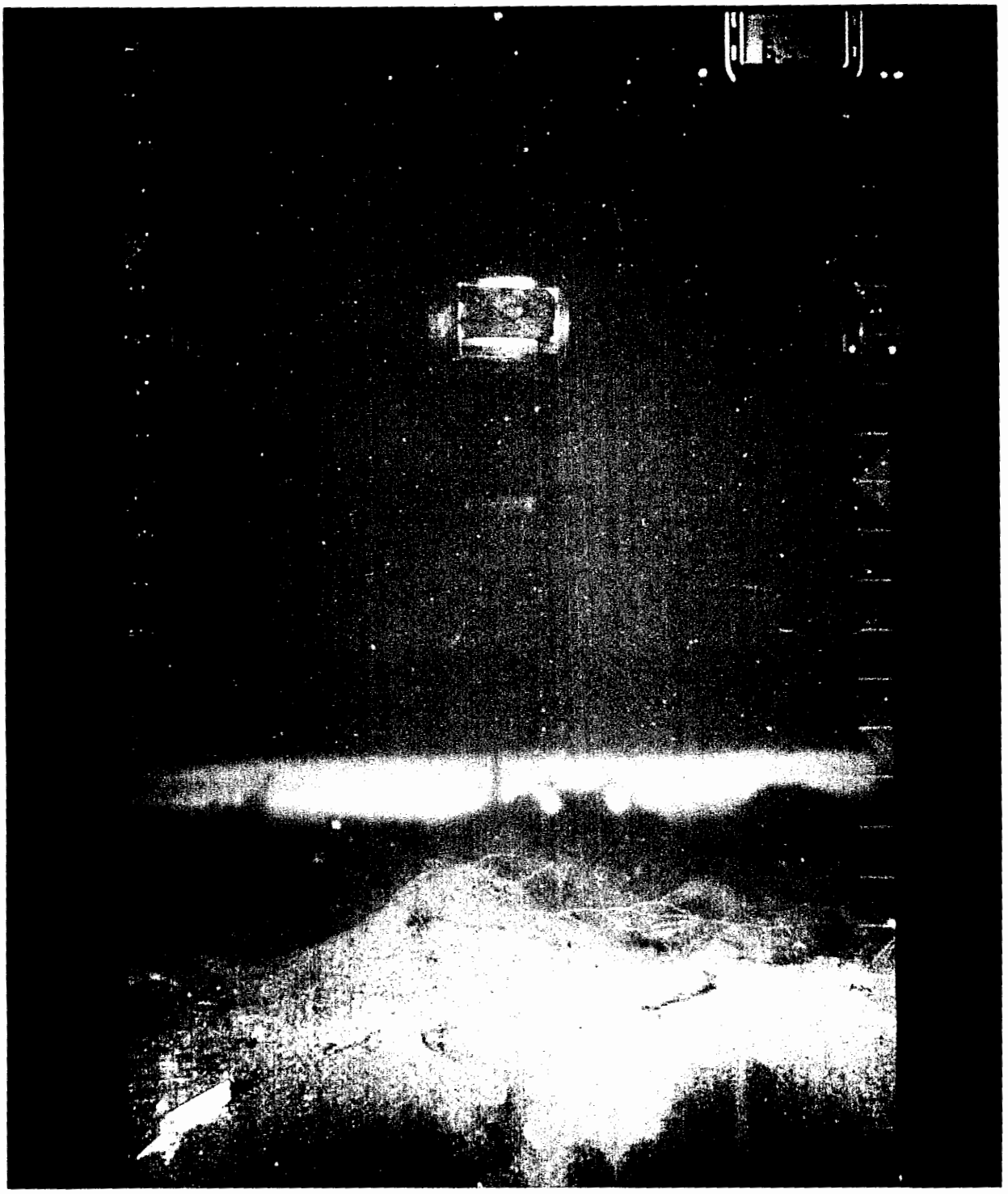


Figure 6-20: Upper Sag Harbor Cove (Station 15). Sand over mud transitional facies at Station 15.

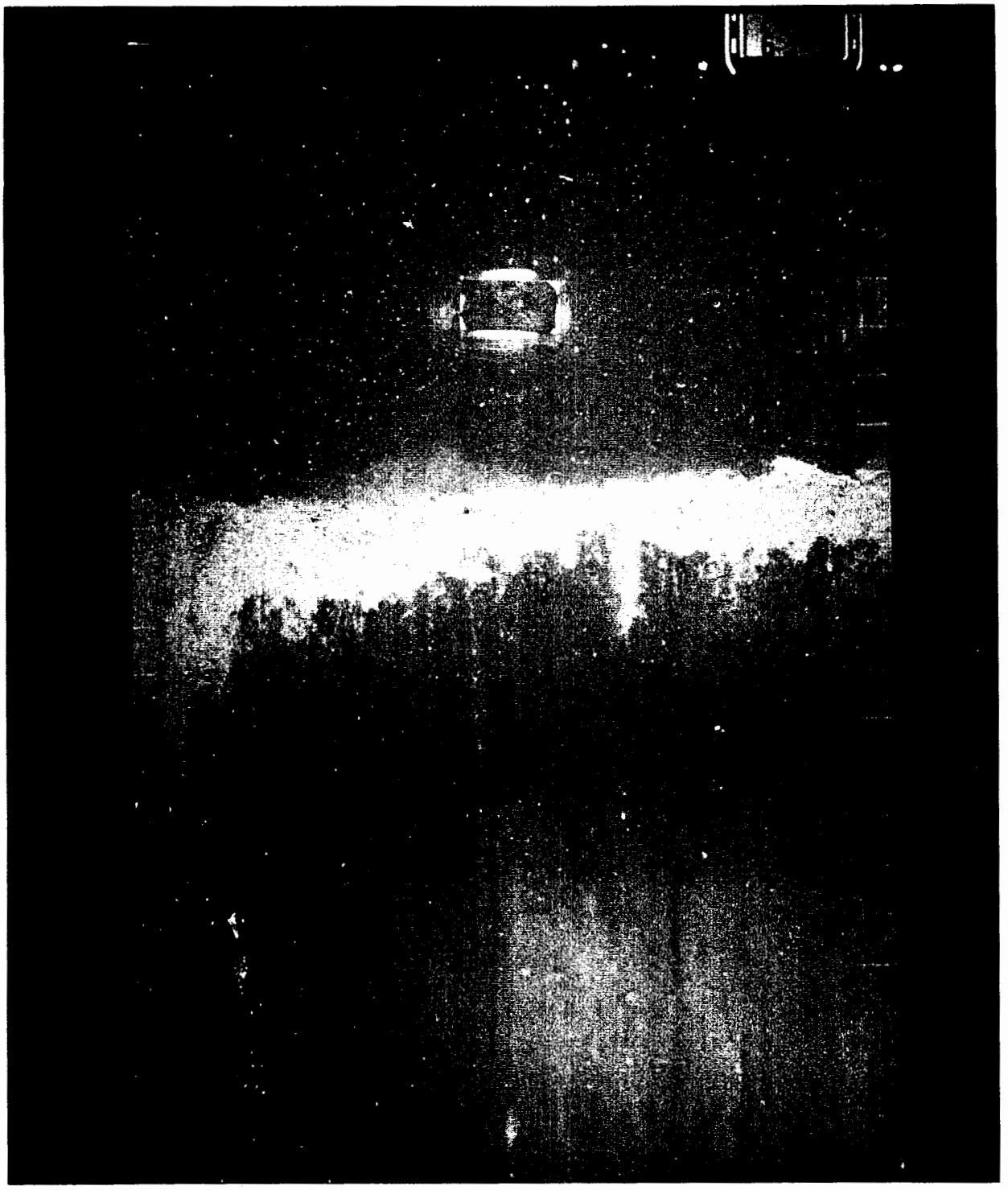


Figure 6-21: Upper Sag Harbor Cove (Station 15). Fine-grained, depositional area at Station 15; note dramatic sediment grain-size shift from previous two Figures.

