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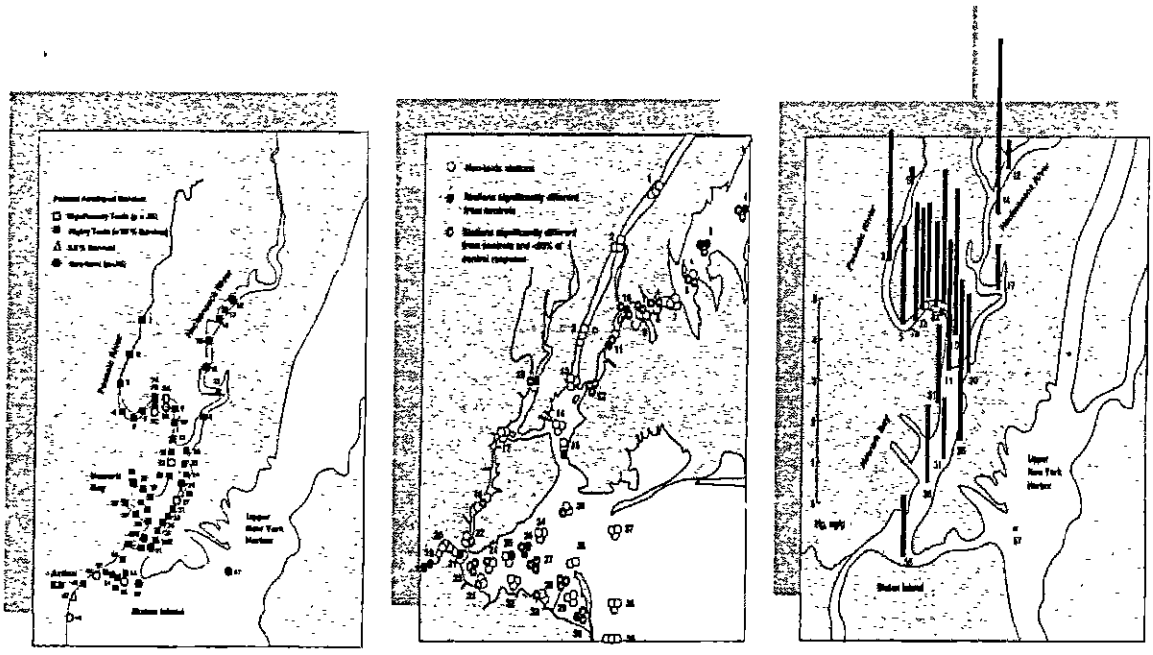
Magnitude and Extent of Sediment Toxicity in the Hudson-Raritan Estuary



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August, 1995

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Coastal Monitoring and Bioeffects Assessment Division

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Magnitude and Extent of Sediment Toxicity in the Hudson-Raritan Estuary

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ABSTRACT

A survey of the toxicity of sediments was performed by NOAA's National Status and Trends (NS&T) Program throughout the Hudson-Raritan Estuary. The objectives of the survey were to determine the spatial patterns of toxicity, the spatial scales (magnitude) of toxicity, the severity (frequency) of toxicity, and the relationships among measures of toxicity and chemical substances in the sediments. This survey was conducted as a part of a nationwide program supported by NOAA's Coastal Ocean Program and the NS&T Program, in which the biological effects of toxicants are determined in selected estuaries and bays.

The survey was conducted in two phases: 117 samples were collected throughout the entire estuary during 1991 (Phase 1) and an additional 57 samples were collected in Newark Bay and vicinity during 1993 (Phase 2). Relatively sensitive toxicity tests were performed under controlled laboratory conditions with portions of each sample. During Phase 1, three independent tests were performed: (1) a 10-day, acute survival test of solid-phase sediments with the amphipod *Ampelisca abdita*; (2) a 48-hour liquid phase test of elutriates with the embryos of the bivalve *Mulinia lateralis* in which both percent survival and normal embryological development were recorded; and (3) a 15-minute microbial bioluminescence test (Microtox™) of organic solvent extracts. Only the amphipod tests were performed on the samples collected during Phase 2. Chemical analyses of selected samples were performed and the concentrations of trace elements, polynuclear aromatic hydrocarbons (PAHs), chlorinated pesticides and other hydrocarbons were reported. Also, during Phase 2 the concentrations of numerous chlorinated dioxins and furans were determined. > What about PCBs ? Pesticides ?

Toxicity test results were compared with responses in controls to determine statistical significance. During Phase 1, 46.2% of the samples were significantly toxic (i. e., different from controls) in the amphipod tests, 26.6% were significantly toxic in either of the bivalve embryo tests, and 40.5% were significantly toxic in the microbial bioluminescence tests. Overall, 69.2% of the samples were toxic in at least one of the four test end-points.

Each toxicity test indicated somewhat different patterns in toxicity, possibly reflecting their different sensitivities to the substances in the samples. Overall, toxicity was most severe in the East River and diminished eastward into Long Island Sound and southward into upper New York Harbor. Also, toxicity was relatively high in Newark Bay, Arthur Kill, and western Raritan Bay and diminished southward and eastward toward the mouth of the estuary. Toxicity was relatively low in the lower Hudson River, upper New York Harbor, and portions of lower New York Harbor and northern Raritan Bay, especially in samples that were relatively high in sand content.

During Phase 2, 48 of 57 samples (84.2%) from Newark Bay and vicinity were significantly toxic in the amphipod survival tests. Amphipod survival was very low in most samples from the lower Passaic River, much of Newark Bay, and most samples from the northern reaches of Arthur Kill. A few samples

from the lower Hackensack River and one sample from upper New York Harbor were not significantly toxic in this test.

During Phase 1 the entire survey area covered approximately 350 km^2. By attributing the toxicity data to the spatial scales of each sampling stratum, the spatial extent of toxicity (kilometers^2) was estimated for each test. The amphipod survival test indicated that approximately 133 km^2 (38.1% of the total area) was toxic. The amphipod survival and microbial bioluminescence tests, together, indicated that approximately 34.2 km^2 (9.8% of the total area) was toxic. All four test end-points, together, indicated approximately 19.9 km^2 (5.7% of the total area) was toxic. During Phase 2, approximately 10.8 km^2 (85.0% of the total survey area of 12.7 km^2 in Newark Bay and vicinity) was toxic relative to the controls.

The causes of the toxicity were not determined. However, in the Phase 1 samples, amphipod survival and microbial bioluminescence diminished and were significantly correlated with increasing concentrations of numerous PAHs. Also, the average concentrations of the PAHs in the toxic samples greatly exceeded the average concentrations in the nontoxic samples and applicable toxicity thresholds. These strong relationships between the two measures of toxicity and the concentrations of the PAHs were driven, in large part, by the samples from the upper East River that were highly toxic and highly contaminated with the PAHs. To a lesser degree the concentrations of some trace elements and chlorinated pesticides were correlated with the inhibition of microbial bioluminescence. The results of the bivalve embryo tests were rarely correlated with the concentrations of any of the potentially toxic substances that were measured.

In contrast to the results from Phase 1, amphipod survival in the Phase 2 samples diminished with and was highly correlated with increasing concentrations of chlorinated hydrocarbons, especially the PCBs, pesticides, and dioxins. The concentrations of the sum of PCB congeners were very high in many of the samples in which amphipod survival was low or zero. Also, amphipod survival decreased with increasing concentrations of lead, mercury, and zinc in the samples. In contrast to the observations in Phase 1, amphipod survival was not correlated with the concentrations of the PAHs in Phase 2.

INTRODUCTION

The Hudson-Raritan Estuary is a very large, highly urbanized estuarine system. It is bounded to the east by the New York Bight and Long Island Sound, and bounded to the west, south and north by highly urbanized and industrialized areas of New York and New Jersey. It is a mixing zone for four major rivers and many wastewater treatment, point-source discharges. As defined in this report, it includes the waters of the extreme western Long Island Sound, the East River, the lower Hudson River, upper and lower New York Harbors, Kill van Kull, Arthur Kill, the lower Passaic River, the lower Hackensack River, Newark Bay, the lower Raritan River, Raritan Bay, Sandy Hook Bay and the waters of the outer harbor east to the Rockaway-Sandy Hook transect (Figure 1).

This estuary has been highly impacted by many human-induced factors (NOAA, 1988a). Many of the historical wetlands have been filled, many water bodies have been channelized for navigation, and huge industrial and residential complexes have been built along the shores. Contaminants have been discharged from wastewater treatment plants, combined sewer overflows, urban runoff, stormwater, petrochemical factories, illegal dumping, atmospheric deposition, and accidental spills.

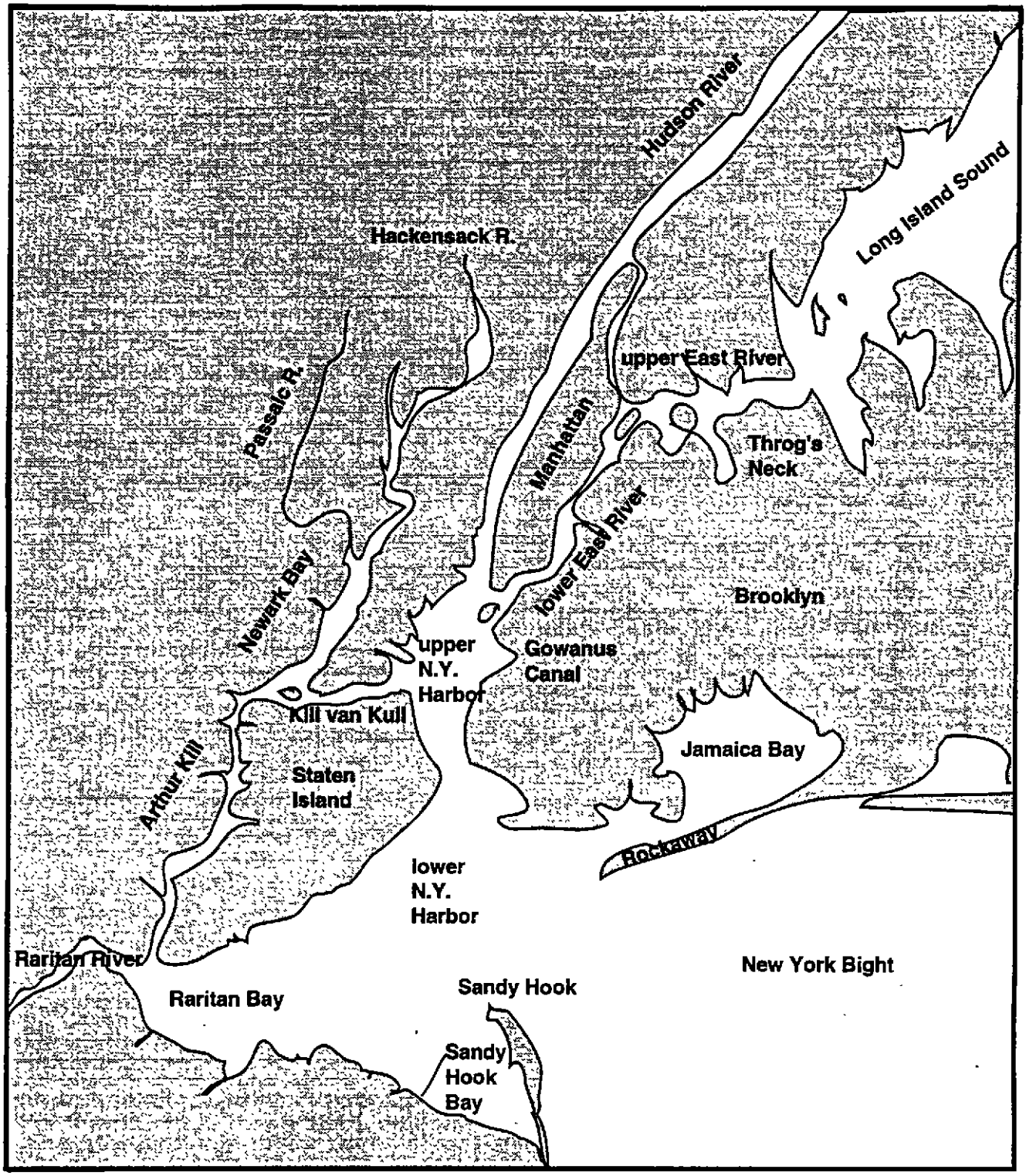

Figure 1. The Hudson-Raritan Estuary study area.

Mueller et al. (1982) estimated that wastewater treatment discharges contributed 40-60 percent of the total input of several trace metals into the estuary. They estimated that 20-40 percent were contributed by the tributary rivers, and 10-30 percent by urban runoff. The data available for estimating sources of toxic organic compounds were less complete than those for metals. Based on the data available, wastewater and the tributaries each contributed about 40 percent of the total PCB load, a substantial portion being transported by the Hudson River.

In 1988 it was estimated that 6.8 million gallons per day of untreated sewage was discharged into the estuary, primarily from Manhattan, Staten Island, and Brooklyn (Gottholm et al., 1993). With the implementation of better source controls at key sewage treatment plants, the rate of discharge from the city of New York decreased to less than 1.0 million gallons per day by 1992.

Over 1,453 accidental incidents, resulting in the release of more than 18 million U.S. gallons of hazardous materials and petroleum products, occurred throughout Newark Bay between 1982 and 1991 (Gunster et al., 1993). The majority of these spills consisted of petroleum products, including fuel oils and gasoline. Many of them occurred in the lower Passaic River, Arthur Kill, Newark Bay, and Kill van Kull.

Data collected by numerous investigators, including the National Status and Trends Program, have indicated that the concentrations of many potentially toxic chemicals are highly elevated in the Hudson-Raritan Estuary. The objectives of this report are to describe the magnitude (severity, multiplicity, incidence) of toxicity, the spatial patterns of toxicity, the spatial extent of toxicity of sediments, and the relationship(s) between sediment toxicity as a measure of toxicant-associated biological effects and potentially toxic substances.

Contaminant Concentrations. Many different assessments have been conducted to determine the presence, concentration, and distribution of toxic chemicals within the estuary. These assessments have been performed by many independent investigators and have shown that toxicants occur throughout the estuary in mixtures that differ from place to place. The toxicants that occur above background levels include PCBs, PAHs, DDT, other pesticides, many trace metals, radioisotopes, dioxins and furans. It is not the purpose of this report to review the results of all of these efforts. Several excellent reports summarize the data on concentrations and distributions of toxicants in the Hudson-Raritan Estuary (e.g., Olsen et al., 1984; Breteler, 1984; NOAA, 1988a; Bopp and Simpson, 1989; Squibb et al., 1991; City of New York, 1987; Huntley et al., 1993; Bonnevie et al., 1993; New York-New Jersey Harbor Estuary Program, 1995).

Based upon the available data from these many studies, several generalized patterns are apparent in the distribution of elevated concentrations of toxicants. These generalities are tempered by many observations of heterogeneity attributable to patchiness in sediment properties, sedimentation rates, scouring, dredging, and proximity to sources and other processes that influence the fate of toxicants. Nevertheless, areas in which relatively high concentrations of different toxicants have been observed frequently include Newark Bay, Arthur Kill, lower Passaic River, lower Hackensack River, Gowanus Canal, western Raritan Bay south of Staten Island, and the bays adjoining the upper East River/western Long Island Sound. Intermediate levels of many toxicants often have been reported for parts of central Raritan Bay, upper New York Harbor, lower Harlem River near Ward's Island, and the lower Passaic River. Relative to these areas, toxicant concentrations often have been lowest in lower New York Harbor south of Coney Island and northwest of Sandy Hook, the East River, Harlem River, lower Hudson River, and eastern Raritan Bay.

Extremely high concentrations of dioxins and furans in sediments and marine biota have been reported for the lower Passaic River (Pruell et al., 1990; Bopp et al., 1991; Tong et al., 1990; Belton et al., 1985). The concentrations of these compounds gradually diminish downstream into Newark Bay and New York Harbor. In addition, the concentrations of PAHs and many trace elements were found in very high concentrations in samples collected in the lower Passaic River, lower Hackensack River, and Newark Bay (Huntley et al., 1993; Bonnevie et al., 1993).

Sediments, mussels, and fish livers from the Hudson-Raritan Estuary analyzed by NOAA as a part of the NS&T Program consistently have contained relatively high concentrations of DDT, other pesticides, PCBs, PAHs, cadmium, chromium, lead, mercury, nickel, tin, and other substances. The concentrations of these and other chemicals often were the highest or among the highest measured at about 250 sites nationwide (NOAA, 1987; 1988b; 1989; 1991; Long and Morgan, 1990). Samples with particularly high concentrations of toxicants were collected near the Throg's Neck Bridge in western Long Island Sound, in the upper New York Harbor near Ellis Island, and in central Raritan Bay. For each of the analytes quantified, NOAA ranked the sediment sites sampled nationwide according to the highest concentrations (NOAA, 1988b: O'Connor and Ehler, 1991; Robertson et al., 1991). Collectively, the sediment and mussel samples from the Hudson/Raritan Estuary ranked the highest overall in contaminant concentrations among the many estuaries sampled by the NS&T Program. The average concentrations of several trace metals appeared to increase in mussel tissues during the period from 1986 through 1988 at several sites in the estuary, whereas the concentrations of several organic compounds decreased during the same period (NOAA, 1989). Sediment samples collected at several sites in 1986 and 1987 had relatively high concentrations of 13 toxicants, compared to concentrations nationwide (NOAA, 1991).

Potential for Toxicant Effects. Some of the sites sampled by the NS&T Program were determined to have toxicant concentrations in sediments that equalled or exceeded known toxicity thresholds (O'Connor and Ehler, 1991). Some of the samples with high chemical concentrations were collected within the Hudson-Raritan Estuary (Gottholm et al., 1993). The concentrations of PAHs, PCBs, mercury, silver, arsenic, and zinc mostly frequently equalled or exceeded the thresholds nationwide.

Long and Morgan (1990) ranked the NS&T Program sites according to their potential to cause toxicity in sediments attributable to elevated concentrations of analytes quantified by the Program. Based upon available data from laboratory-spiked bioassay studies, equilibrium-partitioning models, and matching chemical and biological data from field surveys, they determined the ranges in chemical concentrations that were associated with adverse effects. The Effects Range-Low (ERL) value was identified as the 10th percentile of the database associated with adverse biological effects. The Effects Range-Median (ERM) was identified as the 50th percentile (median) of these data. Long and Morgan (1990) then compared the ambient data from the NS&T Program sites with the ERL and ERM values. Those sites that equalled or exceeded the effects ranges for the most analytes nationwide were ranked highest.

Among the 200+ sites that they evaluated, Long and Morgan (1990) ranked site HRUB in New York Upper Harbor as number 1, the highest. Site LITN near Throg's Neck was ranked number 3, site NYSH in Sandy Hook Bay was ranked number 5, and site HRLB in lower New York Harbor was ranked number 7. All six of the sediment sampling sites located within the estuary were ranked among the top sites nationwide in potential for toxicity. The concentrations of as many as 20 analytes in Hudson-Raritan Estuary sites equalled or exceeded the respective effects ranges. The concentrations of many PAHs were expecially highly elevated compared to the effects ranges.

Breteler (1984) estimated that numerous trace metals, petroleum hydrocarbons, pesticides, and halogenated hydrocarbons posed ecological and/or human health risks in the Hudson-Raritan Estuary. Squibb et al. (1991) compiled and evaluated existing contaminant data from analyses of water, tissues, and sediments from the Hudson-Raritan Estuary performed during the 1980s. They compared the ambient data with several different water quality standards for the protection of marine life, wildlife, and human health. Many trace metals, pesticides, industrial solvents, PCBs, and aromatic hydrocarbons equalled or exceeded these standards in water samples collected in the estuary. Similarly, they compared the

ambient concentrations of toxicants in finfish and shellfish tissues with existing standards. The concentrations of PCBs, tcdd (dioxin), mercury, chlordane, and dieldrin in samples from the estuary often exceeded the standards and were noted as chemicals of high concern. Other contaminants listed as chemicals of moderate concern included arsenic, tDDT, heptachlor, heptachlor epoxide, hexachlorobenzene, lindane, numerous aromatic hydrocarbons, and tcdf (furans).

In the absence of any applicable sediment quality standards, Squibb et al. (1991) compared ambient concentrations of contaminants in sediments with the ERL and ERM values identified by Long and Morgan (1990). In their investigation, Squibb et al. (1991) evaluated data from many different studies, merged the data for selected regions within the estuary, and compared the average, maximum, and minimum concentrations within each region with the effects ranges of Long and Morgan (1990). Where the abundance of data warranted, they treated four subregions of Raritan Bay separately: (I) Western Raritan Bay at the confluence of the Raritan River and Arthur Kill; (II) central Raritan Bay stretching from Staten Island to Sandy Hook Bay; (III) northern Raritan Bay bordering the lower New York Harbor; and (IV) southern Raritan Bay along the New Jersey shore.

Squibb et al. (1991) determined that the concentrations of eight trace metals, PCBs, tDDT, chlordane, dieldrin, tPAHs, and six aromatic hydrocarbons exceeded the ERM concentrations in samples from at least one area within the estuary. In addition, the concentrations of six other aromatic hydrocarbons exceeded the ERLs, but not the ERMs. Squibb et al. (1991) concluded that there was a substantial potential for toxicant-associated biological effects in the sediments of the estuary.

Table 1 summarizes the patterns in exceedances of the ERL and ERM values described by Squibb et al. (1991). Exceedances of the effects ranges were largest and most frequent in sediments collected (in decreasing order) in Newark Bay, Arthur Kill, Gowanus Canal, Hackensack River, lower Jamaica Bay, and near Ward's Island (at the mouth of the Harlem River) (Table 1). The areas in which the chemical concentrations least frequently exceeded the effects ranges were the Harlem River, southern Raritan Bay, and northern Raritan Bay.

Table 1. Regions of the Hudson-Raritan Estuary in which the concentrations of selected toxicants in sediments exceeded respective effects ranges of Long and Morgan (1990). Adapted from Squibb et al. (1991).

Region	Cd	Cr	Cu	Hg	Ni	Pb	Zn	tPCB	tDDT	tPAH
East River	-	*	*	*	-	***	*	**	*	nd
East R. bays	*	***	*	***	*	***	***	***	nd	nd
Harlem River	-	-	-	*	-	***	*	*	nd	nd
Wards Island	*	***	***	**	*	***	***	***	nd	nd
Hudson River	-	*	*	*	-	***	*	**	nd	-
Upper Bay	-	*	*	***	*	**	*	**	nd	*
Gowanus Canal	***	***	*	***	***	***	***	nd	nd	nd
Kill van Kull	*	nd	nd	***	nd	***	***	nd	nd	*
Newark Bay	**	***	***	***	***	***	***	***	***	***
Hackensack R.	**	***	**	***	***	***	***	nd	nd	nd
Passaic River	*	***	*	**	**	***	**	***	nd	***
Arthur Kill	**	*	***	***	***	***	***	***	***	*
Raritan Bay	nd	nd	nd	***	nd	nd	nd	**	*	*

Table 1 continued.

Region	Cd	Cr	Cu	Hg	Ni	Pb	Zn	tPCB	tDDT	tPAH
W. Raritan Bay(I)	**	***	***	nd	*	***	***	nd	nd	nd
C. Raritan Bay(II)	*	**	**	nd	*	***	***	nd	nd	nd
N. Raritan Bay(III) *	**	*	nd	*	**	**	nd	nd	nd	
S. Raritan Bay(IV)	-	**	*	nd	*	**	**	nd	nd	nd
Lower Bay	**	*	*	**	nd	*	nd	**	*	*
Jamaica Bay(I)	-	**	*	**	*	***	**	**	*	nd
Jamaica Bay(II)	-	**	*	**	-	**	*	**	*	*

*** Average concentration > ERM value;

** Only maximum concentration > ERM value;

* ERL value < maximum concentration < ERM value;

- maximum concentration <ERL value;

nd - no data.

Based upon the multiplicity and degree of exceedances of the effects range values in Table 1, it appears that sediments in some regions of the estuary have a very high potential for causing toxicity. Also, based upon the number and degree of exceedances of the effects values, it appears that the potential for toxicity differs among the regions. The regions evaluated by Squibb et al. (1991) are hypothesized to have the following relative potentials for toxicant-associated effects:

- Extremely high potential for toxicity:
  - Newark Bay;
  - Arthur Kill.
- High potential for toxicity:
  - East River bays;
  - vicinity of Ward's Island;
  - Upper Bay;
  - Gowanus Canal;
  - lower Hackensack River;
  - lower Jamaica Bay.
- Moderate potential for toxicity:
  - East River;
  - Hudson River;
  - Kill van Kull;
  - lower Passaic River;
  - western Raritan Bay;
  - central Raritan Bay;
  - Lower Bay;
  - upper Jamaica Bay.
- Lowest potential for toxicity:
  - Harlem River;
  - northern Raritan Bay;
  - southern Raritan Bay.