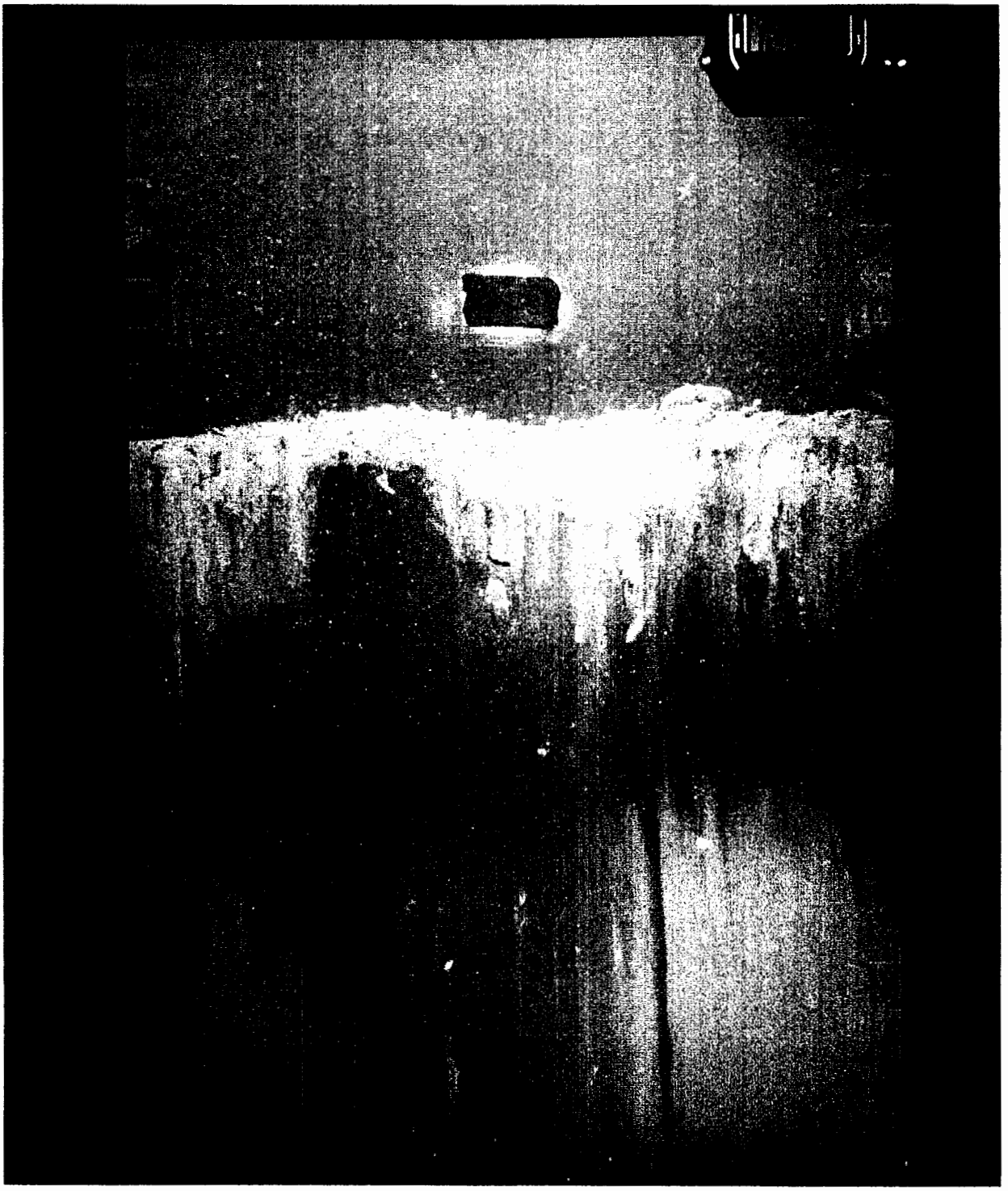


Figure 6-22: East Creek (Station 13). The highly reduced nature of the fine-grained sediment at this station in the shallow areas of Great Peconic Bay is typical of many of the stations sampled in this survey.

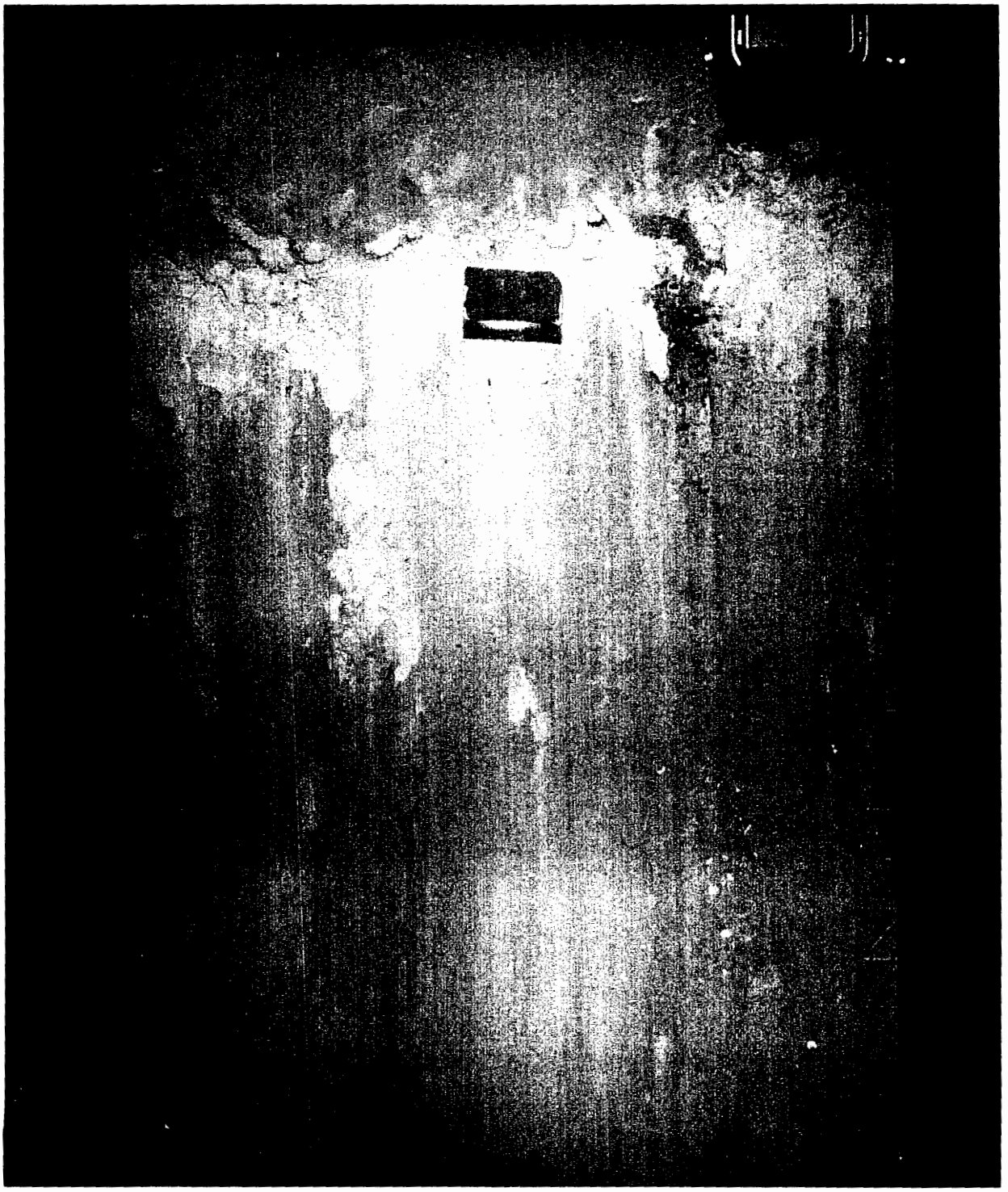


Figure 6-23: West Neck Bay (Station 9). The characteristic flattened tubes at the sediment surface indicate the presence of the amphipod Ampelisca sp.

Figure 6-24: East Creek (Station 13). The dense layers of the sea lettuce Ulva contribute to high organic loading in areas with low flushing rates, causing build-up of methane gas at depths in the sediment (bubbles at depth with glassy appearance).

Table 6-3: Peconic Estuary Sediment Profile Image Summary Parameters

Station	Rep	RPD	Grain Size (Phi)	PPD (cm)	Suc. Stage	Low DO?	Sed. CH4?	OSI
3	1	IND	>4-3	1.8	IND			IND
3	2	IND	Shell-lag	0.3	IND			IND
3	3	IND	Shell-lag	0.3	IND			IND
	Mean			0.8				
6	1	1.4	>4	11.6	1 on 3			7
6	2	1.4	>4	12.8	1			4
6	3	1.7	>4	12.6	1 on 3			8
	Mean	1.5		12.3				6.3
7	1	1.3	>4	10.8	1			3
7	2	1.5	>4	11.6	1			3
7	3	IND	>4	10.3	1			IND
	Mean	1.4		10.9				3
8	1	0.1	>4	17.0	1	Yes		-2
8	2	0	>4	15.8	1	Yes		-3
8	3	0	>4	17.6	1	Yes		-3
	Mean	0		16.8				-2.7
9	1	1.8	>4	18.9	2			6
9	2	1.5	>4	20.1	2			5
9	3	1.8	>4	19.5	2			6
	Mean	1.7		19.5				5.7
10	1	1.1	>4	6.2	1 on 3			7
10	2	0.8	>4	4.8	1 on 3			7
10	3	1.7	>4	6.3	1 on 3			8
	Mean	1.2		5.8				7.3
13	1	0.5	>4	15.6	1->2			3
13	2	IND	>4	23.5	IND		Yes	IND
13	3	0.7	>4	16.8	1			2
	Mean	0.6		18.6				2.5
14	1	IND	>4	18.0	IND			IND
14	2	0.6	>4	12.5	1 on 2			3
14	3	1.7	>4-3	7.5	1			4
	Mean	1.15		12.7				3.5
15	1	1.3	>4-3	1.3	1			3
15	2	0.9	>4-3	0.9	IND			IND
15	3	1.6	>4	13.9	1->2			5
15	4	1.5	>4	3.3	1			3
15	5	0.5	>4	4.2	IND			IND
	Mean	1.16		4.72				3.7
16	1	2.2	>4	17.7	1 on 3			8
16	2	1.7	>4	13.4	2 on 3			8
16	3	IND	>4	23.3	IND			IND
16	4	IND	>4	23.0	3			IND
	Mean	1.95		19.35				8

IND = Indeterminable

Given the broad expanse and relatively shallow nature of the Peconic Estuary, many areas of bottom will experience low or modest flushing rates, so they will be particularly susceptible to ecological stress from nutrient and excess organic loading. Few of the locations sampled showed evidence of mature, deposit-feeding infaunal communities. As macrophytes such as the sea lettuce, *Ulva*, die and start to decompose on the bottom as the season progresses, low dissolved oxygen conditions and high SOD will contribute to further habitat degradation in shallow areas with low circulation rates.

From this study, there do not appear to be any areas with poor habitat quality that could be attributed to excessive sediment contamination. This conclusion is most notable for Noyac Bay (Station 8), which exhibited the "poorest" sediment conditions, based on the lowest OSI, but no ER-L exceedances.

7.0 Conclusions and Recommendations

Several important conclusions and recommendations arise from this study. These are summarized in this section in the context of addressing the primary study objectives listed in Section 1.2 of this report.

7.1 Study Objectives

Review available data on toxic chemical contaminant distributions in sediments and biota to identify (1) contaminants that may pose risk and (2) critical data gaps.

The historical data on chemical contaminant distributions in the Peconic Estuary were insufficient, without additional data generation, to address the objectives of this study. The EMAP data available from the 1990 and 1991 Virginian Province component of that monitoring program were the most relevant to the objectives of this study, and were generally consistent with the new data generated from this study. Focusing essentially on three organic compound classes--PAHs, PCBs, and organochlorine pesticides, fairly low levels of PAHs were reported from the three sampling events/stations (refer to Table 2-1). Additionally, low levels of PCBs and DDT were measured in Little Peconic Bay sediment in the second year (1991) that sampling took place. Metals, which are naturally found at some level in estuarine samples, were of course also reported in the EMAP data set. Several other reports of volatile organic compounds, organochlorine pesticides, and metals are discussed in Section 2 of this report, but do not provide the spatial coverage to assess risk on an estuary-wide scale.

The most critical data gaps from the review of available historical data concerned PAH measurements that include suites of alkylated PAHs, and the general lack of chemical contaminant measurements in sediments on any meaningful spatial scale. This study has generated a small but useful database of high quality contaminant measurements against which future data can be compared. Given the limited scope of this study, some gaps remain, particularly with respect to spatial coverage and classes of pesticides and/or herbicides that might have escaped detection. The reactive nature of many pesticides makes their detection in environmental matrices difficult. For example, the absence of detectable concentrations of aldicarb in sediments collected in this study could be explained by its conversion in sediment to aldicarb sulfoxide and/or aldicarb sulfone, which were not targeted in the analysis. Similar difficulties in detecting chemicals in their original form would, for example, also apply to other carbamate pesticides that may have been used in mosquito control, if such pesticides have been used in Suffolk County. In such cases, direct observation of effects known to be caused by these chemicals may serve as the only evidence of an adverse effect caused by chemical exposure.

Examine spatial distributions of toxic chemical contaminants in estuarine sediments through chemical analyses of field samples.

The sampling design for this study focused on nearshore, depositional environments with a selected few locations in the mid-bay areas to provide some level of reference. In general and predictably, concentrations of chemical contaminants were highest in the sheltered bays and harbors in the vicinity of rivers where fine-grained sediments and decaying organic matter tend to accumulate. Similar spatial trends were seen for both

organic and metals contaminants. Highest concentrations of PAHs were found at Meetinghouse Creek, East Creek, at the Mouth of the Peconic River, and on Upper Sag Harbor Cove. Highest concentrations of PCBs, by far, were found at Meetinghouse Creek; West Neck Bay, Gardiners Bay, and Fish Cove sediments were elevated relative to the remaining stations. Pesticide concentrations were generally low, except for DDT concentrations that appeared elevated at East Creek, Meetinghouse Creek, and Upper Sag Harbor Cove. East Creek and Meetinghouse Creek were the most metals-enriched stations in this study. These distributions are discussed by contaminant class throughout Section 6.

In order to provide some basis for comparison with other coastal systems, Table 7-1 summarizes concentrations of some toxic contaminants that have been measured through the National Status & Trends Program, Mussel Watch Project, of the National Oceanic and Atmospheric Administration, the Delaware Estuary Program (Costa and Sauer, 1994), and the Massachusetts Bays Program (Hyland and Costa, 1995). These databases were used for this comparison because of the similarity in target analytes and general analytical methods used in these programs, including this Peconic Estuary Program study.

Data listed in Table 7-1 are intended only to provide context for contaminant concentrations found in Peconic Estuary sediments--complex coastal systems such as those listed in this table cannot be characterized by single data points and that is not our intent. In general, the highest concentrations measured in this study fall well within the range of sediments from urban, industrial, or agricultural estuaries.

Characterize sediment properties that may influence accumulation of toxic contaminants, such as grain size distribution and organic carbon content.

Sediment properties, specifically TOC and fine-grained sediment content, were found to greatly influence the spatial distributions of toxic contaminants at the study stations. In most cases, elevations in contaminant concentrations were associated with high concentrations of TOC, which ranged from less than 1 percent (Peconic River and Flanders Bay) to 9 percent (Meetinghouse Creek).

Despite limited few study stations, the results of this study appear conclusive regarding the importance of organic carbon in driving accumulations of toxic contaminants in sediments throughout the estuary. An unfortunate aspect of this conclusion is that organic carbon loading results both from natural biogeochemical processes as well as anthropogenic inputs, complicating potential abatement from a management perspective. However, organic carbon and silt + clay content do provide low-cost measurement tools that can be used to focus any future studies that involve targeting toxic contaminants and/or identifying point sources for specific mitigation. This conclusion must not be interpreted to justify using TOC and/or grain size as surrogates for toxic contaminant measurements. Rather, the TOC and/or grain size may be used as a screening or mapping tool to identify locations throughout the estuary where toxic contaminants may be likely to accumulate.

Table 7-1: Comparison of Contaminant Concentrations (μg/g Dry Weight) with Upper-Range Concentrations for Estuarine Sediments.

Location	Total PAHs	Total PCBs	Total DDTs	Cr	Pb	Cu	Hg
Peconic Estuary Program	0.026	<0.001	ND	3.4	3.7	2	0.006
Flanders Bay	0.58	0.004	ND	60	39	26	0.070
Great Peconic Bay	1.2	0.015	ND	58	41	25	0.088
Little Peconic Bay	6.9	0.087	0.020	58	77	129	0.19
Meetinghouse Creek							
Delaware Estuary Program	41	0.3	0.1	58	397	245	0.6
Delaware River	1	0.1	0.02	54	27	16	0.14
Delaware Bay							
Mass Bays Program							
Salem/Beverly Harbors	8.3	0.058	0.002	718	145	57	0.80
Boston Harbor	6.9	0.11	0.008	118	94	96	0.67
Wellfleet Harbor (Cape Cod Bay)	0.72	0.014	0.003	11	57	5	0.061
East Coast NS&T Program	2	250	0.01	85	28	20	0.3
Buzzards Bay, MA	1	30	0.01	70	35	27	0.15
Narragansett Bay, RI	11	360	0.09	140	150	165	0.95
Long Island Sound	9	400	0.05	165	170	130	2
Hudson-Raritan Bay	7	150	0.04	115	70	50	0.2
Chesapeake Bay	0.5	ND	ND	45	20	10	0.05
Charleston Harbor, SC	0.5	10	0.01	23	12	25	0.06
Biscayne Bay, FL							

ND = Not Detected

Compare concentrations of toxic contaminants in the Peconic Estuary to concentrations that have been shown to cause adverse effects to estuarine organisms.

Section 6 of this report featured comparisons of sediment data with ER-L/ER-M values. Exceedances of ER-L values for PAHs, PCBs, DDTs, As, Pb, Ag, Cu, Cd, and Zn suggest some potential for contaminant-induced effects to biological resources. However, most of these exceedances occurred at stations where the accumulation to the exceeding concentrations appeared to be the direct result of very high organic carbon concentrations. At these locations, it is difficult to conclude which factor poses the greatest risk to estuarine resources: the accumulation of toxic contaminants or organic-carbon-related stress (for example, low dissolved oxygen as a result of high chemical oxygen demand).

In the two similar NEP studies for the Delaware Estuary and Massachusetts/Cape Cod Bays systems that have been frequently cited in this report, contaminant accumulations were much less influenced by TOC. That is, sediments from those studies with a far greater range of contaminant accumulations exhibited a much narrower range of organic carbon concentrations. Thus, for the Peconic Estuary specifically, exceedances of ER-L and other sediment quality criteria do not likely predict adverse effects from chemical exposure as accurately as they may for other estuarine systems. While not invalidating the utility of these criteria, this conclusion does reaffirm the importance of employing complementary endpoints of biological effects in any study examining linkages between contaminants and adverse effects within a given system.

Identify chemical contaminants that may adversely affect biological resources of the Peconic Estuary.