The minimum concentration of mercury in the lower Hackensack River (4 ppm) reported by Squibb et al. (1991) exceeded the ERM value (1 ppm) listed by Long and Morgan (1990); the maximum concentration (50 ppm) exceeded this value by a factor of 50-fold. Maximum concentrations of lead in Newark Bay and Arthur Kill exceeded the ERM concentration (110 ppm) by factors of about 8- to 10-fold. The concentrations of DDT, PCBs, total PAHs, chlordane, and dieldrin in Newark Bay, Arthur Kill, and/or the Passaic River were very high relative to concentrations previously associated with toxic effects.

Long and Morgan (1990) reported that in numerous studies the types of biological effects observed in association with exceedances of the effects ranges included high mortality in amphipods, other crustaceans, bivalve larvae, polychaetes, and fish in either spiked-sediment bioassays or toxicity tests of ambient sediments; or altered infaunal community structures and/or reduced abundance of infauna; or acute or chronic effects in aquatic species as predicted by equilibrium-partitioning models.

Both Long and Morgan (1990) and Squibb et al. (1991) recognized the uncertainty in applying the effects ranges as predictors of toxic effects. Many factors control the bioavailability of sediment-associated toxicants and, as a consequence, bulk sediment concentrations often are poor predictors of toxic effects. Both reports recommended that surveys to determine the presence of toxicant-associated effects should be conducted to verify the potential for these effects.

In more recent studies, the concentrations of a number of different substances, notably total PAHs, mercury, lead, and zinc were found in concentrations that exceeded the ERL and ERM concentrations in samples collected in the lower Passaic River, lower Hackensack River, and Newark Bay (Huntley et al., 1993; Bonnevie et al., 1993). These are areas previously identified as highly contaminated.

Previously Measured Biological Effects. The adverse biological effects of toxicants in the Hudson-Raritan Estuary have been apparent for many years (Gottholm et al., 1993). Pearce (1988) reported that portions of the estuary were severely degraded as early as the U.S. Civil War. In the early 1900s some fish were unfit to eat because of high contamination and in the 1920s the shellfish populations crashed due to the effects of wastewaters. Based upon the summaries prepared by several contributors to NOAA (1988a), the major categories of toxicant-associated biological effects reported for the estuary include:

- •alterations to resident microbial communities, including increased resistance to toxicants through long-term continual exposure;
- •alterations and shifts in phytoplankton community structures and diminished species diversity;
- •reduced densities and species diversity of benthic communities;
- •severely reduced abundances of ampeliscid amphipods in benthic communities;
- •elevated prevalences of fin erosion and other diseases in bottom-dwelling fish;
- •elevated prevalences of tumors and other histopathological disorders of bottom-dwelling fish;
- •elevated prevalences of a variety of diseases in crabs, lobsters and shrimp;
- •tissue contamination leading to closures of fisheries and advisories against fish consumption;
- •increased resistance of resident killifish and soft-shelled clams to the effects of subsequent doses of toxicants.

In Mayer (1982), several contributors reported that diminished commercial landings of some species have occurred in the estuary, and that increased prevalences of histopathological disorders and a number of other diseases in fish in the adjacent New York Bight have been recorded. The causes of some of these conditions are unknown, while the cause of others are known or suspected.

During the 1980s and 1990s, numerous fish kills were reported within the estuary; marine mammals that were found stranded often had a variety of different lesions; and anglers were advised to avoid consuming large amounts of fish from the estuary (Gottholm et al., 1993). In addition, in studies performed by the NS&T Program, the prevalence of liver lesions in demersal fish caught in the estuary were significantly elevated relative to reference sites (Gottholm et al., 1993).

Tietjen and Lee (1984) reported that sediments from all of their 10 sampling sites in the Hudson-Raritan Estuary were significantly toxic to the growth of nematodes (*Chromadorina germanica*) in laboratory toxicity tests (Figure 2). Sediments from the lower Hudson River, lower East River, upper New York Harbor, Kill van Kull, Newark Bay, Arthur Kill, Raritan Bay, Sandy Hook Bay and the lower New York Harbor were toxic in these tests. In addition, most of the samples were toxic to another species of nematode, *Diplolaimella punicea*. Tietjen and Lee (1984) reported that toxicity to the growth of both nematodes was correlated with the concentrations of PCB, PAH, and mercury in the test sediments (correlation coefficients of 0.68 to 0.90, p=0.05).

Scott et al. (1990) tested sediments from 10 locations in the estuary for toxicity to two species of amphipods, *Ampelisca abdita* and *Rhepoxynius hudsoni*. A range of 12% to 100% mortality was reported for *A. abdita*, compared to 1% to 8% mortality in reference and control sediments. Eight of the 10 samples were significantly different from controls (Figure 2) and five of the samples caused 100% mortality in *A. abdita*. Toxic samples were collected in Newtown Creek adjacent to the lower East River, Gowanus Canal, Newark Bay, Arthur Kill, and western Raritan Bay. Similarly, a range of 9% to 100% mortality was recorded for the tests with *R. hudsoni*, compared to 3% to 11% mortality in reference and control sediments. Of the 10 samples, four collected in northern Arthur Kill, southern Arthur Kill, Gowanus Canal, and Newtown Creek were toxic to *R. hudsoni*.

Scott et al. (1990) reported that mortality to *A. abdita* was significantly correlated with the concentrations of total PCBs, total PAHs, several pesticides, copper, zinc, chromium, lead, nickel, and cadmium in the test sediments (correlation coefficients of 0.70 to 0.90, $p<0.05$). Also, they reported that mortality to *R. hudsoni* was correlated with the concentrations of total PCBs, total PAHs, lead, and cadmium in the sediments (correlation coefficients of 0.50 to 0.69, $p<0.05$). Mortality to *A. abdita*, but not to *R. hudsoni*, also was correlated with silt and Total Organic Carbon (TOC) content (correlation coefficients of 0.69 to 0.70, $p<0.05$). In addition, Scott et al. (1990) reported that the concentrations of toxicants in samples that were toxic to the amphipods often equalled or exceeded the ERL-ERM ranges of Long and Morgan (1990). The samples that were most toxic had chemical concentrations that exceeded the ERM values for many analytes to the greatest degree.

The Environmental Monitoring and Assessment Program (EMAP) of the U.S. Environmental Protection Agency (EPA) tested sediments from nine locations within the study area in 1990 for chemical concentrations and for survival of the amphipod, *A. abdita* (Schimmel et al., 1994). Five of the nine samples (55%) were significantly different from controls. The toxic samples were collected in the lower Hackensack River, lower Passaic River, upper Newark Bay, upper Arthur Kill, and western Long Island Sound near Hempstead Bay (Figure 2). Two of the nontoxic samples were collected in the basin of western Long Island Sound. The samples from the Hudson River and upper New York Harbor near St. George were nontoxic. Mean percent mortality ranged from 2.5±4.3% to 99.0±2.2%, whereas that in the controls ranged from 6% to 9%. The samples from the Arthur Kill and the lower Passaic River caused the highest mortalities (99.0% and 78.0%, respectively).

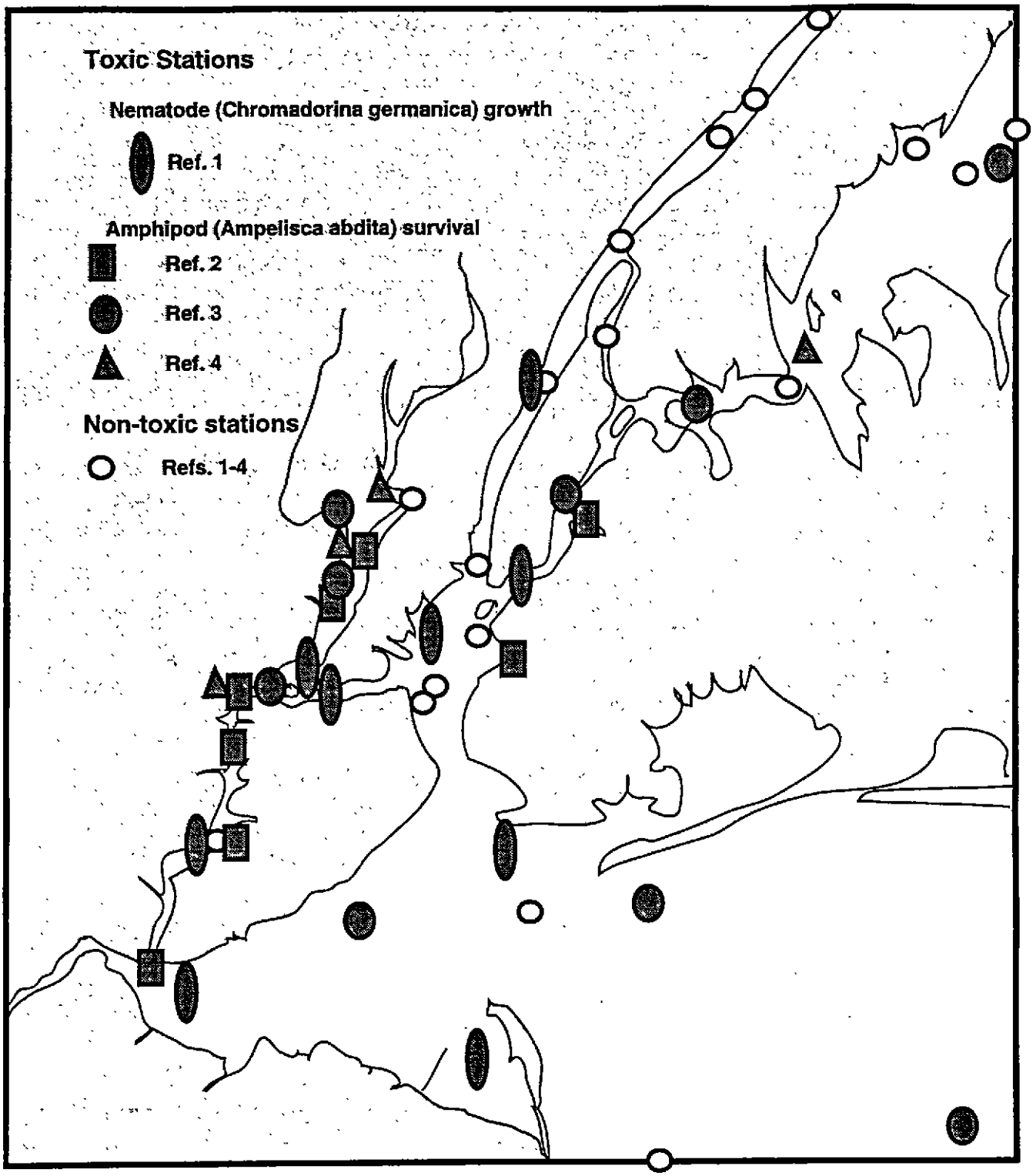

Figure 2. Sampling sites in which sediments were significantly toxic to: (1) nematode (*Chromadorina germanica*) growth (from Tietjen and Lee, 1984); (2) amphipod (*Ampelisca abdita*) survival in static tests (from Scott et al., 1990); (3) *A. abdita* in flow-through tests (from Brosnan and O'Shea, 1993); and (4) *A. abdita* in static tests (from U.S. EPA EMAP, 1990).

Correlations between percent survival of *A. abdita* and the concentrations of trace metals and total organic carbon in the EMAP samples are summarized in Table 2. Survival would be expected to diminish among amphipods exposed to increasing concentrations of toxicants, resulting in negative correlation coefficients. The correlations were conducted with the trace metals data normalized to dry weight, aluminum concentrations, and TOC concentrations. A significant negative correlation between survival and chemical concentrations normalized to dry weight was observed only for antimony (Rho = -0.480, $p<0.05$, n=9). The correlations between percent survival and trace metals concentrations improved when the chemical data were normalized to TOC content; the correlations with lead, cadmium, antimony, and tin were significant. When the trace metals data were normalized to the aluminum concentrations, many of the correlations became highly significant. For example, the correlations between percent survival and the concentrations of cadmium, copper, antimony, and tin were highly significant, and those with nickel, zinc, and selenium were significant. The correlations between percent survival and the concentrations of aluminum and TOC content, however, were not significant.

Table 2. Spearman-rank correlations (Rho) between percent survival of *A. abdita* (n=9) and the concentrations of trace metals normalized to dry wt., aluminum, and total organic carbon (TOC). From U.S. EPA EMAP monitoring data, 1990 (Schimmel et al., 1994).

Chemical	Concentration/ dry weight	Concentration/ aluminum	Concentration/ TOC
Aluminum	+0.385	nd	nd
TOC	+0.133	nd	nd
Chromium	+0.093	-0.181	-0.016
Copper	-0.052	-0.705**	-0.275
Iron	+0.283	nd	nd
Manganese	+0.292	nd	nd
Nickel	+0.088	-0.549*	-0.017
Lead	-0.332	-0.433	-0.607*
Zinc	-0.002	-0.540*	-0.127
Arsenic	+0.044	-0.198	-0.058
Cadmium	-0.343	-0.831***	-0.747**
Antimony	-0.480*	-0.680**	-0.495*
Selenium	+0.019	-0.538*	-0.114
Tin	-0.190	-0.738**	-0.552*
Mercury	-0.044	-0.438	-0.230

* $p< 0.05$
** $p < 0.01$
*** $p < 0.001$

nd = no data

These relatively high correlations between amphipod survival and chemical concentrations were unexpected since the nine samples were collected in widely separated portions of the study area. They were not collected near each other within the zone of influence or dilution gradient of one point source.

Battelle Pacific Northwest Laboratories tested sediment samples from 20 locations in the estuary for the City of New York (Tom Brosnan, City of New York, personal communication; Brosnan and O'Shea, 1993). The samples were collected throughout the estuary in February, 1992 and tested with a flow-

through, 10-day, amphipod survival test, using *A. abdita*. Portions of the same 20 samples were analyzed for only trace metals concentrations. Nine of the 20 samples were significantly toxic (Figure 2). The toxic samples were collected in western Long Island Sound, upper East River, lower East River, lower Passaic River, Newark Bay near Shooters Island, lower New York Harbor and the New York Bight. Sediments collected near Shooters Island indicated 0.0% survival, and those from the lower Passaic River 11.0% survival, compared to 90% survival in the controls. The concentrations of total simultaneously extracted trace metals (SEM) (*u*moles/g) never equalled or exceeded the concentrations of acid volatile sulfide (*u*moles/g), suggesting that trace metals had a minor role in contributing to toxicity.

Aqua Survey, Inc. (1990a, 1990b) tested intertidal and subtidal sediments from numerous locations in the Arthur Kill, Kill van Kull, and Newark Bay for the Exxon Company. The sediments were tested with the estuarine amphipod *Eohaustorius estuarius*, collected from Yaquina Bay, Oregon. Sediments were held at 4°C for approximately one month before the tests were initiated. Nine to 27 samples were tested from each location. No site location map accompanied the toxicity data. Also, no statistical analyses of the data were performed to quantify significant differences between test sediments and controls. The qualitative results are summarized in Table 3.

Table 3. Mean percent mortality of *Eohaustorius estuarius* in sediments from Arthur Kill, Kill van Kull, and Newark Bay (from Aqua Survey, Inc., 1990a, 1990b).

Sampling Location	Sample Description	Mean Mortality	Number of Samples
Yaquina Bay, Oregon	Coarse control	7.5±6.5	18
Yaquina Bay, Oregon	Coarse control	6.9±6.1	8
Yaquina Bay, Oregon	Fine control	8.3±7.4	9
Hackensack River	-	57.0±29.3	27
Arthur Kill			
Mill Creek	-	44.1±27.7	27
Rahway River	-	27.0±19.2	27
Elizabeth River	-	36.1±22.7	27
Sawmill Creek	-	52.6±33.2	27
Sawmill Creek		50.4±24.9	27
NW Pralls Island	Sand	27.8±10.6	9
NW Pralls Island	Mud	38.3±14.9	9
NW Pralls Island	Subtidal	51.7±31.9	9
E. Pralls Island	Subtidal	61.1±14.9	9
Old Place Creek	Subtidal	31.7±17.3	9
Isle of Meadows	Sand	18.9±9.1	9
Isle of Meadows	Mud	43.9±34.5	9
Kill van Kull			
Constable Hook	-	18.8±10.4	26
Shooters Island	Subtidal	29.4±12.6	9
Newark Bay			
Elizabethport	Subtidal	32.2±16.0	9
West Bayonne	Sand	34.4±9.6	9
West Bayonne	Mud	40.0±27.1	9

The mean mortality in all locations exceeded that of the Yaquina Bay controls. Sediments from eastern Pralls Island, the Hackensack River, northwest Pralls Island and Sawmill Creek caused the highest mortality. The results within each of the areas were highly variable, except in the sand sediments from West Bayonne. Lowest mortality was observed in the sandy sediments from Isle of Meadows and Constable Hook. In all three cases in which sand and mud from the same general location were tested, mean mortality was higher in the mud.

In summarizing the data from these small, disparate surveys, several patterns in toxicity seem to emerge. The data from the two Aqua Survey, Inc. surveys generally agree with those from Tietjen and Lee (1984), Scott et al. (1990), the City of New York (Brosnan and O'Shea, 1993), and EPA's EMAP surveys (Schimmel et al., 1994). That is, all five studies indicated that sediments from the Arthur Kill, Newark Bay, the lower Passaic River, and Kill van Kull were highly toxic. Moreover, all five studies indicated that samples from the northern reach of Arthur Kill (from Isle of Meadows to Shooters Island) were particularly toxic. Several of the studies indicated that samples from the lower Hudson River and the upper New York Harbor were not toxic. Also, toxicity to amphipods generally diminished eastward into the western Long Island Sound. Some samples from the lower reaches of the estuary and inner New York Bight were toxic in at least one test.

Numerous small studies of sediment toxicity have been conducted by or for the Army Corps of Engineers throughout the estuary as requirements for ocean disposal dredging permits. These toxicity tests were performed with consistent protocols, and, together, provide internally comparable data for much of the study area. Usually, one to several samples were tested in each study, each consisting of sediments collected in one or more long sediment cores. Data were available and compiled from 76 reports (Public Notices for Dredged Material Disposal, U. S. Army Corps of Engineers, 1985-1993). Tests were conducted with the shrimp *Palaemonetes pugio,* the polychaete *Nereis virens*, and the clam *Mercenaria mercenaria* exposed to solid phase sediments for 10 days, using U.S. EPA/ACOE (1977) protocols. Test results were compared to those from an offshore reference site to determine significant toxicity. Sediments were tested from shipyards, marine terminals, industrial waterways, harbors, sewage outfalls, navigation channels, barge berthing sites, petroleum docks, military docks, tributary rivers, and creeks in all of the major regions of the estuary (Figure 3).

Ninety-two samples were tested with the three bioassays, for a total of 276 individual tests. The majority of the samples did not cause significantly elevated mortality in the test organisms. However, mortality significantly different from the reference materials was indicated in sediments from the lower Raritan River, Arthur Kill, Kill van Kull, Keyport Harbor in Raritan Bay, Gowanus Bay/Canal, and the upper East River near Riker's Island (Figure 3). The samples that were toxic in these tests were collected in many of the same areas in which sediments either were estimated to be highly contaminated (e.g., Squibb et al., 1991) or were toxic in tests performed with other taxa (Figure 2).

Tatem et al. (1991) tested sediments from three sites—Westchester Creek adjoining the upper East River, central Arthur Kill, and Gowanus Creek —for toxicity to the mysid, *Mysidopsis bahia.* The sediments were held for differing periods of time, from 8 days to 40 weeks, before testing was initiated. In the tests performed with sediments held for fewer than 8 days, the samples from Westchester Creek and Arthur Kill were significantly more toxic than offshore reference samples. The Gowanus Creek samples were not toxic.

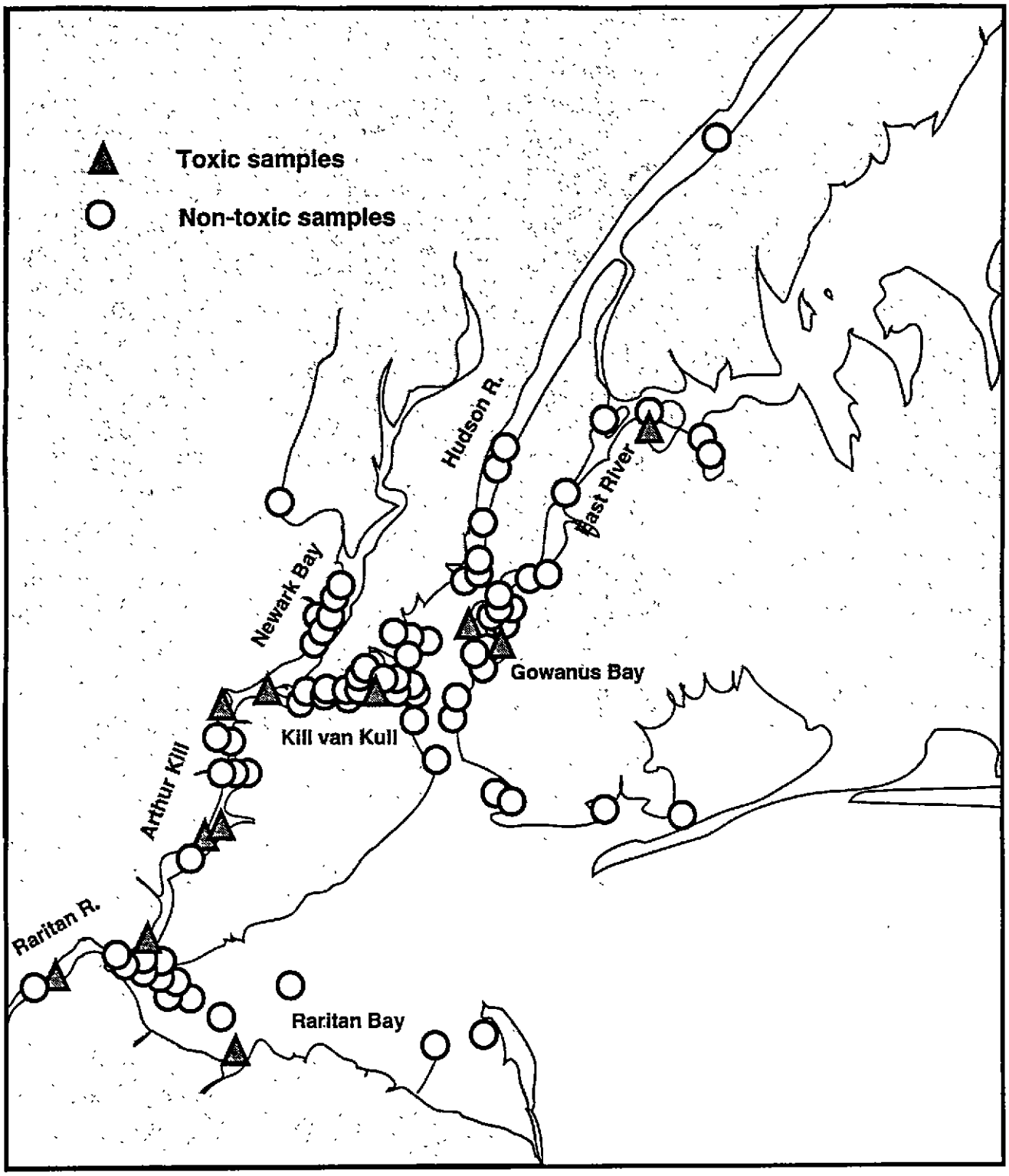

Figure 3. Sampling stations in which survival was significantly different from reference materials in tests of either grass shrimp, polychaetes, or clams during pre-dredging studies (from Army Corps of Engineers Public Notices, 1985-1993).

METHODS AND MATERIALS

NOAA initiated an area-wide survey of sediment toxicity in 1991 to provide internally consistent data on the spatial extent and severity of toxicity to relatively sensitive taxa. The intent of this survey was to sample all of the major regions of the study area, collect surficial fine-grained sediments, and test them to determine the degree of toxicity to laboratory organisms.

Based upon available sedimentological, chemical and biological data from numerous studies, a stratified sampling design was prepared that embraced areas previously identified as highly, moderately, and slightly contaminated. To ensure that samples were collected throughout the entire estuary, the study area was stratified into 13 contiguous regions designated as zones A through M (Figure 4). These zones were established following review of available bathymetric, physiographic and sedimentological information to represent conditions within major components of the study area. For example, zones A and G were intended to represent conditions in the lower reaches of the Hudson and Raritan rivers, respectively. Zones C and D were intended to represent conditions in the upper and lower reaches of the East River, respectively. Zones H through K were selected to represent the different sedimentological and bathymetric regimes reported in Raritan Bay. Samples from zones B and M were intended to provide information from suspected reference areas.

Three sites were sampled within each zone (Figure 4) to provide information on environmental variability. Most sites were chosen based upon reviews of data from previous sedimentological and chemical analyses (e.g., City of New York, 1987). Where no historical data were available, the sites were selected based upon bathymetric and sedimentological information published on applicable navigation charts. The coordinates for the center of each site are listed in Table 4. Similar to the method used in NOAA's Mussel Watch Program (NOAA, 1987), three stations were sampled and tested independently within each site. Sediments from a total of 39 sites and 117 stations were sampled and tested.

Table 4. Locations of sites in the Hudson-Raritan Estuary sampled during Phase 1.