The SPI survey and subsequent analyses provide important perspective on the most likely causes of poor benthic community and habitat conditions in this ecosystem. Given the broad expanse and relatively shallow nature of the Peconic estuary, many areas of bottom will experience low or modest flushing rates, so they will be particularly susceptible to ecological stress from nutrient and excess organic loading. Few of the locations sampled showed evidence of mature, deposit-feeding infaunal communities. As macrophytes such as the sea lettuce, *Ulva*, die and start to decompose on the bottom as the season progresses, low dissolved oxygen conditions and high sediment oxygen demand will contribute to further habitat degradation in shallow areas with low circulation rates.

The results of this study lead us to conclude that toxic chemical contaminants do not pose considerable risk to biological resources on an estuary-wide basis. Although difficult to quantify terms such as "considerable risk," we can conservatively conclude that toxic contaminants do not pose as great a risk to resources as the stress resulting from excessive nutrient and organic carbon loading. We must, however, note that one of the problems associated with high organic carbon concentrations found in this study is the favorable accumulation of predominantly background contaminants to concentrations that could adversely affect biological resources on a local basis. The key distinction in these statements are the aspect of spatial scales implied by "estuary-wide" versus "local." The factors that will determine the extent to which resources may be affected by localized

accumulations of contaminants include the response of potentially affected biological communities to the stresses of the organic carbon loading.

Based on the suite of assessment tools employed in this study, there did not appear to be any stations for which poor habitat quality could be attributed to toxic chemical contamination. However, there remains the potential for localized problems associated with toxic chemicals that may accumulate in fine-grained, organic-rich muds that are found in many of the sheltered embayments, particularly in the western portion of the estuary. In addressing this important study objective, we conclude that the following toxic chemical contaminants may pose potential risk given the necessary circumstances:

- PCBs
- DDTs and any other modern pesticide/herbicide identified subsequent to this study
- Arsenic
- Lead

Although lower in priority, cadmium, zinc, and high-molecular-weight PAHs (i.e., the 4- through 6-ringed priority pollutant PAHs), may also be considered for targeting in future studies.

Determine, to a general level, potential sources of chemical contaminants.

The physical dynamics of this estuary, with respect to limited source inputs, circulation, and flushing, greatly influence chemical contaminant distributions. Such strong parallels between physical and chemical contaminant dynamics suggest that nonpoint sources (e.g., atmospheric deposition, surface runoff, groundwater underflow), which make up the chemical contaminant background or baseline for this system, exceed the influence of localized point sources throughout the estuary. This general conclusion is strongly supported by two lines of evidence: 1) the general correspondence of contaminant concentrations with TOC and silt + clay content and 2) constancy of alkylated PAH compositions throughout all study stations.

It appears that there may be some localized point source(s) for PCBs influencing Meetinghouse Creek. This conclusion is based on the elevation in total PCB at that station beyond what we would predict based on the TOC and silt + clay content.

Identify additional needs for research regarding sources, transport, and fate of toxic contaminants and impacts on living resources, human health, and the ecosystem.

As we have concluded that organic carbon is the greatest single factor driving distributions of toxic contaminants in the Peconic Estuary, it is crucial to accurately understand the dynamics of organic carbon on an estuary-wide basis. This includes characterizing the major sources of organic carbon and modeling its transport and fate. Additional surveys to better map benthic conditions throughout the estuary, perhaps using sediment profile imaging, can provide direct evidence of the extent to which benthic resources are stressed and indirectly indicate (using SPI parameters) offshore locations that may be vulnerable to contaminant accumulations.

Despite the limited sampling for this study, we were able to identify locations with elevations of toxic contaminants. These locations combined high organic carbon and fine-grained sediments to produce accumulations of background contaminants, and in some cases localized sources of contaminants, to concentrations that may adversely affect resources. Not surprisingly, these locations are typically in shallow, protected embayments or creeks. More thorough sampling of sediments from some of these areas for a subset of the chemical contaminants targeted in this study should confirm or clarify the conclusions stated herein regarding potential contaminants of concern and their likely point sources. For any further study, organic carbon concentrations should be measured as a screen, with selected samples analyzed for the reduced target list. The scoping of such a study should be based on available budget, with some compromise to be reached on the following scope issues:

- How many areas to be sampled?

Areas should be selected for sampling based on a reasonable expectation of localized contaminant sources and/or identification of sensitive resources or habitat.

- How many samples to be collected from each area?

At least three samples should be used to chemically characterize an embayment 100 to 300 meters in diameter. The diversity of the benthos is equally or even more important than the spatial area because the intent here is to characterize contaminant problems rather than estimate sediment loadings. Thus, if there are two predominant habitat types within an embayment, each should be represented by a minimum of three samples. Each creek or river should be treated as an "area." Embayments receiving flows from multiple creeks/rivers should include replicate samples from within each creek and replicate samples for the embayment, that is, a reasonable distance from the mouths of the respective creeks. With a screening approach that uses TOC content to select samples for analysis, more than three samples should be collected to ensure that at least three for each area meet the selection criterion for sample analysis. Thus, six composite samples from each "area" should ensure that at least three will be suitable for chemical characterization for that area.

Each sample should represent a composite of at least three surface grabs. Additional reference sites should not be necessary as this study provides adequate characterization of contaminants baselines for the estuary.

- What chemicals to target?

All samples collected should be analyzed for TOC as a screen. A reasonable cutoff for characterization should be areas with mean TOC concentration higher than 3 or 4 percent. Ideally, at least three samples with the highest TOC should be analyzed for an area. However, areas with five or six samples with high TOC may not require that all five or six samples be characterized, especially if an additional area with reasonably high TOC can be included for characterization.

In the absence of a specific suspected target, the priority chemicals for characterization should include PCBs, measured as congeners, DDT pesticides (and additionally identified pesticides/herbicides), and the metals arsenic, lead, cadmium, and zinc. Although high-molecular-weight PAHs may be of some interest, we recommend prioritizing more samples over including PAHs for this estuarine system.

7.2 Management Recommendations

The direct observation of benthic habitat conditions and infaunal succession through sediment profile imaging revealed considerable evidence of a stressed system as indicated by complementary measures of sediment quality. However, as a reviewer of the draft of this report insightfully commented: "The continuum of habitats from disturbed to stable provides a mosaic on varying scales that is extremely important to the overall health and biodiversity of the system." As Rhoads and Germano (1986) addressed in their discussion of "Stage I" versus "Stage III" assemblages in an ecosystem, both have their overall functions and are needed. But what is the critical loading rate of natural organics or contaminants that would cause an equilibrium (Stage III) community retrograde to a Stage I? Further, what is a "healthy balance" of Stage III versus Stage I on a regional scale? These are first-order resource management questions without known answers.

While nature will, no doubt, always have a balance of the successional continuum, clearly there are extreme pulses of disturbance (or stability) when the "ecological pendulum" is too far at either end and the system is "out of balance" so something will happen to cause change. Applying this analogy to the Peconic Estuary, yes, there probably are natural areas of an estuary where flushing rates are low and organic loadings are high, which is part of the normal ecosystem and probably of value for some species with respect to feeding or protected nursery areas. What requires vigilant resource management is when the number of these quiescent, depositional (high sediment oxygen demand, high TOC, low DO) areas start to increase due to anthropogenic stress (e.g., coastline development, leaking septic systems, excessive lawn fertilization along the shoreline) and the estuary reverts to a stagnant swamp. Although, it also follows that there are benefits to a swamp also, from a larger scale ecosystem perspective.

Thus, while we caution that the terms "disturbed" or "poor quality" are indeed subjective when applied to benthic environments, we acknowledge that any resource management perspective is somewhat subjective. It will inherently be biased according to the current societal or scientific beliefs of the day (or from the perspective of the species or group for which the habitat is trying to be managed or maximized). What is needed is a balance, or moderation of all extremes. As to what defines a proper or improper balance as far as ecosystem community types unfortunately remains a subjective, or personal, argument at this point--there are no commonly accepted standards.

With respect to toxic contaminants, management objectives should focus on (1) addressing organic carbon loading, (2) better characterizing the contaminant distributions in the vicinity of East Creek, Meetinghouse Creek, and other potentially contaminated embayments and creeks/rivers, and (3) addressing potentially elevated loadings of heavy metals.

APPENDIX A

Field Site Logs

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 16 - Meetinghouse Creek RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 40°56.20" N TIME ON SITE: 1015

LONGITUDE SITE CENTER: 72°36.87" W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓

EMBAYMENT ___ CHANNEL ___ OTHER ✓ (End of Creek)

SUBSTRATE TYPE: SAND ___ SILT ✓ CLAY ___ OTHER ___

DESCRIPTION OF SITE: Meetinghouse Creek
End of Creek
Near Duck Farm + Boat Slips
Creek ~ 1/16 mile wide at point of taking sample

SAMPLING PERSONNEL: Melissa Rigath, Edith Hutchinson

COMMENTS: 4 grabs composited per sample. Only 1 sample taken - TOC, GS, Organics, Metals

RECORDER: Melissa J Rigath DATE: 9/2/94

Arthur D Little

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 03 - Flanders Bay

RIVER MILE: _____

SAMPLING REACH: _____

NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 40° 55' 20" N

TIME ON SITE: ~~0945~~ 0927 ME MDR 9/21/94

LONGITUDE SITE CENTER: 72° 35' 32" W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓

EMBAYMENT ✓ CHANNEL ___ OTHER ___

SUBSTRATE TYPE: SAND ✓ SILT ___ CLAY ___ OTHER ___

DESCRIPTION OF SITE: Middle of Flanders Bay
Ston ~ ½ mi away
Took 3 grab, per grabs ; moved ~ 2/10 of a mile to
the east. Collect sediment grabs there.
Lots of shells, crabs, etc

SAMPLING PERSONNEL: Edith Hutchinson, Melissa Rigatti

COMMENTS: 5 grabs composited per sample. Only 1 sample taken TOC, GS, Metals, Organ...