Regional Zone	Site Number	Depth (m)	Latitude (°N)	Longitude (°W)
A. Lower Hudson River				
	1	14-15	40°54'52"N	73°54'53"W
	2	12-16	40°52"42"N	73°55'53"W
	3	11-13	40°46'50"N	73°59'28"W
B. Western Long Island Sound				
	4	14-15	40°53'40"N	73°42'15"W
	5	23-27	40°52'00"N	73°45'00"W
	6	17-19	40°49'59"n	73°46'42"W
C. Upper East River				
	7	33-35	40°47'58"N	73°47'13"W
	8	6-14	40°48'16"N	73°58'01"W
	9	10-12	40°47'46"N	73°52'42"W
D. Lower East River				
	10	6-11	40°47'58"N	73°54'04"W
	11	3-6	40°44'39"N	73°57'37"W
	12	3-16	40°42'31"N	73°58'14"W

Table 4 continued.

Regional Zone	Site Number	Depth (m)	Latitude (°N)	Longitude (°W)
E. Upper New York Harbor				
	13	16-18	40°42'16"N	74°01'34"W
	14	15	40°38'38"N	74°03'17"W
	15	6-8	40°36'22"N	74°02'44"W
F. Newark Bay/Arthur Kill				
	16	11-12	40°42'24"N	74°07'06"W
	17	10-14	40°38'43"N	74°10'20"W
	18	9-13	40°34'09"N	74°12'41"W
G. Lower Raritan River				
	19	2	40°21'01"N	74°20'54"W
	20	3-4	40°30'34"N	74°18'13"W
	21	3-5	40°29'50"N	74°16'38"W
H. Western Raritan Bay				
	22	3	40°30'37"N	74°15'25"W
	23	5-6	40°29'12"N	74°15'30"W
	24	5	40°29'20"N	74°13'30"W
I. Central Raritan Bay				
	25	6	49°29'26"N	74°10'52"W
	26	8-9	40°30'06"N	74°09'07"W
	27	9-10	40°29'33"N	74°06'55"W
J. Sandy Hook Bay				
	28	7	40°28'30"N	74°04'24"W
	29	6	40°27'23"N	74°02'00"W
	30	6	40°25'30"N	74°00'42"W
K. Southern Raritan Bay				
	31	3	40°28'05"N	74°13'20"W
	32	4	40°28'02"N	74°09'30"W
	33	6-7	40°28'02"N	74°05'52"W
L. Lower New York Harbor				
	34	6-7	40°30'35"N	74°06'05"W
	35	10-12	40°29'40"N	74°02'40"W
	36	4-7	40°33'42"N	74°03'08"W
M. Outer Bay/New York Bight				
	37	4-7	40°30'00"N	73°58'37"W
	38	8-10	40°28'00"N	73°56'00"W
	39	20-22	40°25'57"N	73°53'43"W

Three toxicity tests were performed on the samples. These tests included a 10-day, solid phase test of survival with the amphipod *Ampelisca abdita*, a 48-hour, elutriate/liquid phase test of normal development and survival with the larvae of the clam *Mulinia lateralis*, and a 15-minute, organic extract test of bioluminescence with the bacterium *Photobacterium phosphoreum* (the Microtox™ test). The battery of four test end-points, together, were intended to provide information with which to evaluate the relative toxicity of the sediments.

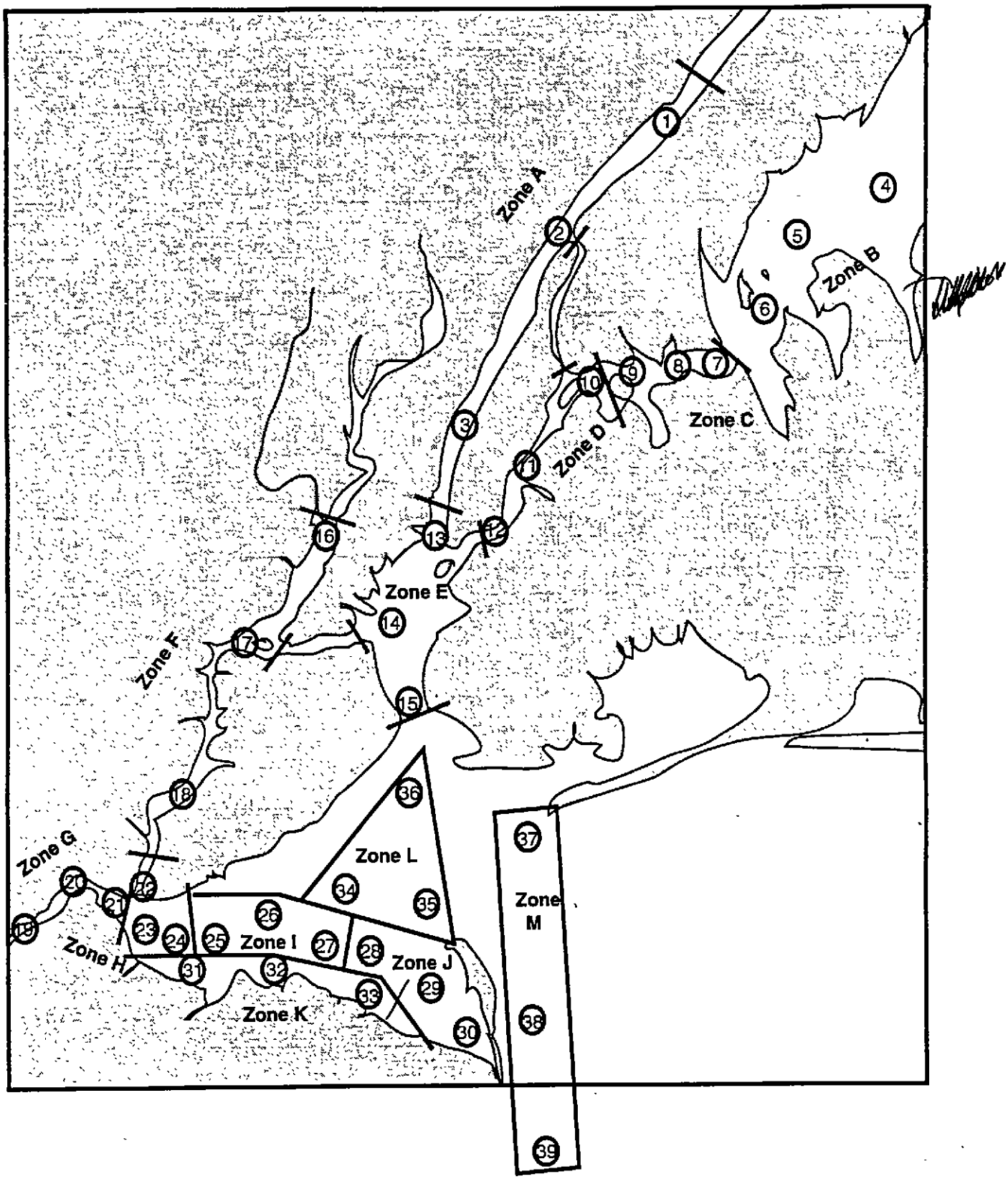

Figure 4. Boundaries of sampling zones (A-M) and locations of sampling sites (1-39) within each zone.

Following the initial survey in 1991, a follow-up Phase 2 was conducted that focused on the Newark Bay area. Sediment samples were collected at 57 randomly chosen stations. The study area was divided into strata that were approximately equal in size such that the data from each sample would have approximately equal spatial weight. Station location coordinates were chosen randomly within each stratum with the aid of EPA's EMAP software and hardware. Locations of the stations within the Passaic River, Hackensack River, Newark Bay, Kill van Kull, and Arthur Kill are listed in Table 5. Unlike Phase 1, the samples collected during Phase 2 were not replicated in the field; that is, only one sample was collected at each station. However, unlike Phase 1, the station locations were selected with a totally random approach.

Table 5. Locations of stations in Newark Bay and vicinity sampled during Phase 2.

	Depth (m)	(°N)	(°W)
Passaic River			
1.	5	40°47.36'	74°08.77'
2.	5	40°46.28'	74°09.28'
3.	7	40°45.28'	74°09.91'
4.	7	40°44.07'	74°09.36'
5.	4	40°44.18'	74°08.70'
6.	4	40°44.36'	74°08.56'
7a.	2	40°44.51'	74°07.99'
7b.	4	40°44.49'	74°08.11'
7c.	5	40°44.45'	74°08.30'
8a.	5	40°44.52'	74°07.41'
8b.	6	40°44.51'	74°07.59'
9.	5	40°44.28'	74°07.05'
10.	3	40°43.52'	74°07.16'
11.	4	40°43.33'	74°07.23'
Hackensack River			
12.	6.5	40°47.83'	74°04.30'
13.	6	40°47.62'	74°04.62'
14.	5	40°47.46'	74°04.74'
15.	3	40°46.97'	74°05.13'
16.	4	40°46.28'	74°05.30'
17.	6	40°44.95'	74°05.15'
18.	6	40°43.56'	74°05.95'
Newark Bay			
19.	4	40°43.06'	74°06.32'
20.	10	40°42.57'	74°06.50'
21.	12	40°42.48'	74°07.08'
22.	3	40°42.28'	74°07.08'
23.	8	40°42.37'	74°07.17'
24.	5	40°42.17'	74°07.08'
25.	4	40°42.13'	74°07.11'
26.	6	40°41.59'	74°07.29'
27.	13	40°41.44'	74°07.37'
28.	14	40°42.90'	74°09.14'
29.	12	40°41.81'	74°08.80'

Table 5 continued.

	Depth (m)	(°N)	(°W)	
30.	12	40°41.65'	74°08.33'	
31.	14	40°41.12'	74°07.90'	
32.	14	40°41.27'	74°09.53'	
33.	10	40°41.28'	74°08.30'	
34.	14	40°41.04'	74°07.99'	
35.	14	40°40.90'	74°08.08'	
36.	13	40°40.67'	74°08.14'	
37.	12	40°41.03'	74°09.16'	
38.	15	40°40.65'	74°08.36'	
39.	12	40°40.41'	74°08.25'	
40.	13	40°40.40'	74°08.32'	
41.	15	40°39.97'	74°08.57'	
42.	14	40°39.50'	74°08.76'	
43.		no sample collected		
44.	14	40°39.55'	74°09.37'	
45.		no sample collected		
Arthur Kill				
46.	2	40°37.02'	74°12.17'	
47.	6	40°37.07'	74°12.16'	
48.	10	40°38.44'	74°11.60'	
49.	2	40°38.69'	74°11.20'	
Kill van Kull				
50.	9	40°38.63'	74°10.09'	
51.	11	40°38.97'	74°09.79'	
52.	6	40°38.56'	74°09'.22'	
53.		no sample collected		
54.	5	40°38.56'	74°08'89'	
55.	5	40°38.56'	74°09.07'	
56.	10	40°38.56'	74°08.89'	
Upper New York Harbor				
	57.	15	40°38.68'	74°09.26'

Sampling Methods. In Phase 1, samples were collected with a modified Van Veen grab sampler (also known as a Young sampler) operated aboard the research vessel Mysidopsis. Samples were collected in five periods: March 18-22; April 1-5; April 15-18; April 28-May 2; and May 13-16, 1991. The center of each site was located with LORAN-C and Global Positioning System units. At each site, a buoy was dropped at the coordinates provided by NOAA. Then, the vessel was moved approximately 100 m. away from the buoy for each of the three stations sampled at the site. The location of each station was determined with Loran and GPS, along with radar ranges and hand-held compass bearings. Generally the stations at each site were equidistant from the site center and about 250 m. apart from each other. In most cases the stations formed a triangle around the site center, but, where conditions dictated otherwise, the stations were arranged in a straight line. Situations were avoided where considerably different environments were sampled at an individual site. For example, stations were located at a site such that all three were in similar depths and had sediments with similar-appearing grain sizes. Stations were not selected to represent conditions off known point or non-point discharges, waste dump sites, etc.

About 5 liters of sediment were collected at each station, requiring repeated deployments of the sampler. The upper 2 cm. of sediment were removed from each sample. The sediments from each station were homogenized thoroughly by stirring. Portions of each sample were placed in polyethylene containers for the toxicity tests and in glass jars for the chemical analyses. The grab sampler and sampling utensils, pans, and other equipment were washed with seawater and acetone between sites, and with seawater between stations. Samples were rejected for any of the following reasons: presence of sediments dropped from previous deployments of the sampler, excessive sediment escaping from grab lids, excessive sand or gravel content (>75%), excessive amount of shells or rocks, or over-penetration of the sampler. One sample from the East River was rejected because of the presence of a leg bone caught in the jaws of the sampler. Only a few stations were relocated to avoid gravel, coarse sand, mussel beds, etc.

At all 117 stations, additional sediments were collected for possible future benthic community analyses. The benthic samples are currently in storage.

Sediments from a Central Long Island Sound (CLIS) site were used as negative (nontoxic) controls in the toxicity tests. This site had been previously tested and found to be nontoxic (survival of *A. abdita* consistently exceeded 90%) and the concentrations of toxicants were relatively low.

During Phase 2 of the survey, samples were collected by U.S. EPA Region 2 personnel during two legs. The first sampling leg (January 2-12, 1993) was conducted aboard the U.S. EPA Ocean Survey Vessel Peter W. Anderson. Samples were collected in central Newark Bay, northern Arthur Kill, Kill van Kull and upper New York Harbor. Each sampling position was recorded by LORAN C, which had been calibrated with the on-board Global Positioning System unit. The second sampling leg was conducted during the period of March 16-29, 1993 aboard the U.S. Army Corps of Engineers (ACOE) Survey Vessel Hudson. During this leg, samples were collected in upper Newark Bay, the lower Passaic River, and the lower Hackensack River by personnel from EPA and the ACOE. Positions were recorded by a Northstar LORAN C unit.

Phase 2 samples were collected with a stainless steel modified van Veen grab sampler. At each station, approximately 8 liters of sediment from the upper 2 cm were collected in multiple deployments of the sampler. A kynar-coated spatula was used to carefully remove the upper 2 cm of sediment. The sediments were completely homogenized before aliquots were prepared for each laboratory. All equipment used in the collection of samples was rinsed with acetone and site water between sampling stations. Samples were rejected if the jaws of the sampler were not completely shut or if the sample consisted of only gravel and sand.

Sediment Testing Methods. Testing methods followed previously published protocols to ensure comparability of the results to previously collected data. The tests with the amphipods and bivalve larvae were performed with fresh, unfrozen sediments, while the Microtox tests were performed with previously frozen sediments. The holding times for the sediments tested with amphipods were 2 to 9 days for nine of the test series and 27-28 days for test series number 10. A number of unavoidable problems were encountered at the initiation of the bivalve larvae tests, causing delays in the completion of these tests. As a result, sediments tested with bivalve larvae were held for 93 to 163 days.

The amphipod test with *Ampelisca abdita* followed the protocols of ASTM (1990) and was conducted in both phases by Science Applications International Corporation. Test animals were collected from tidal flats in the Pettaquamscutt (Narrow) River, a small estuary of the Narragansett Bay, RI. They

were held in the laboratory and acclimated for 2 to 10 days before testing. Test sediments were press-sieved through a 2.0 mm mesh sieve and homogenized. Test chambers were quart-size glass canning jars with inverted glass dishes as covers. Two hundred of sediments were added to each test chamber and covered with 600 mL of laboratory seawater. Aeration was continuous via a glass tube, lighting was continuous during the 10-day static exposures, and temperatures were maintained at 20°C. Five replicate tests were performed with the sediments from each station and the control, using 20 animals in each test chamber. Exposure chambers were checked daily and the number of individuals that were dead, or moribund, on the sediment surface, and/or on the water surface were recorded. Dead animals were removed daily. Amphipods were considered to be dead when they did not respond to a gentle prod with a glass rod.

Six samples collected during Phase 2 were suspected to be highly contaminated with dioxins, and, therefore hazardous. The amphipod survival tests of these samples were performed by Aqua Survey, Inc., using the same ASTM (1990) protocols. The amphipods were obtained from East Coast Amphipod Co., Narragansett, RI (from the same site used by SAIC) and acclimated to test water for 96 hours.

The bivalve larvae test with *Mulinia lateralis* generally followed the protocols of the U.S. EPA/ACOE (1991) with some modifications. Adult male and female clams were induced to spawn by temperature manipulation. Egg stocks of about 1,200 eggs per mL and sperm stocks of about 4 million sperm per mL were prepared. To prepare the embryo stock, 100 *u*L of sperm stock was added to every mL of egg stock and fertilization was allowed to proceed for about 35 min. The embryos were then retained on a 10 *u*m screen, and then resuspended. Next, 0.75 mL of embryo stock was added to vials containing 15 mL of sample or control. Initial embryo counts were performed on the contents of six vials containing 15 mL of seawater. Elutriates were prepared by adding 100 g (wet wt.) of homogenized sediment to 500 mL of laboratory seawater in clean glass jars. The elutriates were mixed for 30 min. using heavy aeration with manual stirring every 10 min. After 30 min., the suspensions were allowed to settle for at least one hour. At least 80 mL of supernatant was gently poured into a 0.4 *u*m filter housing and vacuum filtered until there was enough filtered sample for 5 replicates of 15 mL each. Static test exposures of the liquid phase samples were conducted for 48 hours at 22°C. After 48 hours the tests were terminated by adding 0.75 mL of 50% buffered formalin to each vial. The total number of embryos and the number of normal-appearing embryos were counted.

The Microtox™ tests followed an adaptation of the protocols prepared by U.S. EPA Region 10 (1990). The tests were performed with organic extracts of the sediments. Three grams (wet wt.) of each sediment sample were weighed into a 100 mL Pyrex centrifuge tube with a Teflon lined top. Each sample was centrifuged for 10 min. at 1,750 RPM and the water discarded. Fifteen grams of sodium sulfate was mixed in, then 50 mL of dichloromethane (DCM) was added and mixed. The samples were shaken overnight; centrifugation was repeated; and the supernatant was collected in a 200 mL flask. The extraction steps were repeated twice and the extract solutions collected in a flask. The solutions were evaporated under nitrogen to a volume of about one mL. Undenatured ethanol was added and the volumes reduced to just below one mL in a 100°C water bath. The final volumes were adjusted to 1 mL with undenatured ethanol. An ethanol reagent blank was prepared as above but contained no sediment. Lyophilized bacteria (*Photobacterium phosphoreum*) were reconstituted with 1 mL of deionized water and placed in a Microtox™ cuvette at 4°C. Tests were performed with 10-fold serial dilutions (representing 10, 1.0, 0.1, and 0.01 *u*L of sediment extract) prepared in seawater. Blanks were prepared at the same concentrations by similar dilutions of the ethanol reagent blank. All dilutions were conducted in test cuvettes in temperature-controlled incubation wells. Reconstituted bacteria were added to each at 30-sec. intervals and mixed well to initiate the tests. Exactly five minutes later, light emission was

measured at 30-sec. intervals in the same sequence as the tests were initiated. Between each extract dilution level, the blank of the corresponding concentration was used to adjust the photometer for the contribution of the extraction solvent. To conclude the tests, light emission was measured again at 15 min., and these data were used to calculate the 50% inhibition concentrations (i.e., the EC50s).

In addition to the tests described above that were performed with all of the samples, several others were performed on selected samples as a part of methods development. Tests of the growth of a polychaete (*Armandia brevis*) and an adult sand dollar (*Dendraster excentricus*) were performed with 17 of the samples (Rice et al., in press). Also, nine of the samples were tested with the freshwater amphipod *Diporeia* spp. by the Great Lakes Environmental Research Laboratory (Dr. Peter Landrum). The test animals were acclimated to 20 ppt salinity seawater by the addition of 5 ppt seawater/day and held for 48 hours. Two cm of sieved sediments, in replicates of three per sample, were placed into one-liter beakers, containing 600 mL of seawater at 20 ppt salinity. Twenty animals were used in each replicate. Tests were performed at 4°C, maintained by a constant temperature water bath. The amphipods were monitored daily for sediment avoidance, signs of stress, and mortality. Avoidance of the sediment was observed as the absence of burrowing and migration to the water surface, which resulted in adherance to the surface film. Stress was observed as animals lay on the sediment surface. Dead animals were recorded and removed from the exposure chambers. After 28 days, the beakers were removed from the water bath and the sediment was wet sieved through a 1 mm screen. The numbers of live and dead animals were recorded and the percent mortality and percent survival were calculated.

Estimates of the Spatial Extent of Toxicity. The spatial extent of toxicity within the survey area was estimated using methods similar to those of the Environmental Monitoring and Assessment Program (EMAP) of the U.S. EPA (Schimmel et al., 1994). However, the design of the sampling plans differed between Phases 1 and 2. During Phase 1, the dimensions of each sampling zone (Figure 4) were outlined on navigation charts during the design phase. The locations of each sampling site were determined *a priori* to represent conditions within each zone. These site locations were chosen following a review of existing information of sediment types, bathymetry, and proximity to previously sampled sites. The size of each zone was determined with a planimeter. The toxicity data were weighted to the size of each zone (divided by three, the number of sites in each zone), and the cumulative distribution functions of these data were prepared. Using critical values of toxicity results less than 80% of the control responses (as in the EMAP) and less than 20% of controls (reciprocal of 80%), the size(s) of the area(s) that were significantly toxic and highly toxic, respectively, were estimated.

The principles of a probabalistic sampling design require that the sampling locations be chosen randomly and without knowledge of site-specific conditions (Schimmel et al., 1994). However, that type of sampling design was not strictly adhered to in Phase 1 of this survey. The boundaries and dimensions of each zone were established *a priori*, but the locations of the sampling sites were not selected with a strictly random process. Some sites were chosen to coincide with the locations of sites previously sampled by other investigators. However, none were chosen to represent conditions near any point sources or waste disposal sites. All sites were chosen to represent conditions in the nearby vicinity of the sampling location and within the respective zone. The locations of the individual sampling stations at each site were chosen by the vessel operator in the field as three points on a compass radiating from the site center.

Highly disturbed areas that obviously had been recently dredged were avoided. Also, samples with excessive amounts of coarse sandy materials were avoided, where possible. Within each site, attempts were made in the field to avoid a mixture of stations from deep, dredged channels and shallow, undredged

flats. The boundaries of the sampling zones were chosen based upon major physiographic features, such as points of land and the dimensions of individual waterways. Because of these possible sources of bias in the data, the estimates of the spatial extent of toxicity prepared during Phase 1 must be interpreted as rough estimates, and not as absolutes.

During Phase 2 of this survey, the probabalistic, random-stratified sampling design used by the EMAP (Schimmel et al., 1994) was used within the boundaries of the Phase 2 survey area (Figure 5). During the design phase, the area was subdivided into strata roughly equal in size. The dimensions of these strata were outlined on a navigation chart, the chart was digitized, and the coordinates for the individual stations were selected randomly with the aid of a computer program. One station (one sample) was sampled within each stratum. The toxicity results were weighted to the size of each stratum, the cumulative distribution function prepared, and using <80% of controls as the critical value, the size (and percent) of the area that was toxic was determined.

Chemical Analyses: Phase 1. Sediment samples were chosen for chemical analyses based upon an examination of the toxicity test results. Samples were chosen that represented gradients in the toxicity results and that also represented contiguous geographic strings of stations. Sediments were extracted by Battelle Ocean Sciences in two batches containing approximately 19 field samples each. One procedural blank, one standard reference material, a matrix spike sample, and a matrix spike duplicate sample were extracted with each batch. Each field sample contained 30 g to 50 g of sediment. Sediment dry weight was determined using approximately 5 g of sample material. Analyses were performed for total trace metals, simultaneously extracted metals (SEM), acid-volatile sulfides (AVS), PCB congeners, pesticides, and polynuclear aromatic hydrocarbons (PAHs). Also, analyses were performed for total organic carbon (TOC) and sediment grain size.

Extraction and analytical methods followed those of Peven and Uhler (1993). Sediment was weighed into pre-weighed Teflon jars; surrogate internal standards (to monitor extraction efficiency), sodium sulfate, and 1:1 methylene chloride (DCM):acetone were added to each jar. Samples were extracted with the solvent mixture three times using shaker table techniques. After each extraction, the jar was centrifuged, and the overlying solvent decanted into a labelled Erlenmeyer flask. Solvent from each of the three extractions was combined in the flask. The combined extract was chromatographed through a 20 g alumina column eluted with dichloro-methane (DCM). After column cleanup, the sample extract was concentrated to approximately 900 uL and further processed using a size-exclusion high performance liquid chromatography (HPLC) procedure. Six hundred microliters of the extract were fractionated in this procedure, and the remaining 300 uL archived. After HPLC cleanup, the sample extract was concentrated to approximately 1,000 uL and recovery internal standards were added to quantify surrogate recovery. The final sample was split in half by volume; one half was dedicated to GC/MS analysis of PAHs and the other half was solvent-exchanged with isooctane and analyzed by GC/ECD for PCBs and pesticides.

The analytical methods for the trace metals followed those of Crecelius et al. (1993). Samples were completely digested with 4:1 $HNO_3/HClO_4$ and heated. The digestates were analyzed either by graphite furnace atomic absorption (Ag, Cd, Se), or cold vapor atomic absorption (Hg), or x-ray fluorescence (Al, As, Cr, Cu, Fe, Mn, Ni, Zn), or inductively coupled plasma mass spectrometry (Sb, Sn). Two reagent blanks and three standard reference materials were analyzed in each analytical string of 50 samples.

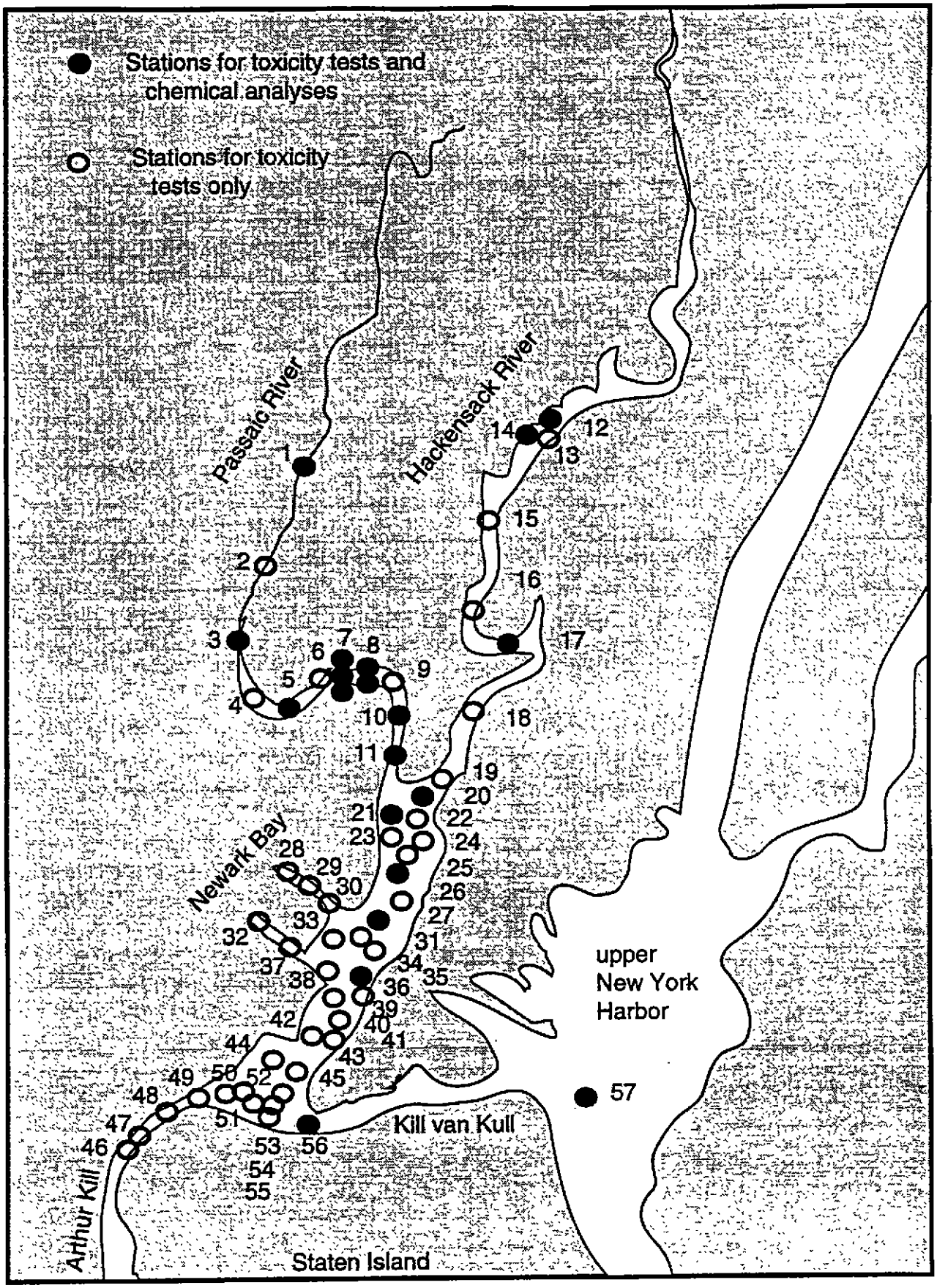

Figure 5. Stations sampled in the Passaic River, Hackensack River, Newark Bay, upper Arthur Kill, Kill van Kull, and upper New York Harbor during Phase 2.

The concentrations of acid volatile sulfides (AVS) and simultaneouslyextracted metals (SEM) were determined in the samples. The analytical methods employed selective generation of hydrogen sulfide by acidifying the sample with 1N HCl, cryogenic trapping of the evolved H_2S, and gas chromatographic separation with photoionization detection. This method gives high sensitivity, low detection limits and very limited chemical interference with minimal sample handling. The AVS analytical system is made of glass and Teflon because of the reactivity of sulfide with metals. The filtered acid solution resulting from the AVS analysis was subsequently analyzed for SEM using graphite furnace atomic absorption, cold-vapor atomic absorption, and inductively coupled mass spectrometry.

Sediment samples were analyzed for total organic carbon (TOC) and total carbonate (TIC) by Global Geochemistry Corporation, Canoga Park, CA. Before the samples were analyzed, LECO filtration crucibles were precombusted for at least 2 hours at 450°C and allowed to cool. Between approximately 175 mg and 250 mg of dried, finely ground and homogenized sample was placed in a pretreated crucible, and 6N HCl added to remove inorganic carbon. After approximately 1 hr, deionized water was flushed through the crucible removing the acid, and the sample was dried overnight. Immediately prior to sample analysis, iron and copper chips were added to accelerate the combustion. A LECO model 761-100 carbon analyzer was used to determine both the TOC and TIC content. The analyzer converts all carbon in the sample to CO_2 at high temperature in the presence of oxygen. The CO_2 was then quantified by thermal conductivity detection. Before sample analysis for TIC, the filtration crucibles were precombusted for at least 2 hrs at 450°C and allowed to cool. Between approximately 175 mg and 250 mg of dried, finely ground, homogenized sample was placed in a pretreated crucible, and the sample placed in a 450°C oven for 2 hrs to remove organic carbon.

The methods used to determine sediment grain size are those according to Folk (1974). Briefly, coarse and fine fractions were seperated by wet-sieving. The fine fractions (silt and clay) were further separated by suspending the sediment in a deflocculant solution and taking aliquots of the settling sediment at timed intervals after the solution was thoroughly mixed. The coarse fraction (sand and gravel) was dried and then separated by sieving through a 2 mm screen.

Chemical Analyses: Phase 2. In Phase 2 of the study, chemical analyses were performed by the National Biological Service, Midwest Science Center laboratory in Columbia, MO. Analyses were performed for total trace elements; SEM, AVS, PAHs; chlorinated pesticides; PCB congeners; and a number of dioxins and furans.

Five-gram subsamples of wet sediment were analyzed for SEM/AVS by treatment with 100 ml 2N HCl for 1 hr in a nitrogen atmosphere. A sulfide-specific electrode was used to measure sulfide liberated from the HCl treatment. The remaining sediment and acid was filtered through a 0.4 um polycarbonate membrane for metals determination. A second 5 g subsample was taken for analysis of percent moisture by oven-drying at 95° C. The remainder of the sample was lyophilized to a constant weight and the dry sediment was utilized for digestion and analysis for total metals and organic carbon. A portion of each filtered SEM extract (6 mL) was diluted with 5.7% nitric acid prior to Zeeman furnace atomic absorption spectroscopy (AAS) to reduce the high chloride ion matrix. Another portion of the SEM extract was similarly diluted and stored in a glass container, which was later used for the determination of mercury by flow injection AAS. A final portion of the SEM extract was subjected to a nitric acid wet digestion/magnesium nitrate dry ash procedure to prepare a digestate suitable for the determination of arsenic and selenium.

For total trace metals, a 0.5 g subsample of dried sediment was placed in a Teflon vessel and digested with nitric acid, hydrochloric acid, and hydrogen peroxide for analysis of total mercury. A second 0.5 g portion of dried sediment was treated with nitric, perchloric, and hydrofluoric acids to prepare a digestate suitable for total metals determination. This latter digestate was diluted with 5.7% nitric acid prior to Zeeman furnace or flow injection AAS. A final portion of dried sediment was placed in a Coulometrics total carbon apparatus and combusted in pure oxygen for the determination of total organic carbon.

Various instrumental approaches were used for the determination of elements in the total recoverable extractions, as well as the SEM fraction. Aluminum and iron in SEM extracts and aluminum, chromium, copper, iron, and zinc in the total sediment digestates were determined by inductively coupled plasma spectroscopy (ICP). Zinc in SEM extracts was determined by flame atomic absorption. Arsenic and selenium in SEM extracts and total sediment digestates were determined by flow injection hydride generation atomic spectroscopy. Mercury was determined on total recoverable digestates by flow injection cold vapor AAS. All remaining analytes (cadmium, chromium, copper, lead, nickel, silver, antimony, and tin in SEM extracts, and cadmium, lead, nickel, silver, antimony, and tin in total sediment digestates) were determined by Zeeman furnace AAS.

For the analyses of organic compounds, the sediments were dried, homogenized, and extracted according to NBS Midwest Science Center procedures. Different sample aliquot sizes were extracted for each class of compounds. In all cases the appropriate internal standards were spiked into the sample before extraction. Sediment samples were mixed with anhydrous sodium sulfate and column-extracted with methylene chloride (MeCl).

For the organochlorine pesticides, sample extracts were injected onto an automated, high-performance gel permeation chromatography (HPGPC) system that was eluted with 80/20 hexane/MeCl. The collected portion then went through serial fractionation on Florisil and silica gel columns. One of the resultant three fractions (the first fraction of the silica gel) was treated for sulfur with acid-activated copper. The three fractions were then analyzed by GC/ECD on two different phase 30-m columns, DB-1 (methyl silicone) and OV-17 (50% phenyl-50% methylsilicone). All GC analyses were cool on-column injections.

For the polynuclear aromatic hydrocarbons (PAHs), the sample extracts were taken through a potassium silicate (KS) cleanup and the HPGPC system. Extracts were treated for sulfur with acid activated copper. The extracts went through a second KS cleanup and then were fractionated on a silver nitrate treated benzenesulfonic acid cartridge which separated chlorinated aromatics from the PAHs. The PAH fractions were analyzed by GC/MS on a quadrapole system in full scan mode. The column was a 60-m DB-5 (5% phenyl-95% methylsilicone). Compounds were determined by comparison of peak retention times to those of a standard and by checking the mass spectra. The concentrations of 12 low molecular weight (2- and 3-ring) PAHs and 12 high molecular weight (4- and 5-ring) PAHs were quantified. Recoveries were determined by deuterated internal standard spikes.

Samples extracted for polychlorinated biphenyls (PCB congeners, mono-ortho, and non-ortho) and polychlorinated dibenzodioxins and dibenzofurans (PCDDs and PCDFs) were taken through two stages of reactive column cleanup followed by HPGPC. After GPC cleanup the extracts were fractionated on an automated C-18/PX-21 carbon column system. Four fractions were collected from the carbon column corresponding to congener PCBs (F1), mono-ortho PCBs (F2), non-ortho (F3) and PCDD/PCDFs (F4).

The congener PCB fractions (F1) were analyzed by GC/ECD on a 60-m DB-5 column; the concentrations of 80 congeners were quantified. The mono-ortho PCB fractions (F2) were analyzed by GC-ECD on a 3-m DB-1 phase column.

For the non-ortho PCB fractions (F3), the analyses were done by capillary gas chromatography interfaced to high resolution mass spectrometry (GC/HRMS). Samples were injected by cool on-column technique onto a retention gap connected to an Ultra-1 (DB-1 equivalent) 50-m capillary column. The MS system resolution was tuned to 10,000. Selected ion monitoring of two mass windows was done for Cl_3 and Cl_4 biphenyls, and Cl_5-Cl_6 biphenyls.

The PCDD/PCDF fractions (F4) went through a final cleanup step on activated basic alumina to remove possible chlorinated co-contaminants. The fractions were then analyzed by capillary GC coupled to HRMS. The column used was a 50-m Ultra-2 (Hewlett-Packard DB-5 equivalent) capillary column. The MS system resolution was tuned to 10,000. Eighteen compounds were detected by selected ion monitoring with five mass windows to measure Cl_1-Cl_8 PCDDs and PCDFs.

The H4IIE rat hepatoma cell bioassay was performed with extracts of the samples from the same 20 samples characterized in the chemical analyses. The induction of cytochrome P450 in the whole extract (F1) was measured following methods of Tillitt et al. (1991). Also, the toxicity of six fractions of the whole extract was determined in each sample: a PAH fraction (F5); a dioxin/furan fraction (F12); a combined PCB fraction (F11); and three planar/co-planar PCB fractions (F7, F8, F9).

Data Analyses. Results of the toxicity tests performed with the amphipods and bivalve embryos were arcsin-square root transformed and compared with the controls with one-tailed, unpaired, t-tests to determine significant differences (n=5 replicates, alpha = 0.05). The tests were conducted in 10 batches, the control sediment was tested along with the environmental samples in each batch, and the results from each test of the control were used in the statistical analyses for each batch. To determine if the mean percent survival at any sites (n=3) were significantly different from mean survival in controls, the untransformed data were evaluated with one-tailed t-tests (alpha=0.05).

The Microtox™ test data were analyzed using a linear interpolation technique to determine concentrations of the extract that inhibited luminescence by 50%. This value (expressed as *u*L of extract per mL of Microtox™ exposure volume) was then converted to mg/mL using the wet weight of sediment in the original extract. To determine differences from controls, a pairwise comparison was made between test samples and LIS controls, using analysis of covariance (ANCOVA). Both the concentrations and response data were log-transformed prior to the analysis to linearize the data. The ANCOVA was first used to determine if the two lines had equal slopes (alpha=0.05), and if they did, it was used to check for equal Y-intercepts (alpha=0.05). To determine which sites were significantly different from controls, the three EC50 values for each site were compared to the control values with a one-way t-test (alpha=0.05).

The relationships between measures of toxicity and the concentrations of physical-chemical variables in the samples were determined in several steps. First, simple, non-parametric, Spearman-rank correlations were performed (Statview 4.0 software). Where the correlations appeared to be significant, the data were examined in bivariate scatterplots to confirm the distribution pattern. Next, to determine which chemicals were most elevated in concentration in the toxic samples, the average concentrations in both toxic and nontoxic samples were compared. Finally, to determine which, if any, toxicants were sufficiently elevated in concentration to cause or contribute to toxicity, the average concentrations in the toxic samples were compared with applicable, effects-based sediment guideline values.

RESULTS

Solid-Phase Amphipod Tests. Results of the amphipod test performed with *Ampelisca abdita* are summarized in Table 6. Tests were performed in a series of 10 batches. The results of the tests of the Central Long Island Sound control sediments are listed first, followed by mean survival data for each station and site. Mean percent survival in the LIS sediments ranged from 83.2% to 99.0%. Normally, an acceptable survival rate in control sediments is 85% or greater. The mean percent survival in the controls in test series 3 and 6 were 83.2% and 85.0%, respectively. In both series, there was no pattern of unusually low survival in tests of the Hudson-Raritan Estuary samples; therefore, the data were accepted and re-testing was not conducted. Furthermore, in series 3 amphipod survival in the test samples was either very high or very low; therefore, the relatively low survival in the controls probably had no effect upon the tests of significance. However, in series 6 amphipod survival approximated 80% in several samples and the tests of significance may have been affected by the results of the tests of the controls.

The sediments from 54 of the 117 stations (46%) were significantly toxic (i.e., different from controls) in the amphipod tests. A total of 16 of the 39 sites (41%) was significantly toxic in this test. Mean percent survival ranged from 0.0 to 99.0% among the 117 stations. Mean percent survival in most of the 117 samples ranged from 80 to 99%, but a considerable number (48) of the test results were in the range of 0 to 79% survival. Among all 117 samples, 0.0% survival was observed in three samples (9-B, 10-A, and 18-C) and 0.1-10.0% survival was observed in five samples (9-A, 9-C, 12-A, 18-C, and 34-B).

Based upon considerable previous experience with this test, differences in amphipod survival between controls and test samples of 20% or more are significantly different in approximately 90% of the cases. Also, the 20% or greater difference from controls was used by EMAP (Schimmel et al., 1994) as a critical value in the interpretation of amphipod bioassay data. Therefore, stations and sites in which mean amphipod survival was equal to or less than 80% of the controls are identified with two asterisks in Table 6.

Of the 43 samples in which amphipod survival was 80% or less of controls, 42 (98%) were significantly different from the controls. Mean amphipod survival in 10 sites was 80% or less of controls and significantly different from controls. There is a lower probability that test results in which mean survival was greater than 80% of the controls were actually significantly different from controls. Therefore, in some samples with relatively high amphipod survival (>80%) the results of the t-tests, alone, may over estimate the incidence of toxicity in these tests.

Sediments from Zone F, Newark Bay/Arthur Kill/Kill van Kull, were most toxic (Table 6). All nine stations and all three sites were significantly toxic to amphipods in this zone. Also, zones C and D, upper East River and lower East River, respectively, were highly toxic. In the upper East River area, all nine stations and two of the three sites were toxic. In the lower East River, abd eight of nine stations were toxic. Sediments from zones B (western Long Island Sound), I (Central Raritan Bay), and K (southern Raritan Bay) were least toxic; none of the stations was toxic in these zones. Sediments from Zone A, lower Hudson River, were relatively low in toxicity. Some of the sediments in Zone M in New York Bight were toxic, especially those from site 39 in the southern portion of this zone.

Several spatial patterns in toxicity were apparent, based upon the data from this test (Figures 6, 7). First, toxicity was very high in the upper East River and rapidly decreased eastward out into western

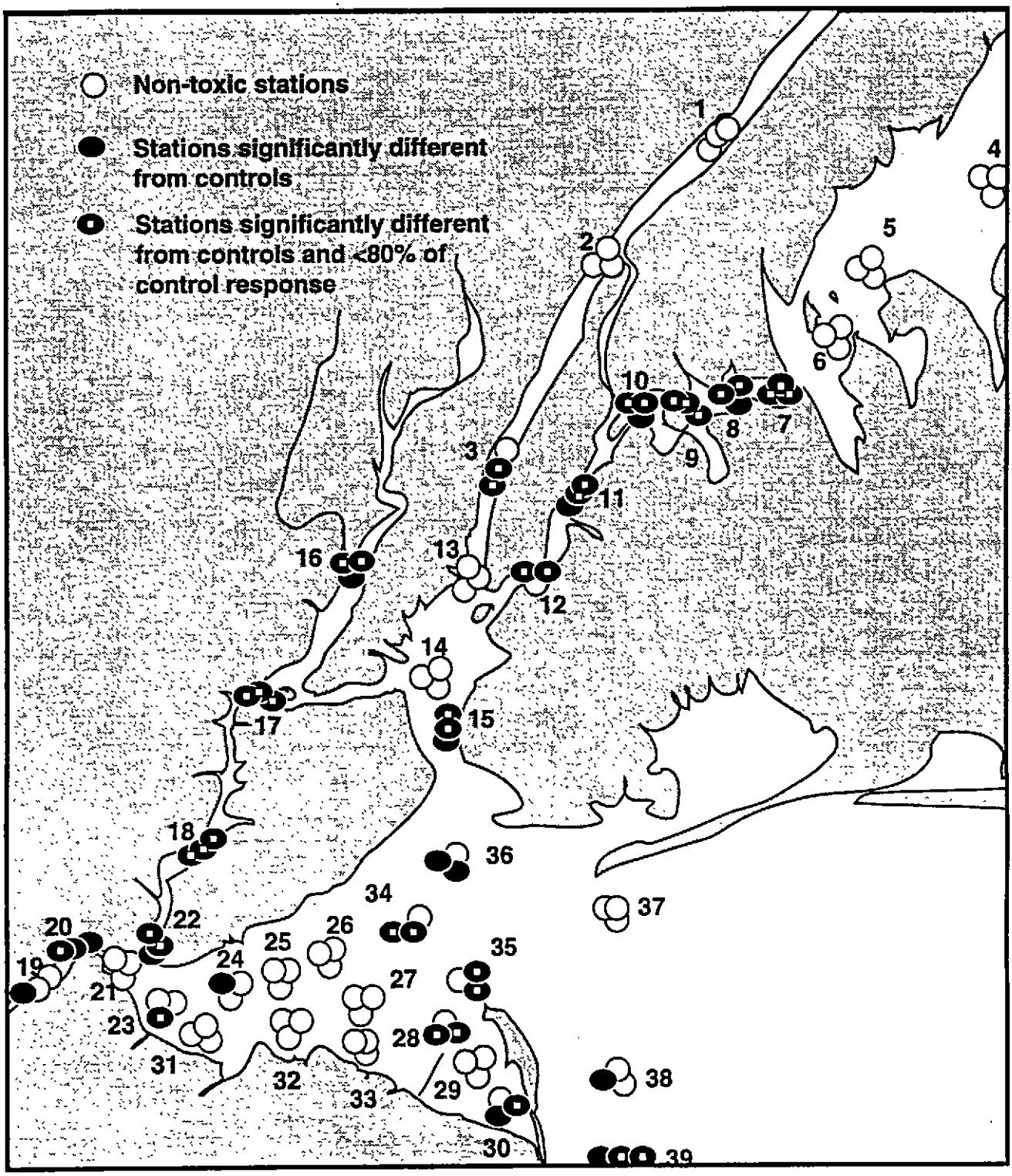

Figure 6. Sampling stations in which the sediments were significantly toxic to *Ampelisca abdita* survival (n=5, alpha <0.05).

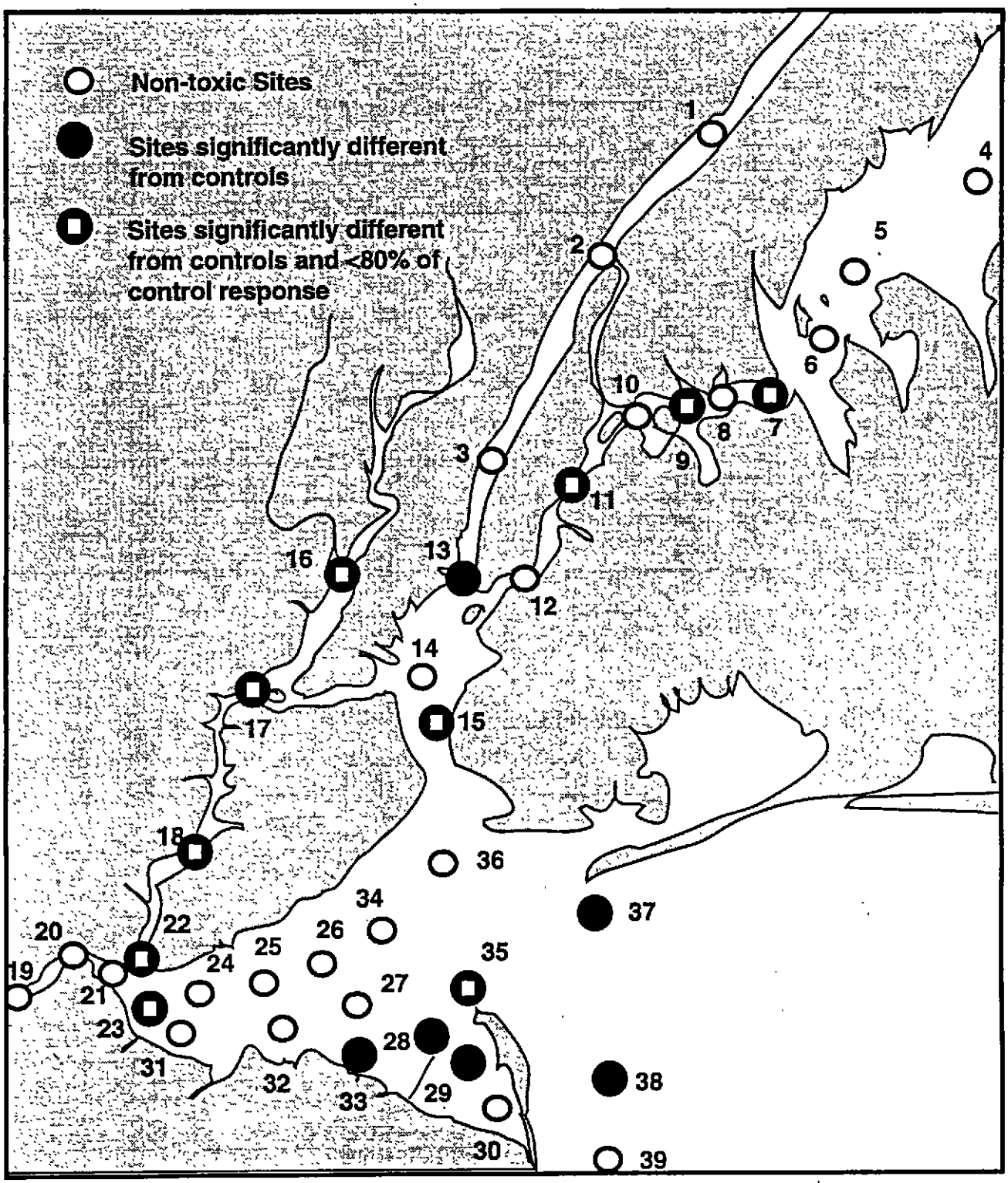

Figure 7. Sampling sites in which the sediments were significantly toxic to *Ampelisca abdita* survival (average of three stations, alpha <0.05).