RECORDER: Melissa J Rigatti DATE: 9/21/94

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 26 - Great Peconic Bay Central Basin/Deep RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 40°56'.00" N TIME ON SITE: 1428

LONGITUDE SITE CENTER: 72°30'.30" W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓

EMBAYMENT ✓ CHANNEL ___ OTHER ___

SUBSTRATE TYPE: SAND ___ SILT ✓ CLAY ___ OTHER ___

DESCRIPTION OF SITE: Great Peconic Bay

Shore ~ ½ M away

SAMPLING PERSONNEL: Edith Hutchinson, Melissa Rigutti

COMMENTS: 4 grabs composited per sample

1st Samp - TOC, GS, Metals, Organics

2nd + 3rd Samples - TOC + GS only

RECORDER: Melissa J Rigutti DATE: 9/20/94

Arthur D Little

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 07- Little Peconic Bay RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 40°59.62" N TIME ON SITE: 1335

LONGITUDE SITE CENTER: 72°25.06" W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓

EMBAYMENT ✓ CHANNEL ___ OTHER ___

SUBSTRATE TYPE: SAND ___ SILT ✓ CLAY ___ OTHER ___

DESCRIPTION OF SITE: Middle of Little Peconic Bay
Shoreline ~ ½ away
Drifted while taking samples ~ 2/10 of a mile. Returned to original site for 3rd sample.

SAMPLING PERSONNEL: Melissa Rigath, Edith Hutchinson

COMMENTS: 4 grabs composited per sample
1st sample - TOC, GS, Metals, Organics
2nd + 3rd samples - TOC + GS only

RECORDER: Melissa J Rigath DATE: 9/20/94

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 28 - Nogac Bay RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 41°00.79"N TIME ON SITE: 1245

LONGITUDE SITE CENTER: 72°20.54"W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓

EMBAYMENT ✓ CHANNEL ___ OTHER ___

SUBSTRATE TYPE: SAND ___ SILT ✓ CLAY ___ OTHER ___

DESCRIPTION OF SITE: Nogac Bay
High Sulfur odor

SAMPLING PERSONNEL: Melissa Rigath, Edith Hutchinson

COMMENTS: 4 grabs composited per sample
1st Sample - TOC, GS, Metals, Organics
2nd + 3rd Samples - TOC + GS only

RECORDER: Melissa J Rigath DATE: 9/20/94

Arthur D Little

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: #9 - West Neck Bay RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 41°03.70' N TIME ON SITE: 1145

LONGITUDE SITE CENTER: 72°21.41" W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓ NA HJR 9/20/94

EMBAYMENT ✓ CHANNEL ___ OTHER ~~✓~~ (Bay)

SUBSTRATE TYPE: SAND ___ SILT ✓ CLAY ___ OTHER ___

DESCRIPTION OF SITE: West Neck Bay
Boating / Residential Area
Eel grass present in Sediment
High Silt. Odor.
Drifted while taking grabs 1/10 of mile. Moved to original spot after taking 2nd sample (all 4 grabs)

SAMPLING PERSONNEL: Melissa Rigath, Edith Hutchinson

COMMENTS: 4 grabs composited per sample
1st sample - TOC, GS, Metals, Organics
2nd + 3rd sample - TOC + GS only

RECORDER: Melissa J Rigath DATE: 9/20/94

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 18 - Gardiners Bay RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 41° 05.87" N TIME ON SITE: 0825

LONGITUDE SITE CENTER: 72° 12.21" W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓

EMBAYMENT ___ CHANNEL ___ OTHER ✓ (Bay)

SUBSTRATE TYPE: SAND ___ SILT ✓ CLAY ✓ OTHER ___

DESCRIPTION OF SITE: Middle of Gardiner Bay

SAMPLING PERSONNEL: Edith Hutchinson, Melissa Rigath

COMMENTS: 4 grabs to go Composited for samples (1 sample only - TOC, GS, Metals, Organics)
Drifted 1/10 of a mile while sampling. (#1-3) Returned to original spot for last grab

RECORDER: Melissa J Rigath DATE: 9/20/94

Arthur D Little

PECONIC ESTUARY PROGRAM
SITE LOG

ADL SITE NO: 11 - Fish Cove RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: _____ TIME ON SITE: 0800

LONGITUDE SITE CENTER: _____

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓

EMBAYMENT ___ CHANNEL ___ OTHER ✓ (cove)

SUBSTRATE TYPE: SAND ___ SILT ✓ CLAY ___ OTHER ___

DESCRIPTION OF SITE: Fish Cove
Middle of Fish Cove
Lots of birds (egrets, ducks, crows) + jellyfish
Landfill nearby
Soil had high sulfur odor
Area had garbage odor

SAMPLING PERSONNEL: Edith Hutchinson, Melissa Rigatti

COMMENTS: 4 grabs per sample. Only 1 sample taken - GS, Metals, PC, Organics

RECORDER: Melissa J Rigatti DATE: 9/21/94

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 12-Peconic River RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: _____ TIME ON SITE: 1100

LONGITUDE SITE CENTER: _____

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ___

EMBAYMENT ___ CHANNEL ___ OTHER ✓ (Beginning of River)

SUBSTRATE TYPE: SAND ✓ SILT ___ CLAY ___ OTHER ___

DESCRIPTION OF SITE: Beginning of Peconic River
Very shallow 6" to 18"
Took Samples in a relatively stable area
~~Did not~~

SAMPLING PERSONNEL: Edith Hutchinson, Melissa Rigatti

COMMENTS: Did not ok grab. Scooped samples using spatula/scoops to only the top two centimeters. ~~Took~~ Took 3 samples.
1st sample - TOC, G.S, Metals, Organics, 2nd + 3rd samples DC + GS only

RECORDER: Melissa J Rigatti DATE: 9/21/94

Arthur D Little

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 13 - East Creek RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 40°56.53"N TIME ON SITE: 1527

LONGITUDE SITE CENTER: 72°33.98"W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ___

EMBAYMENT ___ CHANNEL ___ OTHER ___

SUBSTRATE TYPE: SAND ___ SILT ___ CLAY ___ OTHER ___

DESCRIPTION OF SITE: Creek
~ 1/10 mile wide
Anchored

SAMPLING PERSONNEL: Edith Hutchinson, Melissa Rigath

COMMENTS: 4 grabs composited for Sample.
Took only 1 sample - TOC, GS, Metals + organics

RECORDER: Melissa J Rigath DATE: 9/29/94

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 14-Mouth of Peconic River RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 40°55.27" N TIME ON SITE: 1035

LONGITUDE SITE CENTER: 72°36.85" W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓

EMBAYMENT ___ CHANNEL ___ OTHER ___

SUBSTRATE TYPE: SAND ___ SILTy ✓ CLAY ___ OTHER ___

DESCRIPTION OF SITE: Mouth of Peconic River (Middle of)
High sulfur odor
Lots of shells + Sea lettuce

SAMPLING PERSONNEL: Melissa Rigath, Edith Hutchinson

COMMENTS: 4 grabs composited per sample Only 1 sample taken - TOC, GS Metals organics

RECORDER: Melissa J Rigath DATE: 7/21/94

Arthur D Little

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 15 - Upper Sag Harbor Cove RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 40°69.29'' N TIME ON SITE: 0952

LONGITUDE SITE CENTER: 72° 18.09'' W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓

EMBAYMENT ___ CHANNEL ___ OTHER ✓ (Creek leading into Cove)

SUBSTRATE TYPE: SAND ___ SILT ___ CLAY ___ OTHER ✓ (Mud)

DESCRIPTION OF SITE: Boating Residential Area
Shallow (~3')
Upper end of creek leading into a cove

SAMPLING PERSONNEL: Melissa Rigath, Edith Hutchinson

COMMENTS: 4 grabs Composited per sample
1st sample - TOC, GS, Metals, Organics
2nd + 3rd samples - TOC, GS only

RECORDER: Melissa J Rigath DATE: 9/20/94

PECONIC ESTUARY PROGRAM

SITE LOG

ADL SITE NO: 16 - Meetinghouse Creek RIVER MILE: _____

SAMPLING REACH: _____ NOAA/EMAP SITE CODE: _____

LATITUDE SITE CENTER: 40°56.20" N TIME ON SITE: 1015

LONGITUDE SITE CENTER: 72°36.87" W

PHYSICAL CONDITIONS: HIGH ENERGY ___ LOW ENERGY ✓

EMBAYMENT ___ CHANNEL ___ OTHER ✓ (End of Creek)

SUBSTRATE TYPE: SAND ___ SILT ✓ CLAY ___ OTHER ___

DESCRIPTION OF SITE: Meetinghouse Creek
End of Creek
Near Duck Farm + Boat Slips
Creek - 1/10 mile wide at point of taking sample

SAMPLING PERSONNEL: Melissa Rigath, Edith Hutchinson

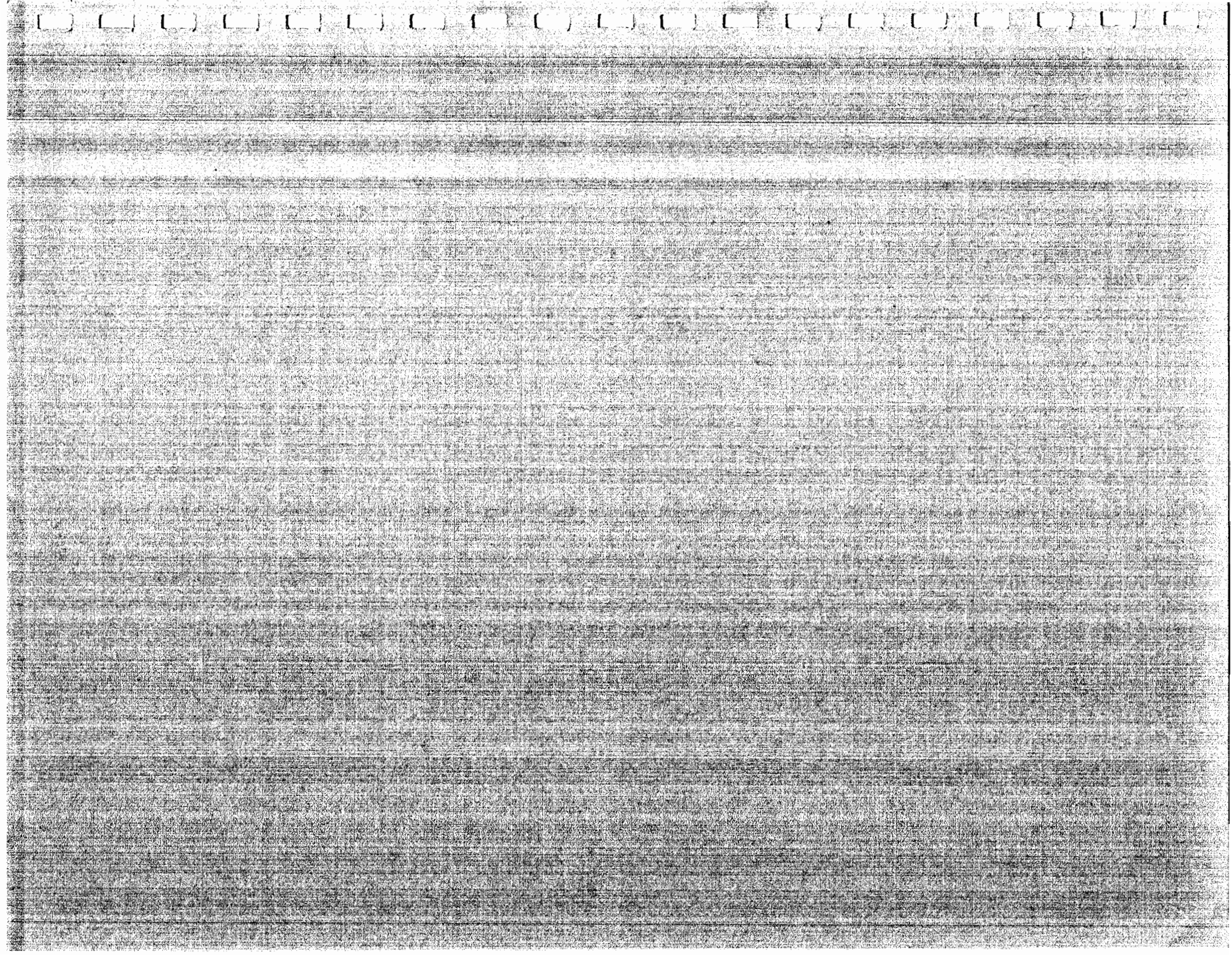
COMMENTS: 4 grabs composited per sample. Only 1 sample taken - TOC, GS, Organics, Metals

RECORDER: Melissa J Rigath DATE: 9/2/94

Arthur D Little

APPENDIX B

PAH, TOC, and Grain Size Data



Station Name	NA	NA	NA	NA	Great Peconic Bay	Great Peconic Bay
Lab ID	AU-S-85PB	AU-S-86EB	AU-S-87SRM	AU-S-88SRM	06PEORG	06PEORGMS
Field ID	BLANK	00PEORGEB	SRM 1941a	SRM 1941a	06PEORG94	06PEORG94
Reporting Limit	10	10	10	10	10	10
Sample Size	10g	10g	4.93g	5.69g	12.5g	12.4g
Sample Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
C0N	16	5.9 J	470	420	5.4 J	73
C1N	ND	2.5 J	160	180	3 J	70
C2N	ND	3.9 J	190	200	5.5 J	38
C3N	ND	ND	190	190	3.7 J	34
C4N	ND	ND	120	120	3.9 J	4.9 J
ACEY	ND	ND	64	65	6.3 J	53
ACE	ND	ND	34	31	0.91 J	49
BIP	ND	1.7 J	53	69	1.6 J	49
C0F	ND	0.54 J	69	65	2.5 J	60
C1F	ND	ND	64	56	1.8 J	2.5 J
C2F	ND	ND	90	91	2.7 J	3.6 J
C3F	ND	ND	180	170	6.6 J	14
C0P	ND	1.5 J	360	330	17	66
C0A	ND	ND	120	110	5.1 J	42
C1P/A	ND	2.5 J	250	220	12	51
C2P/A	ND	2.9 J	210	200	12	16
C3P/A	ND	4.1 J	150	140	6.4 J	8.1 J
C4P/A	ND	4.1 J	190	150	9.2 J	11
C0D	ND	ND	43	40	1.4 J	2.1 J
C1D	ND	0.55 J	61	57	1.7 J	2.3 J
C2D	ND	1.7 J	110	100	3.2 J	3.7 J
C3D	ND	2.1 J	110	95	2.5 J	2.7 J
FLANT	ND	0.96 J	930	800	61	120
PYR	ND	1.3 J	740	620	56	120
C1F/P	ND	1.7 J	440	390	27	33
C2F/P	ND	2.9 J	310	250	16	19
C3F/P	ND	3.4 J	150	150	7.6 J	9 J
BAA	ND	ND	390	320	21	61
C0C	ND	1.4 J	510	440	34	100
C1C	ND	1.1 J	270	240	15	17
C2C	ND	1.4 J	150	140	7.8 J	9.5 J
C3C	ND	ND	120	110	5.6 J	6.9 J
C4C	ND	ND	65	52	3.7 J	2.9 J
BBF	ND	0.59 J	900	930	59	130
BKF	ND	ND	410	400	18	77
BEP	ND	ND	690	800	32	96
BAP	ND	ND	510	450	27	76
PER	ND	ND	320	310	7.2 J	60
IND	ND	ND	600	650	32	94
DAH	ND	ND	110	110	5.1 J	48
BGP	5.5 J	ND	610	670	32	87
%D8N	13 &	35	50	65	46	23 &
%D10AC	40 &	47 &	64	65	55	46 &
%D10PH	55	68	83	81	68	68
%D12BAP	41 &	55	48 &	37 &	58	52
%TOC					2.04	
%TOC (dup)						
% Gravel					0.6	
% Gravel (dup)						
% Sand					2.54	
% Sand (dup)						
% Silt					41.52	
% Silt (dup)						
% Clay					55.34	
% Clay (dup)						

ND - not detected
J - under SOP reporting limits
& - analyte recovery less than or greater than specified range, 50-125%