Long Island Sound. Second, toxicity was relatively high in samples from the lower East River, and decreased southward through upper New York Harbor, lower New York Harbor, and eastward into the entrance of the estuary. Third, toxicity was extremely high in the Newark Bay/Kill van Kull/Arthur Kill area and diminished southeastward through Raritan Bay. Sediments from the lower Raritan River and Sandy Hook Bay were moderately toxic, and this toxicity diminished into central Raritan Bay and eastward into the entrance to the estuary.

Table 6. Mean percent survival of *A. abdita* in 10-day solid-phase toxicity tests of sediments from the Central Long Island Sound (CLIS) control site (n=5), 117 sampling stations (n=5), and 39 sites (n=3) and of *Diporeia* spp. in 9 samples from the Hudson-Raritan Estuary.

			A. abdita			*Diporeia* spp.	
Regional Zone	Sampling Site/Station	Test Series	mean % survival	% of control	Signif-icance	mean % survival	Signif-icance
CLIS	Control	1	92.0		-		
	Control	2	89.5		-		
	Control	3	83.2		-		
	Control	4	91.0		-		
	Control	5	99.0		-		
	Control	6	85.0		-		
	Control	7	92.0		-		
	Control	8	98.0		-		
	Control	9	98.0		-		
	Control	10	92.0		-		
	1-A	3	89.5	107.6	ns		
	1-B	3	85.3	102.5	ns		
	1-C	3	88.4	106.3	ns		
Site 1 Mean	3		87.7	105.5	ns		
	2-A	3	90.8	109.2	ns		
	2-B	3	91.6	110.1	ns		
	2-C	3	84.2	101.3	ns		
Site 2 Mean	3		88.9	106.9	ns		
	3-A	2	89.5	100.0	ns		
	3-B	2	45.3	50.6	**		
	3-C	2	42.1	47.1	**		
Site 3 mean	2		59.0	65.9	ns		
Zone B	4-A	3	98.9	119.0	ns		
	4-B	3	95.8	115.2	ns		
	4-C	3	93.7	112.7	ns		
Site 4 mean	3		96.1	115.6	ns		
	5-A	3	96.9	116.6	ns		
	5-B	3	92.9	111.8	ns		
	5-C	3	94.7	113.9	ns		
Site 5 mean	3		94.8	114.1	ns		

Table 6 continued.

Regional Zone	Sampling Site/Station	Test Series	*A. abdita* mean % survival	*A. abdita* % of control	*A. abdita* Signif-icance	*Diporeia* spp. mean % survival	*Diporeia* spp. Signif-icance
	6-A	4	93.0	102.2	ns		
	6-B	4	84.0	92.3	ns	76.7	*
	6-C	4	92.0	101.1	ns		
Site 6 mean	4		89.7	98.5	ns		
Zone C	7-A	4	30.0	33.0	**	58.7	*
	7-B	4	16.0	17.6	**		
	7-C	4	10.0	11.0	**		
Site 7 mean	4		18.7	20.5	**		
	8-A	4	80.0	87.9	*		
	8-B	4	39.0	42.9	**		
	8-C	4	37.0	40.7	**		
Site 8 mean	4		52.0	57.2	ns		
	9-A	4	3.0	3.3	**		
	9-B	4	0.0	0.0	**	0.0	*
	9-C	4	2.0	2.2	**		
Site 9 mean	4		1.7	1.8	**		
Zone D	10-A	4	0.0	0.0	**		
	10-B	4	17.0	18.7	**		
	10-C	4	72.0	79.1	**		
Site 10 mean	4		29.7	32.6	ns		
	11-A	1	77.0	83.7	*		
	11-B	1	71.0	77.2	**	13.7	*
	11-C	1	70.0	76.1	**		
Site 11 mean	1		72.7	79.0	**		
	12-A	1	2.0	2.2	**		
	12-B	1	70.0	76.1	**		
	12-C	1	86.0	93.5	ns		
Site 12 mean	1		52.7	57.3	ns		
Zone E	13-A	2	76.8	85.9	ns		
	13-B	2	80.0	89.4	ns		
	13-C	2	84.2	94.1	ns		
Site 13 mean	2		80.3	89.8	*		
	14-A	2	93.7	104.7	ns		
	14-B	2	81.1	90.6	ns		
	14-C	2	92.6	103.5	ns		
Site 14 mean	2		89.1	99.6	ns		

Table 6 continued.

Regional Zone	Sampling Site/Station	Test Series	*A. abdita* mean % survival	*A. abdita* % of control	*A. abdita* Signif-icance	*Diporeia* spp. mean % survival	*Diporeia* spp. Signif-icance
	15-A	5	77.9	78.7	**		
	15-B	5	89.0	89.9	*		
	15-C	5	70.0	70.7	**		
Site 15 mean	5	79.0	79.8	**			
Zone F	16-A	2	61.1	68.2	**		
	16-B	2	26.3	29.4	**		
	16-C	2	30.5	34.1	**		
Site 16 mean	2	39.3	43.9	**			
	17-A	1	16.0	17.4	**		
	17-B	1	13.0	14.1	**		
	17-C	1	18.0	19.6	**		
Site 17 mean	1	15.7	17.0	**			
	18-A	2	32.6	36.5	**		
	18-B	2	4.2	4.7	**	55.0	*
	18-C	2	0.0	0.0	**		
Site 18 mean	2	12.3	13.7	*			
Zone G	19-A	7	82.0	89.1	ns		
	19-B	7	89.0	96.7	ns		
	19-C	7	77.0	83.7	*		
Site 19 mean	7	82.7	89.8	ns			
	20-A	9	86.0	87.8	*		
	20-B	9	89.0	90.8	*		
	20-C	9	51.0	52.0	**		
Site 20 mean	9	75.3	76.9	ns			
	21-A	7	85.0	92.4	ns		
	21-B	7	84.0	91.3	ns		
	21-C	7	92.0	100.0	ns		
Site 21 mean	7	87.0	94.6	ns			
Zone H	22-A	6	47.1	55.4	**		
	22-B	6	64.3	75.7	**	25.0	*
	22-C	6	32.0	37.7	**		
Site 22 mean	6	47.8	56.3	**			
	23-A	6	59.2	69.6	ns		
	23-B	6	76.1	89.6	ns		
	23-C	6	65.7	77.3	**		
Site 23 mean	6	67.0	78.8	**			

Table 6 continued.

Regional Zone	Sampling Site/Station	Test Series	*A. abdita* mean % survival	*A. abdita* % of control	*A. abdita* Signif-icance	*Diporeia* spp. mean % survival	*Diporeia* spp. Signif-icance
	24-A	5	87.8	88.7	*		
	24-B	7	89.0	96.7	ns		
	24-C	7	89.0	96.7	ns		
Site 24 mean	5/7	88.6	94.0	ns			
Zone I	25-A	9	99.0	101.0	ns	70.0	*
	25-B	9	93.0	94.9	ns		
	25-C	9	95.0	96.9	ns		
Site 25 mean	9	95.7	97.6	ns			
	26-A	7	94.1	102.3	ns		
	26-B	7	93.0	101.0	ns		
	26-C	7	93.0	101.0	ns		
Site 26 mean	7	93.4	101.4	ns			
	27-A	9	96.0	98.0	ns		
	27-B	9	95.0	96.9	ns		
	27-C	9	93.0	94.9	ns		
Site 27 mean	9	94.7	96.6	ns			
Zone J	28-A	6	70.3	82.7	ns		
	28-B	6	68.0	80.0	**	76.2	*
	28-C	6	66.0	77.6	**		
Site 28 mean	6	68.1	80.1	*			
	29-A	10	81.0	88.0	ns		
	29-B	10	85.0	92.4	ns		
	29-C	10	87.0	94.6	ns		
Site 29 mean	10	84.3	91.7	*			
	30-A	10	87.0	94.6	ns		
	30-B	10	84.0	91.3	*		
	30-C	10	47.0	51.1	**		
Site 30 mean	10	72.7	79.0	ns			
Zone K	31-A	7	95.0	103.3	ns		
	31-B	7	94.0	102.2	ns		
	31-C	7	94.0	102.2	ns		
Site 31 mean	7	94.3	102.6	ns			
	32-A	10	93.0	101.1	ns		
	32-B	10	92.0	100.0	ns		
	32-C	10	86.0	93.5	ns		
Site 32 mean	10	90.3	98.2	ns			

Table 6 continued.

Regional Zone	Sampling Site/Station	Test Series	*A. abdita* mean % survival	*A. abdita* % of control	*A. abdita* Signif-icance	*Diporeia* spp. mean % survival	*Diporeia* spp. Signif-icance
	33-A	10	84.0	91.3	ns		
	33-B	10	88.0	95.7	ns		
	33-C	10	88.0	95.7	ns		
Site 33 mean	10		86.7	94.2	*		
Zone L	34-A	7	80.0	87.0	ns		
	34-B	7	3.0	3.3	**		
	34-C	7	27.0	29.3	**		
Site 34 mean	7		36.7	39.9	ns		
	35-A	6	58.3	68.6	**		
	35-B	6	73.5	86.4	ns		
	35-C	6	63.4	74.6	**		
Site 35 mean	6		65.1	76.5	**		
	36-A	5	92.3	93.2	ns		
	36-B	5	93.0	93.9	*		
	36-C	5	80.4	81.2	*		
Site 36 mean	5		88.6	89.4	ns		
Zone M	37-A	8	95.0	96.9	ns		
	37-B	8	91.0	92.9	ns		
	37-C	8	91.0	92.9	ns		
Site 37 mean	8		92.3	94.3	*		
	38-A	8	95.0	96.9	ns	85.0	ns
	38-B	8	89.0	90.8	ns		
	38-C	8	90.0	91.8	*		
Site 38 mean	8		91.3	93.2	*		
	39-A	8	68.0	69.4	**		
	39-B	8	31.0	31.6	**		
	39-C	8	80.0	81.6	*		
Site 39 mean	8		60.0	60.9	ns		

ns - Not significantly different from controls (alpha >0.05).

* - Statistically significantly different from controls (alpha < 0.05).

** - Mean response significantly different from controls and 80% or less than control response.

Usually, when all of the stations at a site were determined to be significantly toxic, the site mean also was different from the controls. When none of the stations was significantly different from controls, in

most cases the site mean also was not different. For example, the sediments from all nine stations in western Long Island Sound (sites 4, 5, and 6) were not different from controls. Correspondingly, none of these three site means was different from controls. Similarly, all nine stations and all three site means in Newark Bay/Arthur Kill were significantly different from controls. However, there were some deviations from these patterns. For example, all three stations sampled at site 13 were not significantly different from the controls, but the site mean was significantly different. The same situation occurred in sites 29, 33, 37. The variances among the five replicates tested for each station were high, but the variances among the three stations sampled at these sites were small, resulting in a significant difference from the controls. Conversely, all of the stations at sites 10, 20 and 39 were significantly toxic, but due to high variability among stations, the site means were not different from the controls.

Eight of the nine samples tested with the freshwater amphipod *Diporeia* spp. by the Great Lakes Environmental Research Laboratory (Dr. Peter Landrum) were significantly more toxic than controls (Table 6). Mean percent survival in Florissant Soil controls ranged from 88.7 to 100 (n=4, 4 or 8 replicates each). The sample from station 38-A was nontoxic in both amphipod tests. Among the eight samples toxic to *Diporeia* spp., seven also were toxic to *Ampelisca abdita*. Sample 9-B caused zero survivors in both tests. Avoidance of all but samples 38-A and 6-B was significant relative to controls. Avoidance was greatest of samples 18-B and 9-B.

Amphipod test

The results of the amphipod toxicity tests performed during Phase 2 with 57 samples are summarized in Table 7. All except 6 samples were tested by SAIC in Narragansett, R. I. Because of the suspected hazardous condition of samples 7-A, 7-B, 7-C, 8-A, 8-B, and 10, they were tested separately by Aqua Survey, Inc. in Flemington, N. J. Tests organisms used by both SAIC and Aqua Survey were obtained from the same source. In the controls and 6 test samples, water pH ranged from 7.7 to 8.6, temperature ranged from 19.0 to 21.5°C, dissolved oxygen ranged from 5.1 to 7.5 ppm, and salinity ranged from 24.0 to 28.5 ppt in the test samples and 29.5 to 32.5 ppt in the LIS controls. The 96-hr LC50 for the reference toxicant, cadmium chloride, was 0.33 mg/L as chloride. Mean survival (n=5) in the LIS control was 89±5.8% (range of 85-100%).

The amphipod survival in the control sediments ranged from 79% to 95% in the six test series. Usually, acceptable amphipod survival in controls is 85% or greater. However, the data from test series 5, in which survival was 79%, were accepted since survival in all the test samples was either very high or very low. The results would not have changed significantly if the samples had been retested.

Amphipod survival ranged from 0.0% in two samples to 100% in one sample (Table 7). In 48 (84%) of the 57 samples that were tested, mean amphipod survival was 80% of controls or less. In 46 (96%) of the 48 samples in which amphipod survival was 80% of controls or less, the results were significantly different from the controls.

Table 7. Mean percent amphipod (*A. abdita*) survival in the 1993 Newark Bay survey performed during Phase 2.

Station Number	Test Series	Mean % survival ± std. dev.	Percent of Control	Significantly less than control (alpha=0.05)	<80% of Control
LIS Control	1[a]	95.0±5.0	100	-	-
LIS Control	2[a]	95.0±5.0	100	-	-

Table 7 continued.

Station Number	Test Series	Mean % survival ± std. dev.	Percent of Control	Significantly less than control (alpha=0.05)	<80% of Control
LIS Control	3	96.0±2.2	100	-	-
LIS Control	4	97.0±4.5	100	-	-
LIS Control	5	79.0±10.8	100	-	-
LIS Control	6[b]	89.0±6.2	100	-	-
1	3	73±2.7	76.0	*	*
2	3	22±16.8	22.9	*	*
3	3	30±9.4	31.3	*	*
4	5	21±13.4	26.6	*	*
5	5	23±11.5	29.1	*	*
6	5	25±11.7	31.6	*	*
7A	6	31±8.2	34.8	*	*
7B	6	29±10.8	32.6	*	*
*7C	6	8±4.5	9.0	*	*
8A	6	17±13.0	19.1	*	*
8B	6	13±7.6	14.6	*	*
9	5	22±7.6	27.8	*	*
10	6	18±13.5	20.2	*	*
11	5	41±6.5	51.9	*	*
12	5	76±6.5	96.2	ns	-
13	5	59±15.6	74.7	*	*
14	5	61±17.8	77.2	ns	*
15	5	65±12.7	82.3	ns	-
16	5	65±15.4	82.3	ns	-
17	5	57±19.2	72.2	*	*
18	4	76±12.9	78.4	*	*
19	4	66±18.5	68.0	*	*
20	4	77±6.7	79.4	*	*
21	4	17±8.4	17.5	*	*
22	4	77±10.4	79.4	*	*
23	4	53±13.5	54.6	*	*
24	4	74±6.5	76.3	*	*
25	4	84±8.2	86.6	*	-
26	3	0±0	0	*	*
27	4	19±5.5	19.6	*	*
28	2[a]	75±10.0	83.3	*	-
29	2	57±2.9	63.0	*	*
30	2	62±18.9	68.5	*	*
31	1[a]	50±8.7	52.6	*	*
32	1	35±10.0	36.8	*	*
33	1	60±13.2	63.2	*	*
34	1	75±17.3	78.9	ns	*
35	1	62±5.8	64.9	*	*
36	1	65±5.0	68.4	*	*

Passaic R. samples (14)

Table 7 continued.

Station Number	Test Series	Mean % survival ± std. dev.	Percent of Control	Significantly less than control (alpha=0.05)	<80% of Control
37	1	55±5.0	57.9	*	*
38	1	53±20.2	56.1	*	*
39B	1	68±7.6	71.9	*	*
40B	2	78±10.4	87.0	ns	-
41	2	87±7.6	96.3	ns	-
42C	2	70±5.0	77.8	*	*
43	No sample collected				
44	2	60±5.0	66.7	*	*
45	No sample collected				
46	3	8±17.9	8.3	*	*
47	3	0±0	0	*	*
48	1	57±12.6	59.6	*	*
49	1	18±10.4	19.3	*	*
50	3	35±6.1	36.5	*	*
51	2	70±5.0	77.8	*	*
52	3	22±14.0	22.9	*	*
53	No sample collected				
54	3	31±5.5	32.3	*	*
55	3	2±4.5	2.1	*	*
56	2	75±15.0	83.3	ns	-
57	2	100±0.0	111.1	ns	-

[a] Tests of each sample in series 1 and 2 were tested with three replicates, instead of the usual five replicates tested in all of the other samples.
[b] Samples in series 6 were tested by Aqua Survey, Inc.

Amphipod survival was very low in the samples from much of the lower Passaic River and throughout Newark Bay (Figure 8). Samples that were toxic to amphipods were collected throughout the Phase 2 study area. The six samples from the lower Hackensack River were less toxic to the amphipods than those from the lower Passaic River. Two samples—one from central Newark Bay and one from the upper Arthur Kill—caused zero percent survival. In contrast, the sediment from station 57 in upper New York Harbor was not toxic in this test. Station 57 in Phase 2 and site 14 in Phase 1 were located at the same coordinates and were not toxic to amphipod survival in either phase.

Elutriate/Liquid Phase Bivalve Larvae Tests. The sediments from 109 of the 117 stations were tested with the larvae of *Mulinia lateralis*. Insufficient material from 8 stations remained following the performance of the amphipod and Microtox tests to allow performance of the bivalve embryo tests. Percent survival and percent normal morphological development were measured. Percent survival and percent normal development data (as decimal equivalents) for each station (n=5) were arcsin-square root transformed and evaluated with one-tailed, unpaired, t-tests to determine statistically significant differences from the respective controls (n=5, alpha=0.05). To determine if the mean percent survival at any sites (n=3) were significantly different from mean survival in controls, the untransformed data were evaluated with one-tailed t-tests (alpha=0.05).

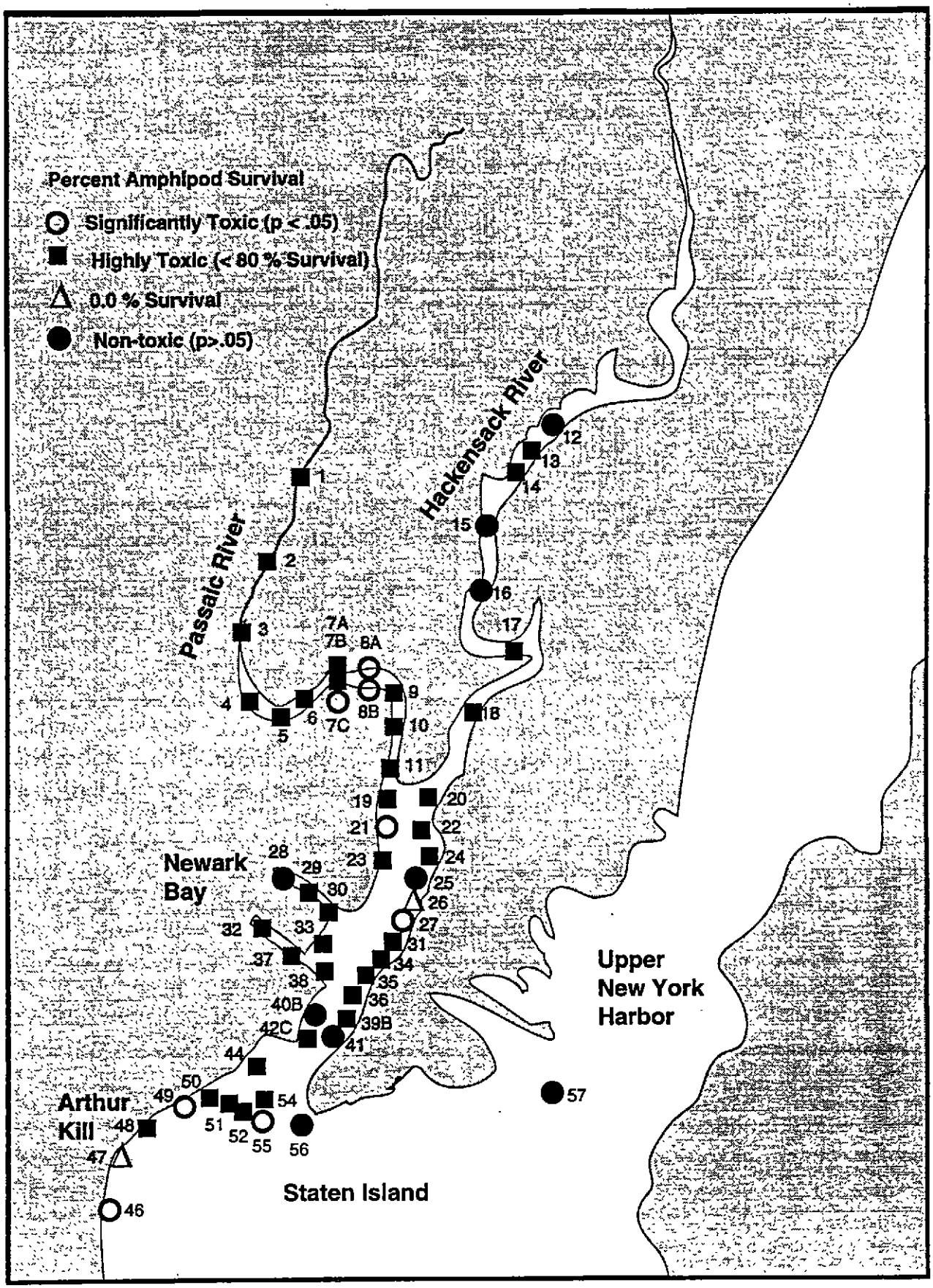

Figure 8. Distribution of stations in Newark Bay and vicinity that were toxic, highly toxic, and non-toxic in amphipod (A. *abdita*) survival tests.

Results of tests of seawater controls and Central Long Island Sound control sediments are followed by the results of the tests from each study site (Table 8). Data from test samples are listed as percent of controls for both end-points. Stations and sites that were significantly different from the respective CLIS controls (t-tests, alpha = 0.05) are indicated with asterisks and those that, additionally, were 80% or less than the control response are listed with two asterisks. Tests were performed in a series of seven batches of samples. Several unavoidable problems were encountered after the samples were collected, necessitating the storage of the samples for 93 to 175 days before the tests were initiated, well beyond the normal allowable storage time of 14 days. The long holding times may have caused some changes in the toxicity of the samples, but do not, alone, invalidate the results.

As observed in the amphipod percent survival data, survival of bivalve larvae was >80% of controls in the majority of the stations. Percent survival relative to controls ranged from 17.6% in sediments from station 39-B to >100% in many samples. Several samples caused 20-30% survival. In 29 of the sites the results from all samples that were tested indicated agreement as to toxic or nontoxic conditions within the site. In some samples (e.g., station 18-A) variability was very high among the laboratory replicates, and as a consequence, no statistically significant difference was observed from controls. Also, in a few cases variance among stations was relatively small, and despite relatively high mean percent survival, there was a significant difference from the control. Station means that were 80% of controls or less were frequently (21 of 29 samples, 72.4%) significantly different from controls.

Percent larvae survival was significantly lower than controls in sediments from 23 of 109 stations (21%) and 7 of 39 sites (18%) (Table 8). Percent survival was significantly lower than controls, and in addition, less than 80% of controls in 21 stations and 4 sites. Based upon this test, toxicity was highest in sediments from site 6 (western Long Island Sound), site 7 (upper East River), site 11 (lower East River), site 17 (mouth of Newark Bay), site 20 (lower Raritan River), site 30 (Sandy Hook Bay), and site 37 (mouth of the estuary). At least one of the stations and the site mean were significantly different from controls at these sites. Toxicity generally was lowest in sediments from the lower Hudson River, western Long Island Sound, lower New York Harbor, and much of Raritan Bay.

Percent normal embryo development ranged from 0.0% in samples from Site 30 to >100% in numerous samples (Table 8). Between 90% to 100% normal development occurred in 47 of the samples. Percent normal development was significantly lower than controls in sediments from 21 of 109 stations (19%) and 6 of 39 sites (15%). Also, percent normal development was significantly lower than controls, and additionally, less than 80% of controls in 19 of the samples and 4 of the sites. Based upon this test end-point, toxicity was highest in sediments from sites 5 and 6 (western Long Island Sound), site 7 (upper East River), and 30 (Sandy Hook Bay). At least one of the stations and the site mean were significantly different from controls at these sites. Toxicity generally was lowest in sediments from the lower Hudson River, upper and lower New York Harbor, and much of Raritan Bay.

Both end-points of this test indicated that sediments from sites 6, 7 and 30 were significantly toxic (Table 8). Based upon the t-tests, the data from the two tests indicated 95 of the same stations were either nontoxic or toxic. Also, based upon the results of the t-tests, the two end-points indicated agreement on the presence and absence of toxicity in 30 of 39 sites. At 32 of the 39 sites both survival and normal development were either greater than 80% or both were less than 80% of controls. Sediments from some stations (e.g., 7-A, 7-B, 34-B, 39-B) were highly toxic to both end-points.