Station Name	Great Peconic Bay	Flanders Bay	Little Peconic Bay	Noyac Bay	West Neck Bay	Gardiners Bay
Lab ID	06PEORGMSD	03PEORG	07PEORG	08PEORG	09PEORG	10PEORG RE
Field ID	06PEORG94	03PEORG94	07PEORG94	08PEORG94	09PEORG94	10PEORG94
Reporting Limit	10	10	10	10	10	10
Sample Size	11.9g	23.5g	13.3g	11.4g	10.5g	14.9g
Sample Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
C0N	63	1.6 J	11	15	13	57
C1N	91	0.63 J	5.4 J	5.9 J	4.9 J	7.6 J
C2N	43	1.3 J	9.8 J	11	11	11
C3N	37	ND	7.2 J	8.3 J	6.9 J	9.4 J
C4N	3.4 J	ND	7 J	6.8 J	8.4 J	11
ACEY	59	0.39 J	13	16	12	23
ACE	55	ND	1.4 J	2 J	1.5 J	2.9 J
BIP	56	0.48 J	2.1 J	2.5 J	2.1 J	4.1 J
C0F	63	ND	4.8 J	5.5 J	4.6 J	7.2 J
C1F	1.8 J	ND	3.8 J	4.1 J	3.6 J	7.6 J
C2F	2.6 J	ND	7 J	7.3 J	6.4 J	10
C3F	8.2 J	ND	16	18	14	24
C0P	68	0.79 J	32	37	21	44
C0A	57	0.26 J	11	14	10	14
C1P/A	54	0.75 J	27	30	19	37
C2P/A	13	0.82 J	28	29	20	36
C3P/A	6.6 J	ND	14	15	12	20
C4P/A	7.6 J	ND	17	21	13	25
C0D	1.6 J	0.11 J	2.8 J	3.3 J	2.5 J	3.5 J
C1D	1.7 J	ND	3.9 J	4.5 J	2.8 J	4.9 J
C2D	3 J	ND	6.2 J	6.9 J	5.5 J	9.1 J
C3D	2.3 J	ND	5 J	5.9 J	5.4 J	8.1 J
FLANT	120	2.6 J	120	140	110	150
PYR	110	2.1 J	110	130	90	140
C1F/P	27	1.1 J	60	67	41	89
C2F/P	16	0.72 J	34	37	26	53
C3F/P	7.1 J	ND	16	16	12	25
BAA	60	1 J	43	50	31	66
C0C	100	1.5 J	68	79	55	86
C1C	15	0.54 J	30	33	22	54
C2C	7.4 J	ND	16	17	12	25
C3C	5.6 J	ND	11	11	8.9 J	18
C4C	2.5 J	ND	4.6 J	4.2 J	4.5 J	13
BBF	92	2.9 J	140	150	98	170
BKF	63	0.89 J	45	45	31	42
BEP	76	1.6 J	75	77	53	83
BAP	78	1.2 J	57	66	40	68
PER	60	0.24 J	18	17	12	27
IND	79	1.5 J	79	81	52	110
DAH	49	0.21 J	12	12	6.7 J	18
BGP	70	1.4 J	72	75	49	95
%D8N	45	33 &	15 &	24 &	18 &	6.2 &
%D10AC	55	50	26 &	48 &	41 &	27 &
%D10PH	74	68	37 &	72	60	50
%D12BAP	76	52	26 &	53	54	50
%TOC		0.18	1.67	2.09	3.21	1.43
%TOC (dup)						
% Gravel		1.63	0.58	0.42	0	0.55
% Gravel (dup)						
% Sand		95.53	7.66	10.93	3.59	12.48
% Sand (dup)						
% Silt		2.07	33.69	37.21	46.29	24.06
% Silt (dup)						
% Clay		0.78	58.07	51.45	50.12	62.91
% Clay (dup)						

ND - not detected
J - under SOP reporting limits
& - analyte recovery less than or greater than specified range, 50-125%

Station Name	Fish Cove	Peconic River	East Creek	Mouth of Peconic River	Upper Sag Harbor	Meetinghouse Creek
Lab ID	11PEORG	12PEORG	13PEORG	14PEORG	15PEORG	16PEORG
Field ID	11PEORG94	12PEORG94	13PEORG94	14PEORG94	15PEORG94	16PEORG94
Reporting Limit	10	10	10	10	10	10
Sample Size	8.57g	20.8g	9.60g	12.1g	12.4g	4.40g
Sample Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
C0N	22	12	41	11	9.4 J	94
C1N	7.4 J	3.4 J	12	4.3 J	6.7 J	25
C2N	11	3.5 J	18	14	11	46
C3N	9 J	2.2 J	17	29	12	37
C4N	11	1.2 J	17	27	15	38
ACEY	26	14	64	61	19	140
ACE	4 J	12	9.7 J	2.9 J	4.8 J	15
BIP	3.6 J	0.97 J	4.2 J	1.9 J	2 J	10
C0F	9.5 J	9.7 J	24	12	8.8 J	34
C1F	5.4 J	2.3 J	11	26	5 J	19
C2F	9.2 J	1.5 J	20	37	11	35
C3F	20	6 J	72	46	35	120
C0P	43	59	94	86	87	150
C0A	25	23	74	38	19	110
C1P/A	31	15	66	160	48	96
C2P/A	26	9.3 J	59	140	60	97
C3P/A	15	7.6 J	32	56	62	59
C4P/A	20	22	64	66	76	100
C0D	4.2 J	3.5 J	7.3 J	8.2 J	6.6 J	12
C1D	4 J	1.5 J	6.6 J	26	10	12
C2D	7.4 J	1.9 J	10	41	31	23
C3D	7.3 J	2 J	12	22	55	24
FLANT	190	160	520	430	270	790
PYR	150	140	390	390	240	610
C1F/P	77	55	210	290	130	300
C2F/P	46	33	120	120	97	180
C3F/P	20	13	43	45	67	82
BAA	66	72	140	170	100	260
C0C	92	91	380	220	140	440
C1C	41	34	90	100	93	150
C2C	21	12	36	42	68	68
C3C	14	9.9 J	27	22	72	59
C4C	11	5.2 J	14	9.6 J	40	47
BBF	190	220	460	350	250	810
BKF	58	50	140	94	71	270
BEP	95	110	210	170	150	410
BAP	81	89	130	160	140	290
PER	26	32	50	54	66	110
IND	87	110	170	160	130	360
DAH	15	21	30	30	25	69
BGP	85	99	150	140	130	320
%D8N	14 &	32 &	11 &	22 &	34 &	5.2 &
%D10AC	35 &	51	40 &	46 &	58	21 &
%D10PH	54	68	76	67	71	47 &
%D12BAP	43 &	47 &	56	50	71	38 &
%TOC	3.98	0.67	6.56	3.11	4.06	9.48
%TOC (dup)		0.67				9.62
% Gravel	0	3.9	0	10.79	1.15	0
% Gravel (dup)				7.06		
% Sand	10.48	94.28	1.89	38.79	72.12	2.11
% Sand (dup)				39.34		
% Silt	50.73	1.29	64.38	19.37	15.82	68.04
% Silt (dup)				20.93		
% Clay	38.8	0.53	33.72	31.05	10.9	29.86
% Clay (dup)				32.67		

ND - not detected
J - under SOP reporting limits
& - analyte recovery less than or greater than specified range, 50-125%

APPENDIX C

PCB and Pesticide Data

Station Name	NA	NA	NA	NA	Great Peconic Bay	Great Peconic Bay
Lab ID	AU-S-85PB	AU-S-86EB	AU-S-87SRM	AU-S-88SRM	06PEORG94	06PEORG94MS
Field ID	Blank	00PEORG94	SRM 1941a	SRM 1941a	06PEORG94	06PEORG94
Reporting Limit	0.1	0.1	0.1	0.1	0.1	0.1
Sample Size	10g	10g	4.93g	5.69g	12.5g	12.4g
Sample Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
8	ND	ND	3.7	2.8	ND	J
ALPHA-BHC	ND	ND	J	J	ND	J
HCB	ND	ND	38	44	ND	J
BETA-BHC	ND	ND	J	4.2	ND	J
GAMMA-BHC	ND	ND	J	J	ND	J
18	ND	ND	J	J	ND	J
DELTA-BHC	ND	ND	J	1.1	ND	J
28	ND	ND	12	10	ND	10
HEPT	ND	ND	J	2.1	ND	8.7
52	ND	ND	8.9	10	ND	11
ALDRIN	ND	ND	J	J	ND	J
44	ND	ND	4.5	12	ND	J
HEPT EPOX	ND	ND	5.4	J	ND	J
66	ND	ND	7.5	8.7	ND	J
GAMMA-CHLORDANE	ND	ND	1.3	6.5	ND	J
2,4'-DDE	ND	ND	J	J	ND	J
101	ND	ND	11	7.8	ND	13
alpha-CHLORDANE	ND	ND	2.2	1.7	ND	J
trans-NONACHLOR	ND	ND	J	J	ND	13
DIELDRIN	ND	ND	13	12	ND	J
4,4'-DDE	ND	ND	6.8	9.6	1	1.2
77	ND	ND	J	J	ND	J
2,4'-DDD	ND	ND	1.3	1.9	ND	J
ENDRIN	ND	ND	J	J	ND	J
118	ND	ND	10	14	0.23	0.33
4,4'-DDD	ND	ND	5.9	6	0.59	0.64
2,4'-DDT	ND	ND	J	J	J	14
153	ND	ND	16	13	0.22	14
105	ND	ND	2.9	1.6	J	J
ENDOSULFAN SULFATE	ND	ND	J	J	J	J
4,4'-DDT	ND	ND	J	J	J	J
138	ND	0.16	16	11	0.37	0.41
126	ND	ND	J	J	J	15
187	ND	ND	22	23	0.94	1.2
128	ND	ND	1.9	2.3	J	J
ENDRIN KETONE	ND	ND	J	J	J	J
METHOXYCHLOR	ND	ND	J	J	J	J
180	ND	ND	5	4.1	0.18	15
MIREX	ND	ND	0.7	J	J	13
170	ND	0.05 J	3.6	2.2	J	J
195	ND	ND	2.7	2.2	J	J
206	ND	ND	3.8	3.9	J	16
209	ND	ND	10	10	0.19	16
%DBOFB	50	51	43 &	40 &	44 &	48 &
%103	72	68	74	66	81	92
%198	86	72	113	96	85	94

ND - not detected
J - under SOP reporting limits
& - analyte recovery less than or greaterthan specied range, 50-125%