Table 8. Mean percent survival and normal morphological development (expressed as percent of controls) in 48-hour tests of elutriates with the larvae of *Mulinia lateralis*.

Regional Zone	Sampling Site/station	Test Series	Percent Survival[a]	Percent Normal
SEAWATER CONTROL		1	98.6	81.0
		2	74.1	99.3
		3	100.9	99.2
		4	97.7	99.6
		5	95.0	92.6
		6	88.0	100.0
		7	89.0	98.2
CLIS CONTROL		1	81.1	95.7
		2	91.2	99.1
		3	73.4	98.3
		4	94.1	100.0
		5	87.0	99.7
		6	84.0	100.0
		7	91.5	99.2
Zone A	1-A	3	105.7	101.7
	1-B	3	121.1	101.7
	1-C	3	117.3	101.7
Site 1 mean			114.1	101.7
	2-A	3	100.0	101.7
	2-B	3	135.6	101.7
	2-C	3	nd	nd
Site 2 mean			117.8	101.7
	3-A	2	94.8	99.5
	3-B	2	99.5	100.9
	3-C	2	103.4	99.9
Site 3 mean			99.2	100.1
Zone B	4-A	4	89.5	95.6
	4-B	4	71.1	92.2
	4-C	4	88.8	94.7
Site 4 mean			83.1	94.2*
	5-A	4	82.3	23.2**
	5-B	4	93.7	37.3**
	5-C	4	55.9**	12.0**
Site 5 mean			77.3	24.2**
	6-A	4	75.7**	85.0*
	6-B	4	56.6**	46.5**
	6-C	4	59.2**	37.6**
Site 6 mean	4		63.8**	56.4**

Table 8 continued.

Regional Zone	Sampling Site/station	Test Series	Percent Survival[a]	Percent Normal
Zone C	7-A	4	40.2**	10.5**
	7-B	4	22.4**	2.8**
	7-C	4	51.8**	10.9**
	8-A	4	81.0*	92.4
	8-B	4	99.4	44.5**
	8-C	4	60.6**	93.2
Site 8 mean			80.3	76.7
	9-A	5	99.1	100.3
	9-B	5	82.4	87.4
	9-C	5	92.0	100.3
Site 9 mean			91.2	96.0
Zone D	10-A	5	24.6**	13.3**
	10-B	5	53.5**	12.7**
	10-C	5	83.4	93.0
Site 10 mean			53.8	39.7
	11-A	2	88.0	100.3
	11-B	2	76.1**	97.9
	11-C	2	88.0	94.3*
Site 11 mean			84.0*	97.5
	12-A	1	118.9101.8	
	12-B	1	97.8	97.8
	12-C	1	73.5	34.8**
Site 12 mean			96.7	78.1
Zone E	13-A	3	110.5	100.7
	13-B		nd	nd
	13-C	3	71.1	101.7
Site 13 mean			90.8	101.2
	14-A	3	127.8	101.0
	14-B	3	132.7	100.9
	14-C	3	95.1	100.1
Site 14 mean			118.5	100.7
	15-A	5	89.8	98.1
	15-B	5	88.6	95.8
	15-C	5	88.5	100.3
Site 15 mean			89.0*	98.1

Table 8 continued.

Regional Zone	Sampling Site/station	Test Series	Percent Survival[a]	Percent Normal
Zone F	16-A	3	139.4	101.7
	16-B	3	122.1	101.0
	16-C	3	143.2	100.3
Site 16 mean			134.9	101.0
	17-A	2	75.5	99.1
	17-B	2	74.5**	100.9
	17-C	2	53.4**	95.6
Site 17 mean			67.8**	98.5
	18-A	2	65.9	99.6
	18-B	2	112.0	99.0
	18-C	2	97.7	99.1
Site 18 mean			91.9	99.2*
Zone G	19-A	6	96.0	98.5
	19-B	6	109.7	99.8
	19-C	6	96.0	99.3
Site 19 mean			100.6	99.2
	20-A	7	96.9	100.1
	20-B	7	94.5	100.8
	20-C	7	91.5*	100.0
Site 20 mean			94.3*	100.3
	21-A	6	102.1	100.0
	21-B	6	119.8100.0	
	21-C	6	108.4	100.0
Site 21 mean			110.1100.0	
Zone H	22-A	5	95.6	99.5
	22-B	5	92.0	nd
	22-C	5	68.4	63.2
Site 22 mean			85.3	87.7
	23-A	5	97.7	98.2
	23-B	5	87.0	90.0
	23-C	5	87.5	99.8
Site 23 mean			90.7	96.0
	24-A	5	82.4	83.6
	24-B		nd	nd
	24-C	5	111.1	99.1
Site 24 mean			96.7	91.3

Table 8 continued.

Regional Zone	Sampling Site/station	Test Series	Percent Survival[a]	Percent Normal
Zone I	25-A	7	112.9100.8	
	25-B	7	102.3	100.8
	25-C	7	119.3100.8	
Site 25 mean			111.5100.8	
	26-A	7	71.3**	17.6**
	26-B	7	113.1	100.8
	26-C	7	104.6	100.8
Site 26 mean			96.3	73.1
	27-A	7	77.5	100.8
	27-B	7	95.3	99.9
	27-C	7	90.7	99.0
Site 27 mean			87.8	99.9
Zone J	28-A	6	97.9	100.0
	28-B		nd	nd
	28-C		nd	nd
Site 28 mean			97.9	100.0
	29-A	6	110.4	93.7
	29-B	6	91.2	55.2**
	29-C	6	109.5	100.3
Site 29 mean			103.7	82.8
	30-A	6	70.1**	0.0**
	30-B	6	73.5**	0.0**
	30-C		nd	nd
Site 30 mean			71.8**	0.0**
Zone K	31-A	7	98.5	100.8
	31-B	7	116.3	100.8
	31-C	7	94.5	100.8
Site 31 mean			103.1	100.8
	32-A	6	102.1	100.0
	32-B	6	105.7	97.8
	32-C	6	118.4	98.3
Site 32 mean			108.7	98.7
	33-A	6	118.4	100.0
	33-B	6	115.7	99.3
	33-C	6	105.5	100.0
Site 33 mean			113.3	99.8
Zone L	34-A		nd	nd
	34-B	5	50.2*	20.9
	34-C		89.5	98.2
Site 34 mean			69.9	59.5

Table 8 continued.

Regional Zone	Sampling Site/station	Test Series	Percent Survival[a]	Percent Normal
	35-A	6	115.0	99.5
	35-B			nd
	35-C	6	119.9	100.0
Site 35 mean		117.4	99.8	
	36-A	5	78.4	72.4
	36-B	5	97.7	99.6
	36-C	5	79.4	85.6
Site 36 mean		85.2	85.9	
Zone M	37-A	7	73.4**	100.8
	37-B	7	92.7	100.6
	37-C	7	81.9	72.0
Site 37 mean		82.7*	91.1	
	38-A	7	96.9	100.5
	38-B	7	97.7	100.0
	38-C	7	80.7	99.7
Site 38 mean		91.8	100.1	
	39-A	7	60.7**	6.7**
	39-B	7	17.6**	11.5**
	39-C	7	95.3	100.5
Site 39 mean		57.9	39.6	

[a] Percent survival relative to seawater controls.
* Significantly different from controls (t-test, alpha = 0.05).
** Significantly different from controls and 80% or less than the control response.

The spatial patterns in toxicity for the two end-points of this test are illustrated in Figures 9 through 12. As with the pattern seen in the *Ampelisca abdita* survival test, the bivalve larvae survival test indicated relatively high toxicity in the upper East River stations, diminishing eastward into western Long Island Sound (Figure 9). Also, samples from Kill van Kull (site 17), inner Sandy Hook Bay (site 30), and two offshore sites (37 and 39) were toxic in this test. Based upon the site means, toxicity in this test was high in sites 6, 7, 17, and 30 (Figure 10).

The percent normal development end-point also indicated high toxicity in sediments from sites 5-8 in the upper East River and western Long Island Sound (Figure 11). However, toxicity to this test did not diminish nearly as much into western Long Island Sound as in the amphipod and bivalve survival tests. Sediments from sites 4 and 5 were more toxic to bivalve normal development than to amphipod or bivalve embryo survival. The very high toxicity indicated by the amphipod survival test in the Newark Bay/Arthur Kill area (sites 16-18) was not as apparent in the bivalve larvae development tests. Sediments from site 16 at the head of Newark Bay were very toxic to amphipods, but not to bivalve larvae. Site 17 sediments were toxic in the survival test, but not in the development test.

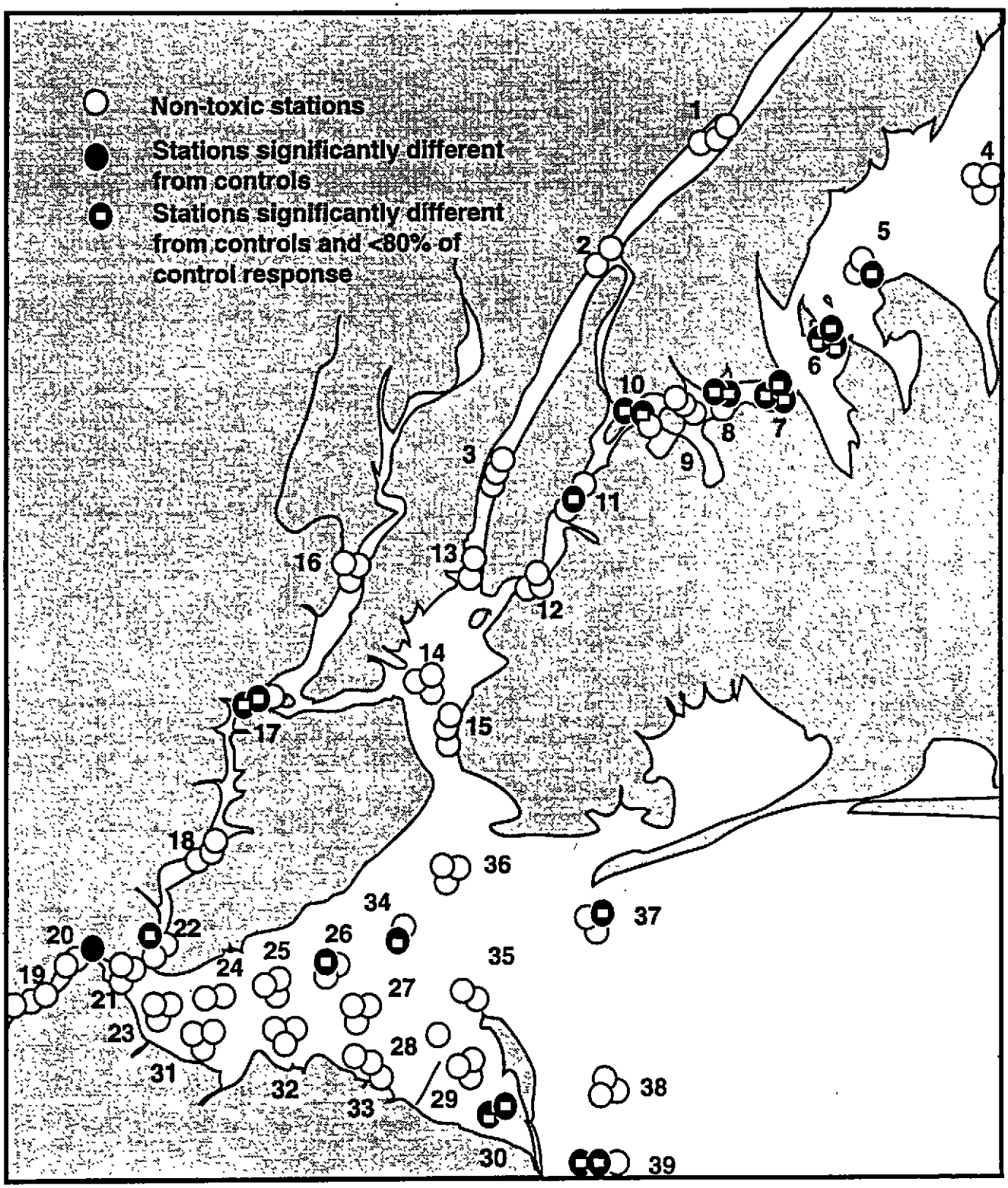

Figure 9. Sampling stations in which the sediment elutriates were significantly toxic to *Mulinia lateralis* larvae survival (n=5, alpha <0.05).

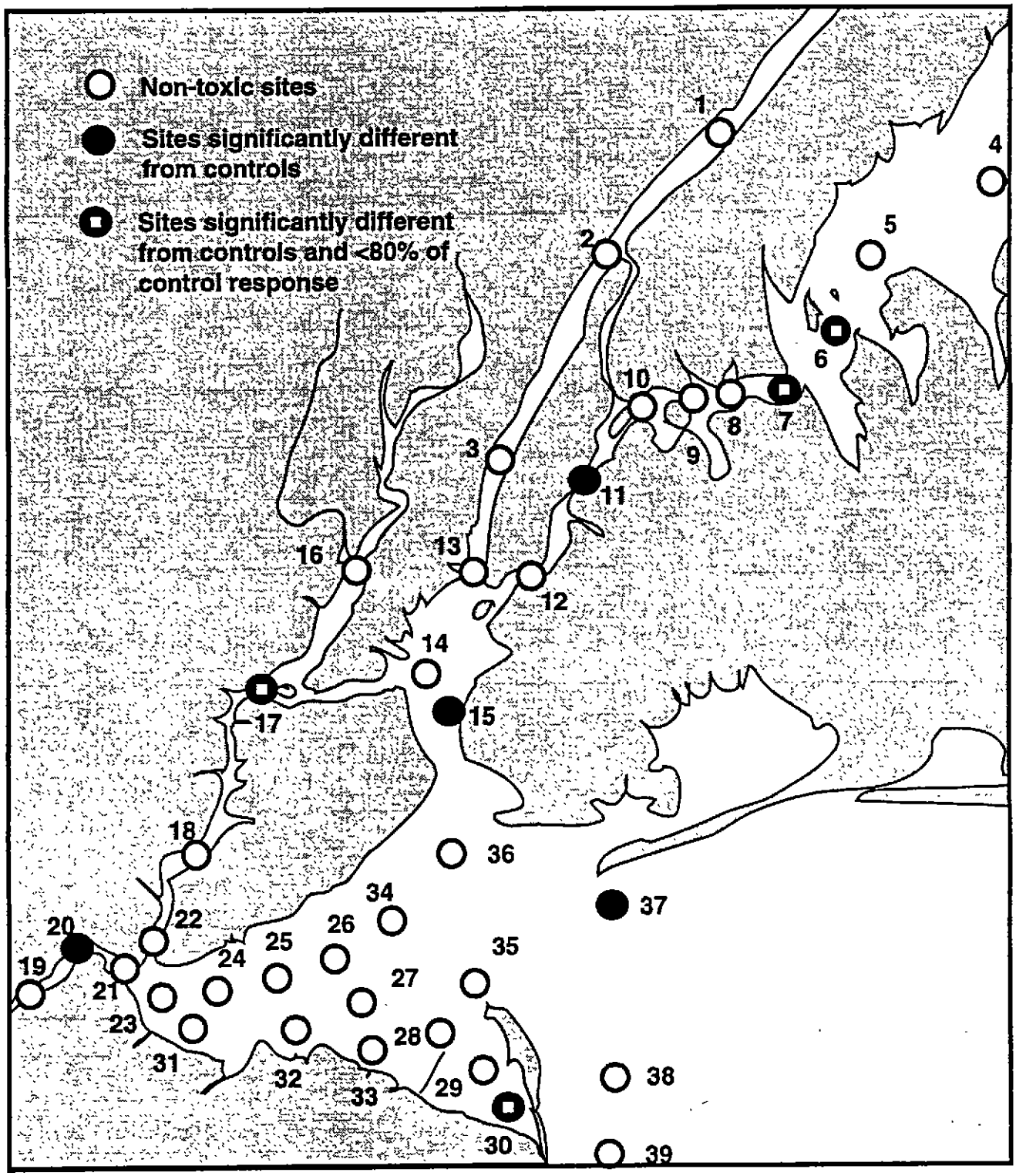

Figure 10. Sampling sites in which the sediment elutriates were significantly toxic to *Mulinia lateralis* larvae survival (average of three stations, alpha <0.05).

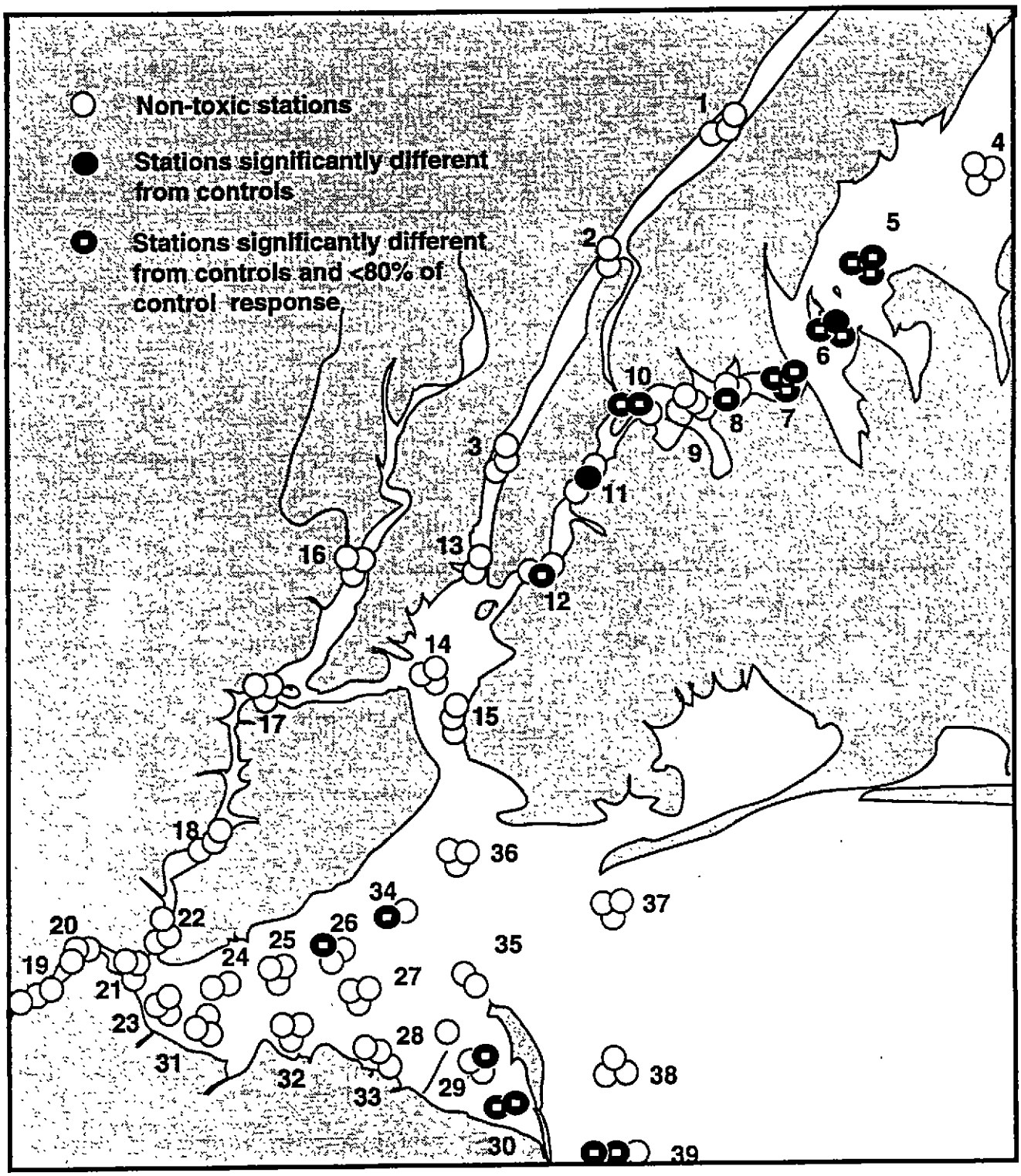

Figure 11. Sampling stations in which the sediment elutriates were significantly toxic to *Mulinia lateralis* larvae normal development (n=5, alpha <0.05).

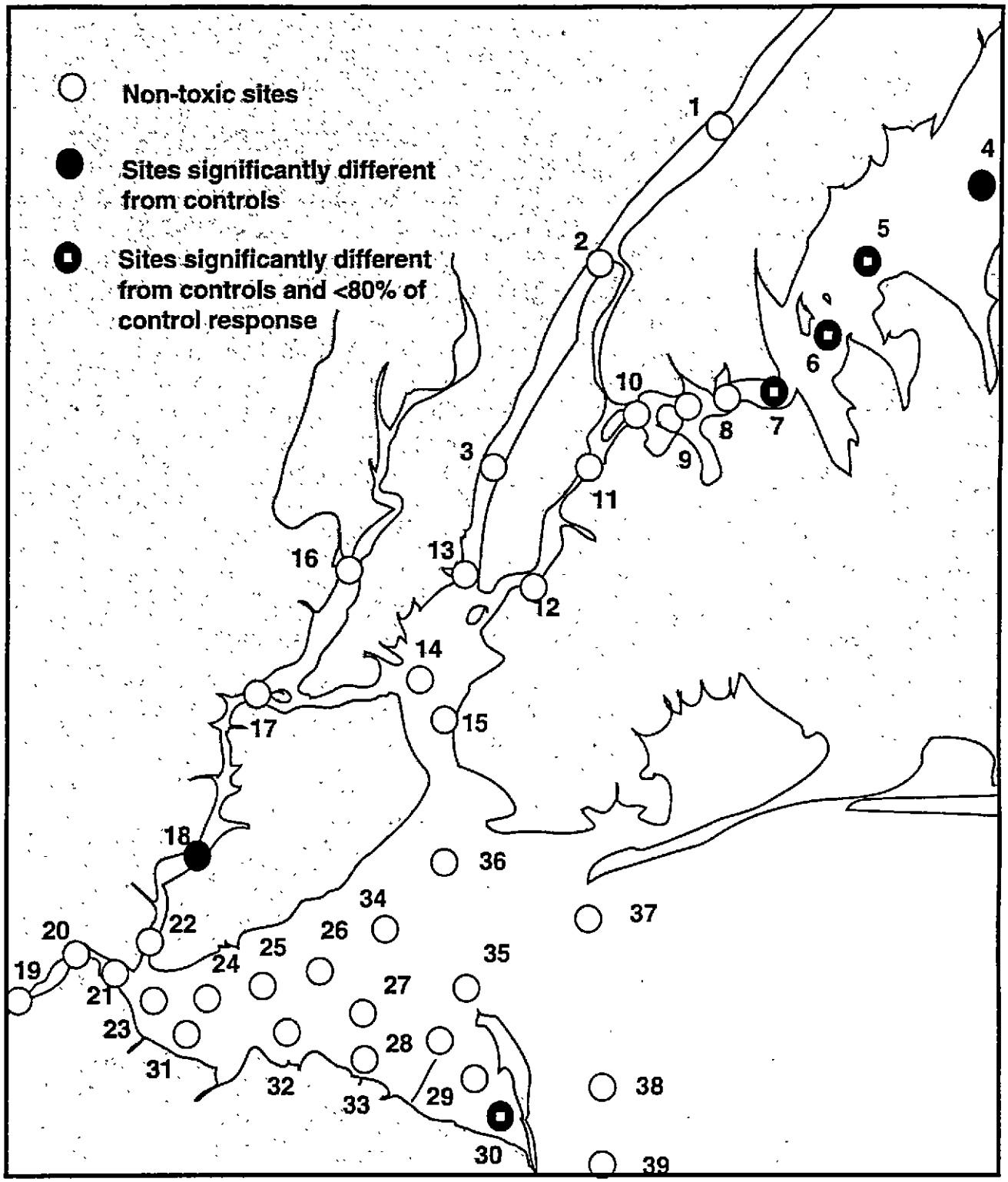

Figure 12. Sampling sites in which the sediment elutriates were significantly toxic to *Mulinia lateralis* larvae normal development (average of three stations, alpha <0.05).

Toxicity to bivalve development was not nearly as high in lower Raritan River sediments (site 20) as in the amphipod test. All three of the stations at site 39 were significantly toxic to amphipods and two of the three were toxic to both end-points of the bivalve larvae test, but the site mean was not significantly different from controls in any of the three test end-points. Two of the three samples from site 30 in Sandy Hook Bay were toxic to all three test end-points and toxicity diminished northeastward out into lower New York Harbor.