Station Name	Great Peconic Bay	Flanders Bay	Little Peconic Bay	Noyac Bay	West Neck Bay	Gardiners Bay
Lab ID	06PEORG94MSD	03PEORG94	07PEORG94	08PEORG94	09PEORG94	10PEORG94
Field ID	06PEORG94	03PEORG94	07PEORG94	08PEORG94	09PEORG94	10PEORG94
Reporting Limit	0.1	0.1	0.1	0.1	0.1	0.1
Sample Size	11.9g	23.5g	13.3g	11.4g	10.5g	14.9g
Sample Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
8	J	J	J	0.27	1.5	0.43
ALPHA-BHC	J	J	J	ND	0.24	0.047 J
HCB	J	0.12	J	ND	0.48	J
BETA-BHC	J	J	J	ND	0.76	J
GAMMA-BHC	J	J	J	ND	0.36	J
18	J	J	J	ND	0.81	J
DELTA-BHC	J	J	J	ND	1.6	J
28	11	0.036 J	0.38	ND	0.74	0.65
HEPT	10	J	J	ND	J	J
52	12	J	0.48	ND	1.2	0.97
ALDRIN	J	ND	J	ND	J	J
44	J	ND	J	ND	0.82	1
HEPT EPOX	J	ND	J	ND	J	J
66	J	ND	0.68	0.32	0.71	0.54
GAMMA-CHL(	J	ND	J	ND	0.3	J
2,4'-DDE	J	ND	J	ND	0.52	J
101	14	ND	0.47	0.31	0.53	0.81
alpha-CHLORD	J	ND	J	J	0.36	0.13
trans-NONACH	14	ND	0.61	J	J	0.89
DIELDRIN	J	ND	J	0.23	0.35	J
4,4'-DDE	0.85	ND	1.6	1	3.6	0.77
77	J	ND	J	J	J	J
2,4'-DDD	0.23	ND	0.19	J	0.47	J
ENDRIN	J	ND	J	J	J	J
118	0.26	ND	0.69	0.63	0.89	0.96
4,4'-DDD	0.31	ND	0.9	0.78	1.4	0.69
2,4'-DDT	16	ND	J	J	J	J
153	15	ND	1	0.83	0.71	1.4
105	J	ND	J	J	J	0.38
ENDOSULFAN	J	ND	J	J	0.29	J
4,4'-DDT	J	ND	J	0.54	J	J
138	J	ND	0.62	0.71	0.79	1.2
126	16	ND	J	J	J	J
187	0.88	ND	1.9	2	1.8	1.8
128	J	ND	J	J	0.38	0.29
ENDRIN KETC	J	ND	J	J	0.31	J
METHOXYCH	J	ND	J	J	J	0.019 J
180	16	ND	0.53	0.39	0.47	0.69
MIREX	14	ND	0.39	0.28	0.7	0.21
170	J	ND	J	J	J	0.062 J
195	J	ND	J	J	0.32	J
206	18	ND	0.29	0.13	0.33	0.25
209	17	ND	0.36	0.17	0.41	0.42
%DBOFB	47 &	52	54	52	53	42 &
%103	85	77	86	85	88	80
%198	88	87	87	89	98	83

ND - not detected
J - under SOP reporting limits
& - analyte recovery less than or greaterthan specied range, 50-125%

Station Name	Fish Cove		Peconic River		East Creek		Mouth of Peconic River		Upper Sag Harbor		Meetinghouse Creek	
Lab ID	11PEORG94		12PEORG94		13PEORG94		14PEORG94		15PEORG94		16PEORG94	
Field ID	11PEORG94		12PEORG94		13PEORG94		14PEORG94		15PEORG94		16PEORG94	
Reporting Limit	0.1		0.1		0.1		0.1		0.1		0.1	
Sample Size	8.57g		20.8g		9.6g		12.1g		12.4g		4.4g	
Sample Units	ng/g		ng/g		ng/g		ng/g		ng/g		ng/g	
8	3.1			J	0.99		0.7		1.5		4.4	
ALPHA-BHC	0.46			J		J	0.24			J	0.031	J
HCB		J		J	0.73			J	0.1			J
BETA-BHC		J		J		J		J		J		J
GAMMA-BHC	0.44			J		J	0.47			J		J
18		J		J		J		J		J		J
DELTA-BHC		J	0.086	J		J		J	0.98		7.9	
28	0.71		0.45		0.39		0.5		0.34		1.4	
HEPT		J		ND		J		J		J		J
52		J		ND		J		J		J	4.2	
ALDRIN		J		J		J		J		J		J
44		J	2.7			J	0.47		1.1		3.6	
HEPT EPOX		J		J		J		J		J		J
66	0.73			J		J		J		J	2.4	
GAMMA-CHL(	0.31		0.88		1.5			J	2.8		2.9	
2,4'-DDE		J		J		J	2.1		0.88			J
101	0.86			J	1.1		1.1		0.8		4.9	
alpha-CHLORD		J	0.64		2.1		0.56		2.6		3	
trans-NONACH		J	0.47		2.1			J	3		3.2	
DIELDRIN	0.55			J	1.7		0.65		0.53		5	
4,4'-DDE	2.2		1.2		21		25		22		53	
77		ND		J		J		J		J		J
2,4'-DDD	0.39		2.1		4.3		5.6		6.7		10	
ENDRIN		J		J		J		J		J		J
118	0.73			J		J	1		0.82		5.2	
4,4'-DDD	1.8		7.5		20		15		29		52	
2,4'-DDT		J		J	4.8			J	1.4		3.4	
153	0.78			J	1		0.66		1.5		5.8	
105		J		J		J		J		J	1.6	
ENDOSULFAN		J	0.11		13			J	0.69		2.3	
4,4'-DDT	1.2		0.68		27		0.63		9.5		17	
138	1.1			J	1.1		0.89		1.6		5.7	
126		J		J		J		J		J		J
187	2.8			J		J		J		J		J
128		J		J		J		J	0.46		1.5	
ENDRIN KETC		J	0.14			J	0.28			J	0.97	
METHOXYCH		J		J	0.24			J	0.075	J		J
180	0.56			J	0.38		0.6		1.1		1.8	
MIREX	0.33		0.22		0.7		0.4		1.4		2.1	
170	0.13		0.068	J	0.28			J		J	0.34	
195		J		J		J		J		J		J
206	0.13			J		J	0.087	J	0.34		0.5	
209	0.19		0.065	J	0.12		0.19		0.23		0.25	
%DBOFB	61		49	&	53		64		74		60	
%103	96		87		95		105		82		113	
%198	90		86		90		99		75		106	

ND - not detected
J - under SOP reporting limits
& - analyte recovery less than or greaterthan specied range, 50-125%

APPENDIX D

Trace Metals Data

Arthur D Little

Sample ID	Location	Ag (ppm)	Al (%)	As (ppm)	Be (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Hg (ppm)	Ni (ppm)	Pb (ppm)	Sb (ppm)	Se (ppm)	Tl (ppm)	Zn (ppm)
03PEMET94	Flanders Bay	0.06	0.44	0.8	0.1	0.04	3.4	2.0	0.006	1.3	3.7	0.04	0.2	0.51	12.1
06PEMET94	Great Peconic Bay	0.53	7.08	9.7	2.2	0.14	60.2	26.2	0.070	27.2	38.9	0.48	0.5	0.50	121
07PEMET94	Little Peconic Bay	0.49	6.54	8.6	1.8	0.11	57.0	25.7	0.088	22.5	41.4	0.32	0.6	0.46	118
07PEMET94	Little Peconic Bay	0.45	6.25	8.3	1.7	0.10	60.6	25.3		22.1	40.2	0.34	0.6	0.45	112
07PEMET94	Little Peconic Bay	0.61	6.40	8.6	1.9	0.12	57.9	25.4		22.3	41.5	0.38	0.6	0.46	114
08PEMET94	Noyac Bay	0.54	6.44	8.9	2.0	0.43	63.6	31.0	0.109	25.9	42.4	0.36	0.7	0.50	130
09PEMET94	W. Neck Bay	0.53	7.61	10.8	2.2	0.21	69.9	48.3	0.171	27.4	58.1	0.38	0.8	0.60	137
10PEMET94	Gardiners Bay	0.68	6.97	8.4	2.0	0.08	57.2	25.3	0.092	23.6	39.2	0.33	0.5	0.45	110
11PEMET94	Fish Cove	0.41	6.77	14.9	2.0	0.77	65.0	55.4	0.107	28.6	48.3	0.43	0.9	0.67	138
12PEMET94	Peconic R. W Conn. Ave.	0.09	0.42	0.7	0.2	0.04	3.5	3.0	0.008	1.0	9.9	0.09	0.2	0.03	25.5
13PEMET94	East Creek	0.75	5.97	13.1	2.0	1.77	59.9	104	0.108	24.7	64.5	0.54	1.2	0.70	183
13PEMET94	East Creek								0.119						
13PEMET94	East Creek								0.110						
14PEMET94	Mouth of Peconic R.	1.40	3.58	13.3	1.1	0.91	37.5	32.2	0.097	15.2	36.1	0.33	0.8	0.37	101
15PEMET94	Upper Sag Harbor Cove	0.20	2.18	8.1	0.7	0.25	18.4	21.5	0.050	5.9	81.2	0.32	0.4	0.19	51.5
16PEMET94	Meeting House Creek	1.30	5.51	18.8	1.7	0.88	57.7	129	0.194	25.1	76.9	0.86	1.7	0.64	296
Typical Sediment*		0.1	7.2	7.7	2	0.2	72	33	0.2	52	19	1.2	0.4	(1)	95

*Salomons and Forstner (1984)