Microbial Bioluminescence Tests of Organic-Extracts. An initial range-finding experiment was conducted with sediments previously tested with the amphipods. Each of the sediments that indicated high, intermediate, and low toxicity to the amphipods were tested with three sediment concentrations (3, 10, and 15 g wet weight of sediment) to provide a dilution series. This experiment showed that extracts from 3 g of sediments were sufficient to cause a 50% reduction in light output by the Microtox^{tm} bacteria. In addition, separation and precipitation of extract phases occurred in the vials during the extraction procedures with the 10 and 15 g extracts from both the intermediate and high toxicity samples. These results indicated that the 10 and 15 g concentrations were too high and would lead to spurious light attenuation. A total of 116 of the 117 sediment samples was tested with Microtox^{tm}. The sediment concentrations (EC50s) that caused 50% light inhibition were determined, along with the 95% confidence limits, for the Central Long Island Control and each test sediment. Duplicate tests were run for each sample. Mean EC50 values (mg sediment/mL) and the 95% confidence intervals are listed in Table 9. Samples that were significantly different from controls are listed with one asterisk. Those samples in which the mean EC50 was 80% or less of the control are listed with two asterisks.

The mean EC50s of the two tests of the controls were 2.02 and 2.1 mg/mL (Table 9). Of the 116 samples that were tested, 47 (41%) were significantly toxic (i.e., different from controls) in this test. Many of the samples (32) caused EC50 values of 1.6 mg/mL or less (80% of controls). However, in some cases the test samples were less toxic than the CLIS controls (as indicated by EC50 values greater than 2.1). This test indicated that 19 of the 39 sites (49%) were significantly different from controls. The mean EC50s for 14 sites were significantly different from controls and 80% of the control response or less.

All three of the sites in zones C and D were significantly different from controls, whereas none of the sites in zones A, G, and M were toxic in this test. Stations 6-C, 9-B, 28-A, and 36-B were the most toxic, as indicated by the lowest mean EC50s. All but one of the nine stations in zone B (western Long Island Sound), and zone D (lower East River) were different from controls in this test. None of the stations in zone A (lower Hudson River) and zone M (New York Bight) were toxic, and only one each in zone E (Upper New York Harbor) and zone L (Lower New York Harbor) was different from controls.

Table 9. Results of Microtox^{tm} tests of microbial bioluminescence in organic extracts of sediments; mean EC50's (n=2) and 95% confidence intervals for stations, and mean EC50's (n=3) for sites.

Regional Zone	Sampling Site/station	Mean EC50 (mg/mL)	95% Confidence Interval
CLIS Control	1	2.02	2.00-2.03
	2	2.11	2.01-2.16
	Mean	2.06	n/a

Table 9 continued.

Regional Zone	Sampling Site/station	Mean EC50 (mg/mL)	95% Confidence Interval
Zone A	1A	16.33	15.81-16.84
	1B	11.80	10.49-13.11
	1C	14.13	13.88-14.45
	Site 1 mean	14.09	ns
	2A	15.34	14.90-15.80
	2B	2.12	2.07-2.15
	2C	15.58	15.40-15.78
	Site 2 mean	11.01	ns
	3A	2.16	2.14-2.20
	3B	2.02	1.98-2.05
	3C	1.90	1.84-1.94
	Site 3 mean	2.03	ns
Zone B	4A	1.72*	1.68-1.76
	4B	1.58**	1.57-1.59
	4C	1.46**	1.41-1.51
	Site 4 mean	1.59**	
	5A	1.38**	1.38-1.38
	5B	1.69*	1.65-1.72
	5C	1.65*	1.61-1.67
	Site 5 mean	1.57**	
	6A	2.14	2.11-2.19
	6B	1.41**	1.34-1.47
	6C	0.30**	0.29-0.45
	Site 6 mean	1.28	ns
Zone C	7A	1.86	1.86-1.86
	7B	1.54	1.51-1.58
	7C	1.35	1.30-1.39
	Site 7 mean	1.58**	
	8A	1.80	1.77-1.84
	8B	1.27**	1.26-1.30
	8C	1.64**	1.62-1.67
	Site 8 mean	1.57**	
	9A	1.54**	1.49-1.59
	9B	0.72**	0.69-0.74
	9C	1.34	1.29-1.39
	Site 9 mean	1.20**	
Zone D	10A	1.38**	1.37-1.38
	10B	1.64**	1.59-1.70
	10C	1.66*	1.66-1.67
	Site 10 mean	1.56**	
	11A	1.84	1.83-1.84
	11B	1.53**	1.45-1.59
	11C	1.73*	1.71-1.74
	Site 11 mean	1.70*	

Table 9 continued.

Regional Zone	Sampling Site/station	Mean EC50 (mg/mL)	95% Confidence Interval
	12A	1.51**	1.35-1.62
	12B	1.48**	1.45-1.50
	12C	1.48**	1.44-1.49
	Site 12 mean	1.49**	
Zone E	13A	1.68	1.58-1.75
	13B	2.28	2.25-2.33
	13C	1.86	1.60-2.07
	Site 13 mean	1.94	ns
	14A	22.23	20.93-23.59
	14B	11.27	11.19-11.36
	14C	7.23	6.90-7.55
	Site 14 mean	13.58	ns
	15A	1.57	1.48-1.65
	15B	1.87	1.86-1.89
	15C	1.69*	1.69-1.69
	Site 15 mean	1.71*	
Zone F	16A	2.05	2.03-2.07
	16B	1.75*	1.73-1.76
	16C	1.59**	1.58-1.61
	Site 16 mean	1.80	ns
	17A	1.35	1.25-1.45
	17B	1.33	1.31-1.34
	17C	1.49	1.44-1.51
	Site 17 mean	1.39**	
	18A	1.76	1.69-1.80
	18B	1.46**	1.45-1.48
	18C	1.81	1.61-1.89
	Site 18 mean	1.68*	
Zone G	19A	2.38	2.37-2.38
	19B	1.82*	1.80-1.83
	19C	1.79*	1.79-1.79
	Site 19 mean	2.00	ns
	20A	2.39	2.31-2.44
	20B	1.85	1.78-1.89
	20C	1.73	1.71-1.75
	Site 20 mean	1.99	ns
	21A	1.72*	1.70-1.74
	21B	1.65	1.64-1.66
	21C	2.32	2.23-2.42
	Site 21 mean	1.90	ns

Table 9 continued.

Regional Zone	Sampling Site/station	Mean EC50 (mg/mL)	95% Confidence Interval
Zone H	22A	1.59**	1.57-1.62
	22B	1.83	1.79-1.86
	22C	1.73	1.65-1.76
	Site 22 mean	1.72*	
	23A	1.43**	1.41-1.47
	23B	1.41**	1.36-1.45
	23C	1.58	1.28-1.78
	Site 23 mean	1.47**	
	24A	1.56**	1.52-1.59
	24B	2.07	2.04-2.10
	24C	2.13	2.05-2.22
	Site 24 mean	1.92	ns
Zone I	25A	1.98	1.92-2.02
	25B	1.80	1.77-1.83
	25C	2.01*	1.94-2.08
	Site 25 mean	1.93	ns
	26A	1.96*	1.90-2.02
	26B	1.82*	1.78-1.87
	26C	1.56**	1.54-1.58
	Site 26 mean	1.78	ns
	27A	1.49**	1.46-1.51
	27B	1.57**	1.54-1.59
	27C	1.50**	1.50-1.50
	Site 27 mean	1.52**	
Zone J	28A	0.28**	0.27-0.28
	28B	1.27**	1.25-1.29
	28C	1.33**	1.32-1.34
	Site 28 mean	0.96**	
	29A	2.14	2.07-2.22
	29B	2.22	2.13-2.32
	29C	2.32	2.29-2.34
	Site 29 mean	2.23	ns
	30A	1.45**	1.36-1.51
	30B	1.54**	1.45-1.58
	30C	1.68*	1.64-1.71
	Site 30 mean	1.56**	
Zone K	31A	1.47**	1.41-1.53
	31B	1.47	1.40-1.52
	31C	1.77	1.74-1.80
	Site 31 mean	1.57**	
	32A	2.00	1.95-2.03
	32B	1.75*	1.73-1.78
	32C	1.86	1.84-1.87

Table 9 continued.

Regional Zone	Sampling Site/station	Mean EC50 (mg/mL)	95% Confidence Interval
	Site 32 mean	1.87	ns
	33A	2.00	1.95-2.05
	33B	1.45**	1.42-1.48
	33C	2.44	2.38-2.52
	Site 33 mean	1.96	ns
Zone L	34A	1.56	1.29-1.77
	34B	2.10	1.96-2.22
	34C	2.61	2.60-2.61
	Site 34 mean	2.09	ns
	35A	1.79	1.76-1.82
	35B	no data	
	35C	1.78	1.76-1.80
	Site 35 mean	1.79*	
	36A	1.57	1.54-1.60
	36B	1.03**	0.95-1.12
	36C	1.50	1.44-1.58
	Site 36 mean	1.37**	
Zone M	37A	>29.80	n/a
	37B	>32.60	n/a
	37C	>29.60	n/a
	Site 37 mean	>30.77	ns
	38A	20.12	19.99-20.19
	38B	21.55	21.10-22.12
	38C	22.00	21.85-22.17
	Site 38 mean	21.22	ns
	39A	2.45	2.41-2.48
	39B	2.61	2.59-2.64
	39C	17.89	17.49-18.29
	Site 39 mean	7.65	ns

* Station or site mean significantly different from controls (alpha=0.05).
** Mean response significantly different from controls and 80% or less than control response.
ns Mean response not significantly different from controls.

The data from this test indicated several spatial patterns in toxicity among the stations and sites (Figures 13 and 14). Many of the stations and sites in the lower East River, upper East River, and western Long Island Sound were toxic, whereas none were toxic in the adjacent lower Hudson River and only one was toxic in the upper New York Harbor. Second, many of the stations and sites in Arthur Kill, western Raritan Bay, central Raritan Bay, and Sandy Hook Bay were toxic, whereas only one of the stations in adjacent lower New York Harbor and outer bay/New York Bight was toxic. Also, none of the three sites in lower Raritan River was toxic. There was considerable heterogeneity in toxicity within Raritan Bay, but not in the outer bay/New York Bight, where all samples and sites were non-toxic.

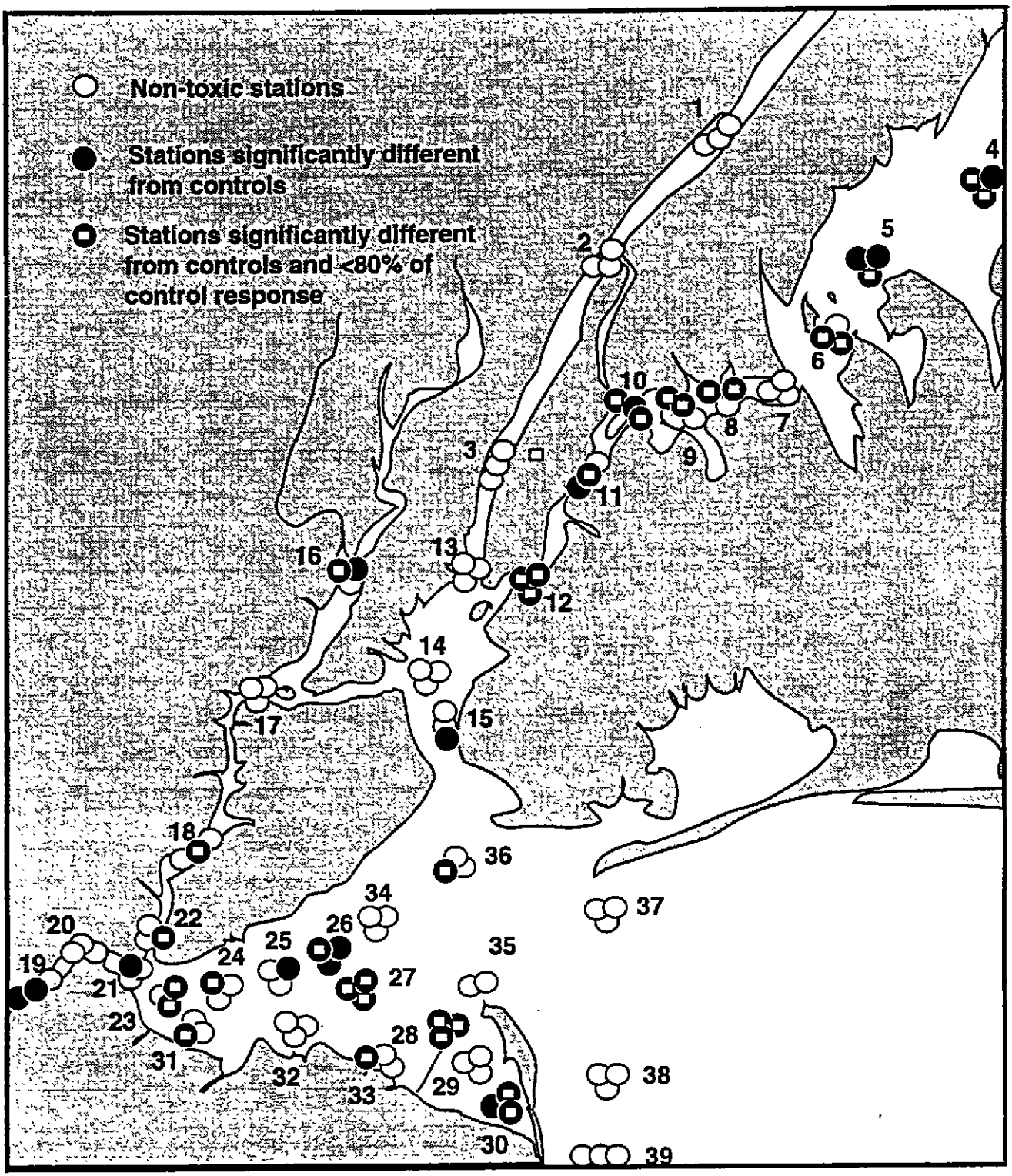

Figure 13. Sampling stations in which the sediment extracts were significantly toxic to microbial bioluminescence (n=5, alpha <0.05).

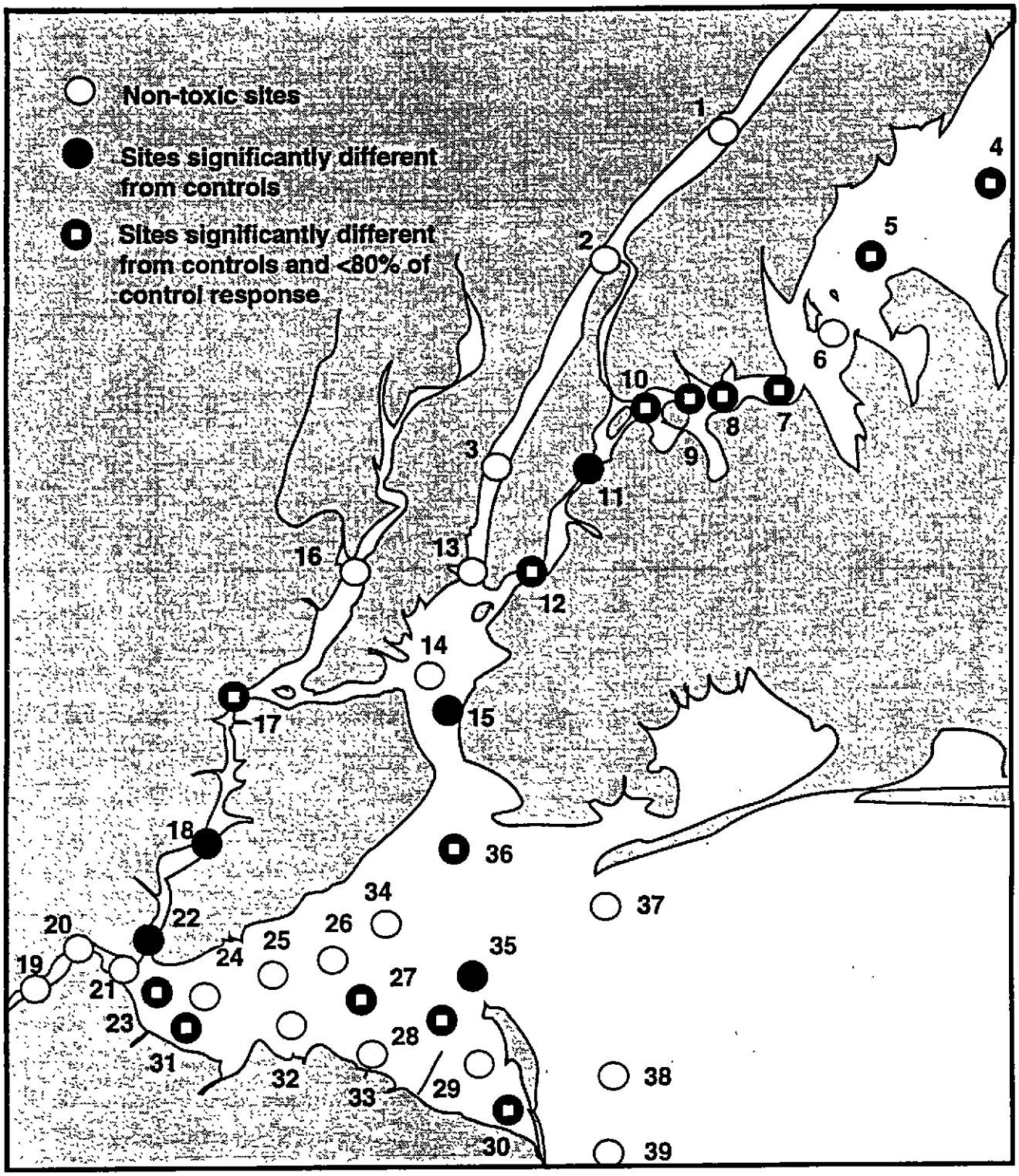

Figure 14. Sampling sites in which the sediment extracts were significantly toxic to microbial bioluminescence (average of three stations, alpha <0.05).

In December 1989, the National Marine Fisheries Service (NMFS) collected sediments from 19 locations in the estuary and tested them for toxicity with the Microtox™ bioluminescence test (DeMuth et al, 1993). Tests were performed with three types of extracts: (1) saline solution extracts; (2) sequential saline and organic extracts; and (3) organic extracts. Duplicate tests were performed with most samples. The effective concentrations (EC50s) that caused 50% reductions in light output were determined for each of the three tests.

As judged by the lowest EC50 values, the Microtox™ tests indicated that the sediments from Newtown Creek (a tributary of the lower East River); Throg's Neck (upper East River); and Shooters Island (Arthur Kill) were among the most toxic (Table 10). Samples from Rockaway Bay, Fall Hook Channel, Ambrose Channel, and Jamaica Bay were the least toxic in the Microtox™ tests.

Table 10. Results of microbial bioluminescence (Microtox™) tests of sediments from the Hudson-Rartian estuary performed with three kinds of sediment extracts (from DeMuth et al., 1993).

Samping Sites	Saline EC50[a]	Sequential organic EC50[b]	Organic EC50[c]
1. Throg's Neck	1.7±0.1	3400±500	1170±24
2. Mt. St. Vincent	ns	14600	1750±270
3. Union City	ns	12600±1400	4370±910
4. The Battery	1.0, ns	10600±200	3300±1700
5. Newtown Creek	0.7±0.3	500±200	1200±300
6. The Narrows	1.7, ns	11200	4200±900
7. Newark Bay	ns	7600±1700	3550
8. Shooters Island	0.8, ns	9200±600	1280±100
9. Deep Point	ns	8600±6500	6300±1300
10. Ward Point	ns	8900±5700	2260±120
11. East Reach	ns	18700±1720	4420±1160
12. Chapel Hill Channel	1.5, ns	4200±4100	1600±300
13. Sandy Hook Bay	ns	1700±300	1820
14. Rockaway Bay	3.6, ns	46800±2800	49600±5500
15. Fall Hook Channel	8.7±4.5	25300±14000	7880±3820
16. Ambrose Channel	1.7, ns	29100±19400	8630±1140
17. Jamaica Bay	5.1±4.3	10900±3200	4100±2840

[a]Results of tests performed with saline extracts, reported as the amount of sediment equivalents (g) that decreased light output by 50%.
[b]Results of tests performed with organic extracts previously extracted with saline solution, reported as amount of sediment equivalents (ug) that decreased light output by 50%.
[c]Results of tests performed with organic extracts, reported as the amount of sediment equivalents (*u*g) that decreased light output by 50%.

Polychaete and Sand Dollar Growth Tests. In 1991, the NMFS (Rice et al., in press) tested 17 of the 117 samples collected in Phase 1 of the present survey (Table 11). In these samples, impaired growth was measured among polychaetes (*Armandia brevis*) and adult sand dollars (*Dendraster excentricus*). Both species were collected from Puget Sound for the tests. Significant reductions in growth were quantified by comparisons of the data with animals exposed to unspecified controls. The sediments

from Throg's Neck (site 7) were significantly toxic to polychaete growth, causing 0.0% growth relative to the controls (the lowest rate of growth observed). Also, sediments from site 28 in East Reach (western Raritan Bay) and site 29 in Sandy Hook Bay were significantly toxic and caused very low rates of growth. The polychaete test appeared to be more sensitive than the sand dollar test, indicating 13 of 17 samples were significantly different from controls, as compared to 8 of 17 in the sand dollar test. Sediment from only two of the sites were not significantly toxic in both tests: those from site 36 in lower New York Harbor and site 37 in the entrance to the estuary. Sediments from five of the sites were toxic to both species. The observations of toxicity in site 11 (East River), site 17 (near Shooters Island), site 16 (Newark Bay), site 20 (lower Raritan River), and site 29 (Sandy Hook Bay) were consistent with those of previous investigators. Also, they were consistent with the results of the Microtox™, bivalve larvae, and amphipod tests.

Table 11. Results of polychaete (Armandia brevis) impaired growth tests, and sand dollar (Dendraster excentricus) impaired growth tests of sediments from the Hudson-Rartian estuary (from Rice et al., in press).

Samping Sites	Polychaete Growth (percent)	Sand dollar Growth (percent)
1. Lower Hudson River	50.3*	88.7*
3. Lower Hudson River	74.6*	ns
6. Western Long Island Sound	51.4*	ns
7. Upper East River	0.0*	ns
11. Lower East River	ns	71.1*
13. Upper New York Harbor	ns	78.0*
14. Upper New York Harbor	ns	82.0*
16. Newark Bay	39.4*	71.9*
17. Arthur Kill	59.2*	36.9*
20. Lower Raritan Bay	55.2*	71.8*
22. Western Raritan Bay	81.2*	ns
25. Central Raritan Bay	69.4*	ns
28. Sandy Hook Bay	15.0*	85.7*
29. Sandy Hook Bay	10.5*	ns
36. Lower New York Harbor	ns	ns
37. Outer Bay	ns	ns
38. Outer Bay	52.1*	ns

*Significantly reduced growth compared to controls (percent growth observed relative to normal controls).

Estimates of Spatial Extent of Toxicity. The spatial extent of toxicity was estimated separately with the data from both Phases 1 and 2 (Tables 12, 13 and 14). The size of the entire survey area sampled during Phase 1 was estimated at 350 km^2. During Phase 2, the survey area covered approximately 12.7 km^2, some of which overlapped with the area sampled during Phase 1. The area in which toxicity test results were less than 80% of the control responses was determined.

Based upon separate analyses of the data from the four test end-points in Phase 1, 89.4 to 136.1 km^2 were estimated to be toxic (i.e., toxicity test results were less than 80% of the control responses). These areas represented approximately 25% to 39% of the total study area. Based upon a critical value of less than 20% of controls (the reciprocal of 80%), the area estimated to be highly toxic ranged from 0 to 16 km^2, representing from 0% to 4.6% of the survey area.

Table 12. Estimates of the spatial extent of toxicity* (km^2 and percent of total area) in the Hudson-Raritan Estuary based upon the cumulative distribution functions of data from each of four test end-points.

	Toxic Area (<80% of controls)	Highly Toxic Area (<20% of controls)
Amphipod survival	133.3 km^2 (38.1%)	12.0 km^2 (3.4%)
Bivalve larvae survival	87.4 km^2 (25.0%)	0
Bivalve larvae development	103.8 km^2 (30.0%)	16.1 km^2 (4.6%)
Microtox bioluminescence	136.1 km^2 (38.9%)	0

* Based upon critical values of <80% and <20% of control responses.
Total survey area: 350 km^2

Based upon the amphipod survival test performed in Phase 1, approximately 133 km^2 of the Hudson-Raritan Estuary were toxic (Table 12). Since toxicity was most widespread in the amphipod tests, the results of the other three end-points were compared to it to determine concordance in the estimates of the spatial extent of toxicity. Toxicity was second most widespread in the microbial bioluminescence test. Based upon both the amphipod and microbial bioluminescence tests (Table 13), approximately 34 km^2 were toxic (9.8% of the total). Based upon these data and, using the critical value of less than 80% of control responses, site 7 (located near Throg's Neck), site 10 (located in the upper East River), and site 30 (located in Sandy Hook Bay) were significantly toxic in all four test end-points, representing about 20 km^2 (5.7% of the total area).

Table 13. Estimates of concordance in the spatial extent of toxicity* (km^2 and percent of total area) in the Hudson-Raritan estuary among the four toxicity test end-points.

	Toxic Area	
	Kilometer^2	Percent
Amphipod survival	133.3	38.1%
Amphipod survival and microbial bioluminescence	34.2	9.8

Table 13 continued.

	Toxic Area	
	Kilometer^2	Percent
Amphipod survival, microbial bioluminescence, and bivalve development	23.6	6.7
Amphipod survival, microbial bioluminescence, bivalve development and survival	19.9	5.7

* Based upon a critical value of <80% of control responses.

The spatial extent of toxicity in Phase 2 of the survey was calculated separately since the survey design was different from that used in Phase 1 (Table 14). The study area in Phase 2 covered approximately 12.7 km^2. Within that area, about 10.8 km^2 were significantly toxic (<80% of controls) and about 1.2 km^2 were highly toxic (<20% of controls) in the amphipod survival tests. These areas represented approximately 85% and 9.7% of the total, respectively.

Table 14. Estimates of the spatial extent of toxicity* (km^2 and percent of total area) in Newark Bay and vicinity, based upon the cumulative distribution function of data from amphipod survival tests.

	Significantly Toxic (<80% of controls)	Highly Toxic (<20% of controls)
Amphipod survival	10.8 km^2 (85.0%)	1.2 km^2 (9.7%)

* Based upon a critical values of <80% and <20% of control responses.
Total survey area: 12.7 km^2

Concentrations and Distribution of Contaminants in Sediments: Phase 1. Following a review of the data from the toxicity tests, chemical analyses were performed on 38 selected samples from Phase 1. Samples selected for chemical analyses were not chosen randomly; rather, they were chosen to represent toxicity gradients within selected regions of the study area. Concentrations of trace elements, acid-volatile sulfides, simultaneously extracted metals, polynuclear aromatic hydrocarbons (PAHs), PCBs, pesticides, organic carbon, carbonate, and sediment grain sizes are listed in Appendices A-E. Patterns in the distribution of selected chemicals among the stations sampled in Phase 1 are illustrated in Figures 15-20.

The portion of the sediments consisting of fine-grained materials (silt + clay) in the selected samples varied from 0.0% at stations 37B and 38B to 76.7% at station 17B (Figure 15). The samples from western Long Island Sound (sites 4-6), the Hudson River (sites 1 and 2), East River (sites 10 and 12), upper Arthur Kill (site 17), western Raritan Bay (sites 23 and 24), and the lower New York Harbor (site

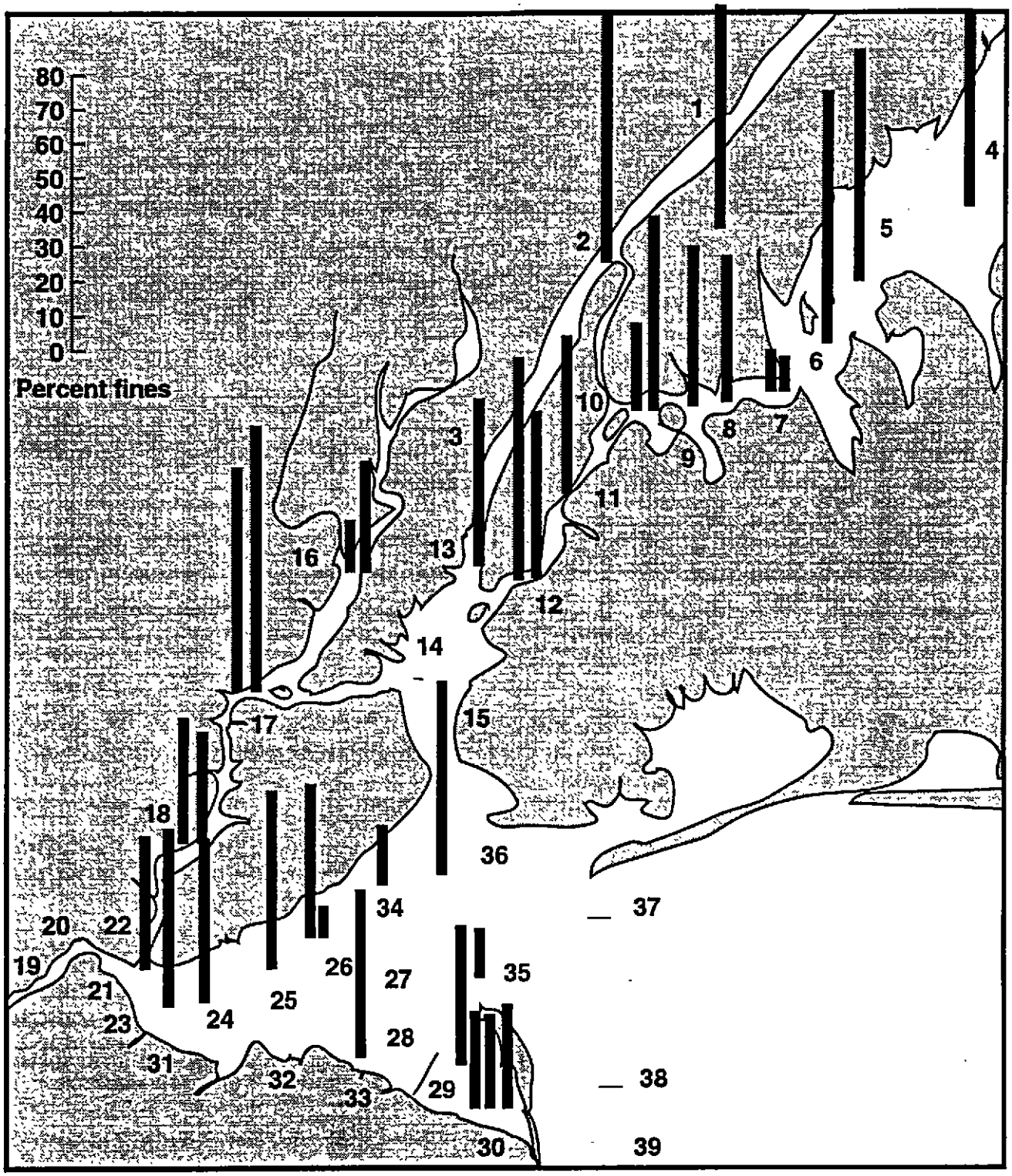

Figure 15. Percent fine-grained sediments (silt + clay) at selected stations in the Hudson-Raritan Estuary.

36) had relatively high percent fine-grained materials (over 50%). Samples with relatively low percent fines were collected in the upper East River (site 7), lower Hudson River (site 13), upper New York Harbor (site 14), upper Newark Bay (site 16), and in the lower New York Harbor (sites 26, 34, 35, 37, and 38).

The concentrations of total organic carbon (TOC) ranged from 0.7% (at sites 37 and 38) to 3.6-4.8% (at sites 11 and 12) up to a maximum of 5.0% at site 9 (Figure 16). Curiously, sample 7B had low percent fines (10.4%), but very high TOC content (4.4%). In most samples the TOC content ranged from 2% to 3% with very few samples having less than 1% TOC. Multiple samples from most sites had similar concentrations of TOC. However, the two samples from sites 7 and 10 had considerably different concentrations, reflecting within-site heterogeneity. The two samples collected in the mouth of the estuary (sites 37 and 38) had extremely low TOC content and consisted entirely of sand (100% sand). Also, the sample from site 14 in upper New York Harbor was 98.5% sand and had only 0.25% TOC.

The concentrations of mercury in most samples ranged from 1.0 to 2.5 ug/g (Figure 17). Samples from sites 7, 9, and 10 had 4.7 to 5.0 ug/g Hg. Sample 18C from the Arthur Kill had 15 ug/g Hg, considerably higher than any of the other samples. Samples with relatively low mercury concentrations were those from western Long Island Sound, the lower Hudson River, upper New York Harbor, lower New York Harbor, and near the Sandy Hook-Rockaway Point transec.

In most samples, the molar ratios of total simultaneously extracted metals (SEM) to total acid volatile sulfides (AVS) ranged from 0.04 to 0.22 (Figure 18). However, in sample 34B the ratio was 0.74, in sample 14A it was 0.80, and in sample 2A it was 2.42. In sandy samples 37B and 38B, the concentrations of AVS were very low, and the SEM/AVS ratios were 9.32 and 5.47, respectively. There were no consistent spatial patterns in the SEM/AVS ratios throughout the study area.

In most samples, the concentrations of total PCBs (sum of 20 congeners) ranged from 100 ng/g to 200 ng/g (Figure 19). The PCB concentrations were relatively high in a few samples, notably the sample from station 12A in the East River which had 1972.8 ng/g. The concentrations of total PCBs exceeded 450 ng/g in samples from stations 1A, 11B, 12B, 17B, 17C, and 18C. The relatively high PCB concentrations in the samples from the East River gradually decreased into the western Long Island Sound. Also, the relatively high concentrations in the Arthur Kill gradually diminished towards the Sandy Hook-Rockaway Point transect at the estuary entrance.

In most samples, the concentrations of total PAHs (sum of 24 PAHs) ranged from 4,000 ng/g to 20,000 ng/g (Figure 20). However, the samples from sites 7, 8, 9, 10, and 11 in the East River and site 17 in Kull van Kull had concentrations that exceeded 20,000 ng/g total PAH. The concentration of total PAH in sample 9B from the upper East River was 1,123,355 ng/g. The high concentrations of PAHs in the East River decreased considerably eastward into Long Island Sound. Also, the moderate concentrations of PAHs in the Arthur Kill diminished eastward toward the Sandy Hook-Rockaway Point transect at the estuary entrance. The lowest concentrations of these compounds were found in samples collected in the upper New York Harbor and beyond the estuary entrance.

Concentrations and Distribution of Contaminants in Sediments: Phase 2. In Phase 2 of the survey, sediments from 20 of the 57 sampling stations in Newark Bay and vicinity were analyzed for chemical concentrations. These 20 stations included station 57 in upper New York Harbor, which was sampled during Phase 1 (listed as Site 14 in Phase 1). A full suite of trace elements, organo chlorine

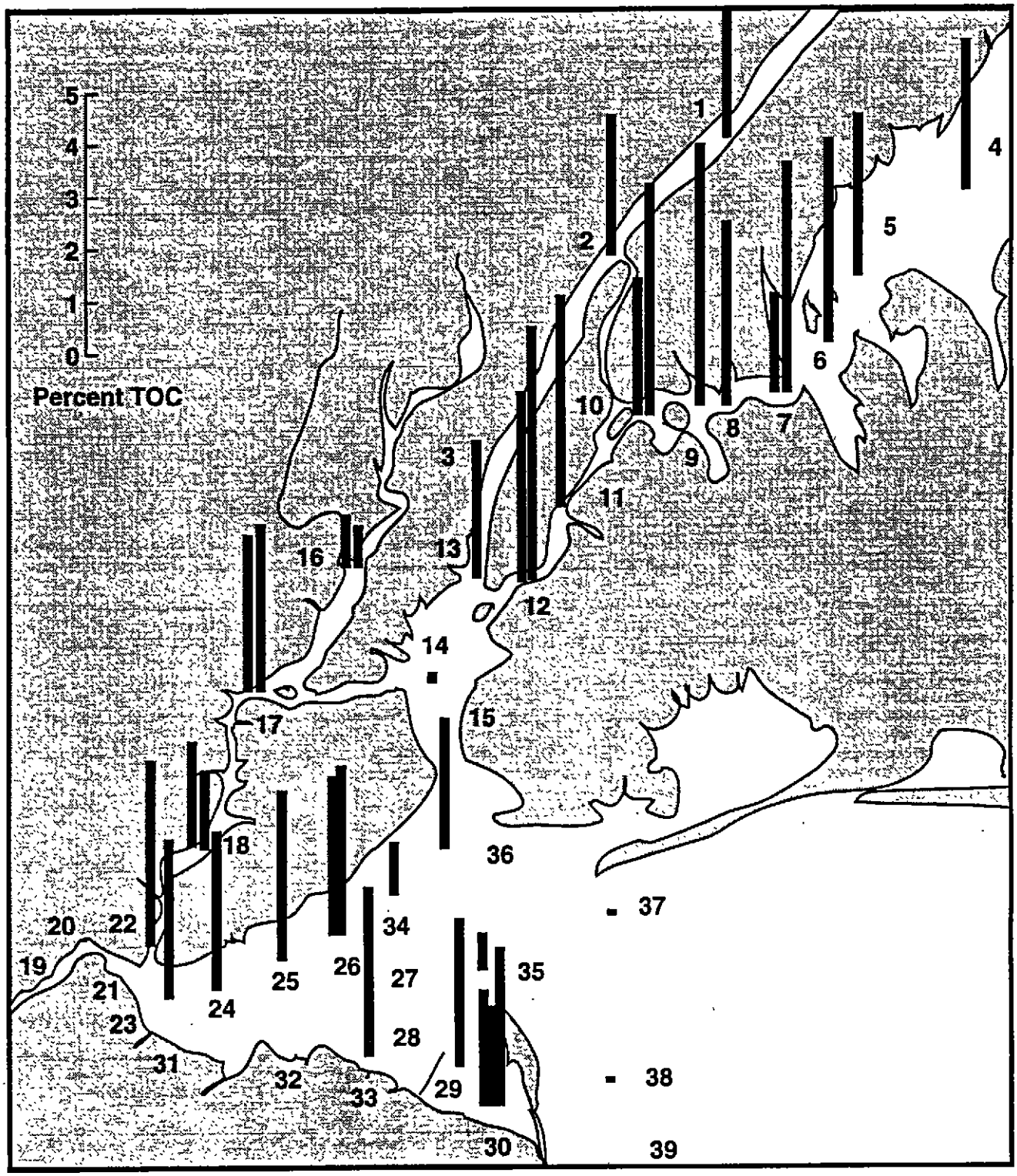

Figure 16. Percent total organic carbon (TOC) in selected stations in the Hudson-Raritan Estuary.

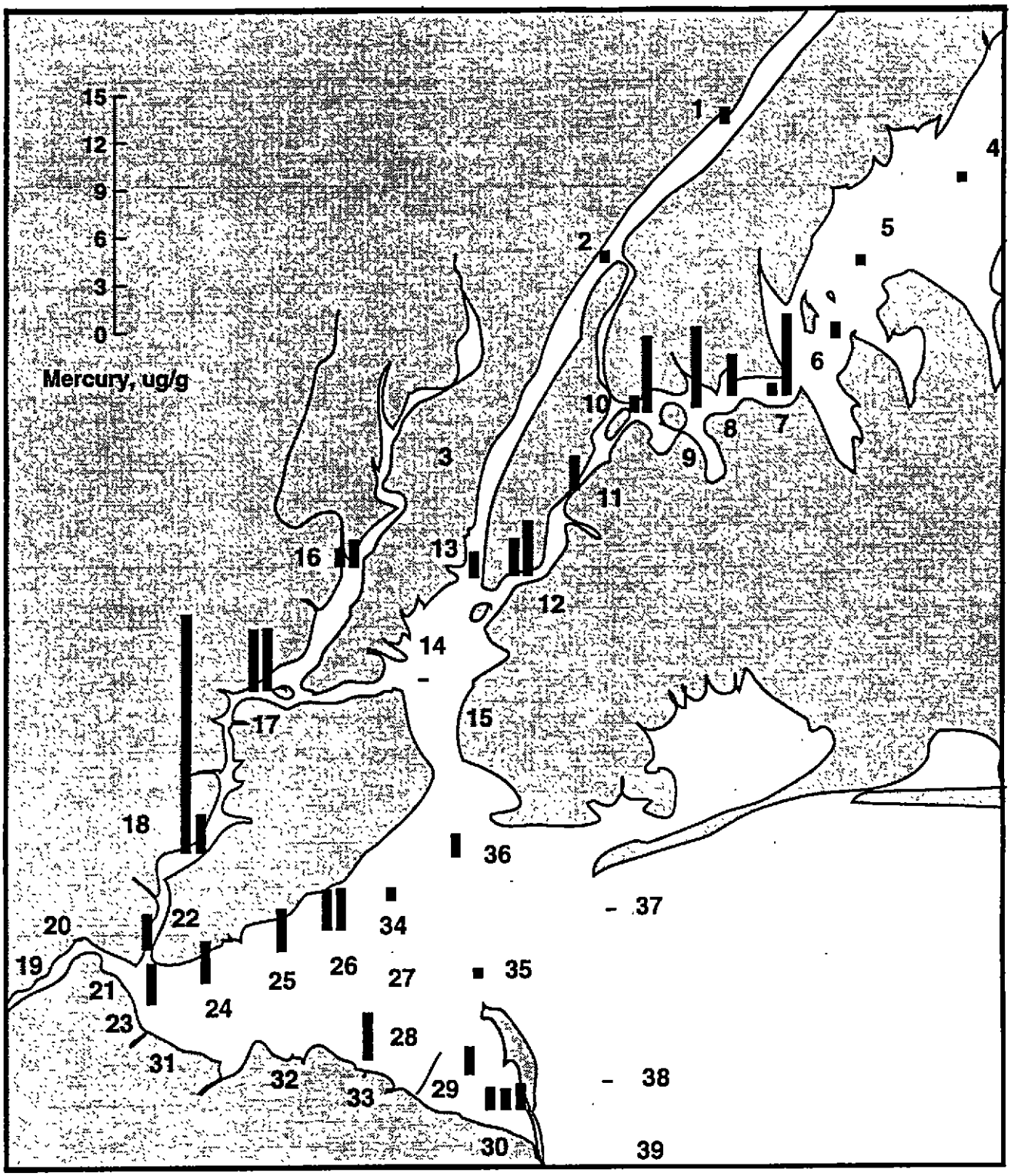

Figure 17. Mercury concentrations in selected stations in the Hudson-Raritan Estuary.

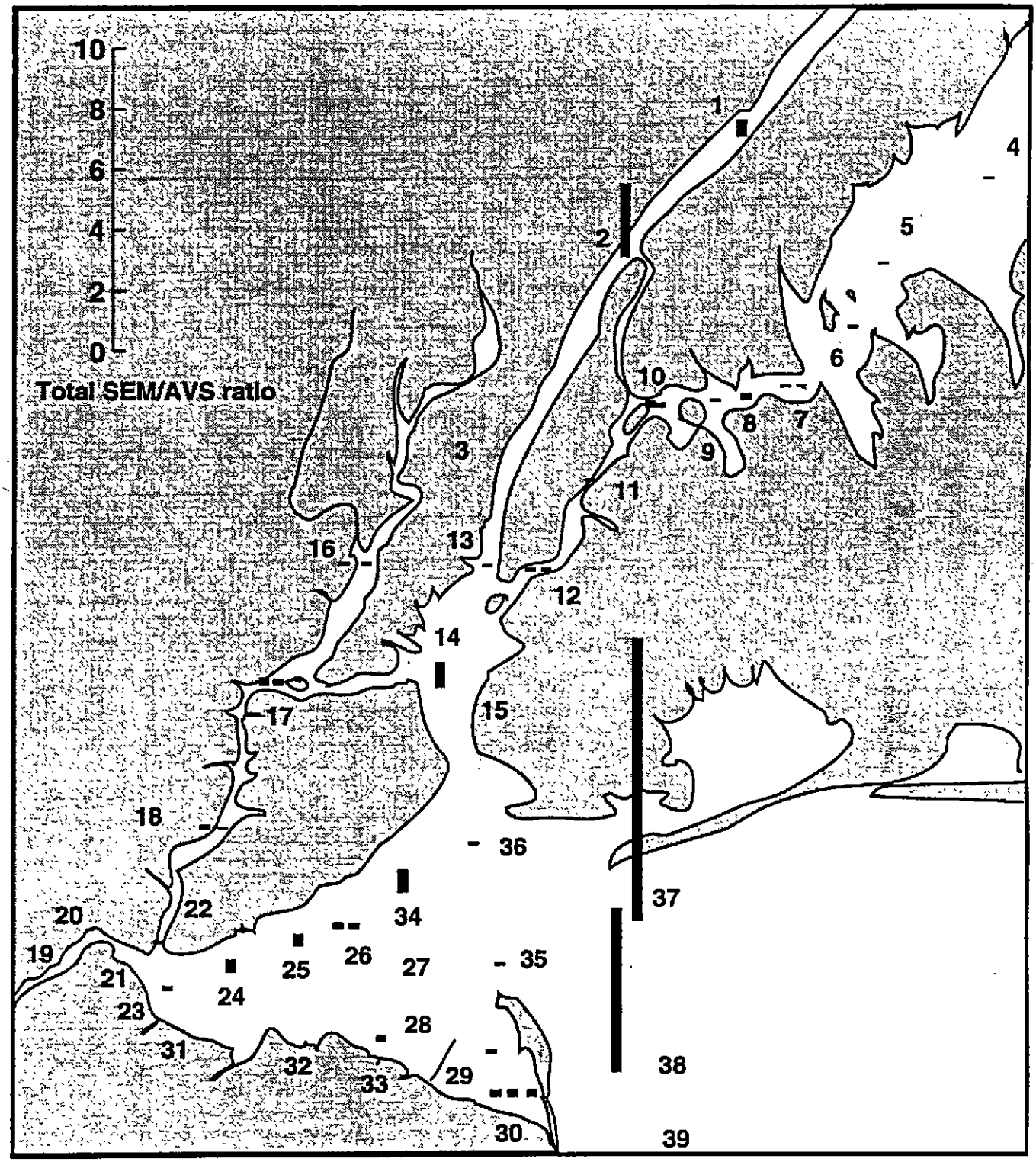

Figure 18. Ratio of total simultaneously-extracted metals concentrations (*u*mole/g) to acid-volatile sulfide concentrations (*u*mole/g) in selected stations in the Hudson-Raritan Estuary.

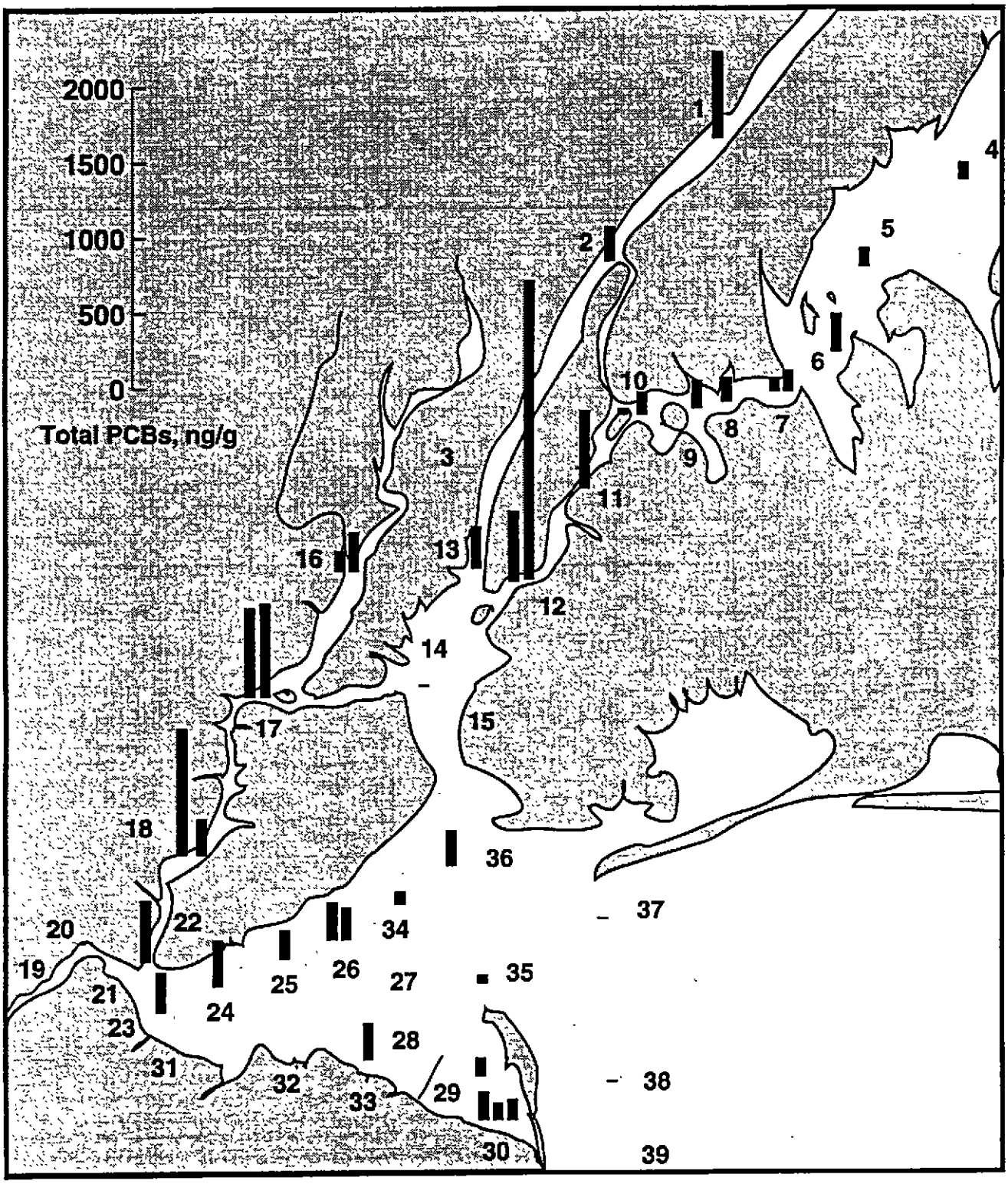

Figure 19. Total PCB concentrations (sum of 20 individual congeners, ng/g) in selected stations in the Hudson-Raritan Estuary.

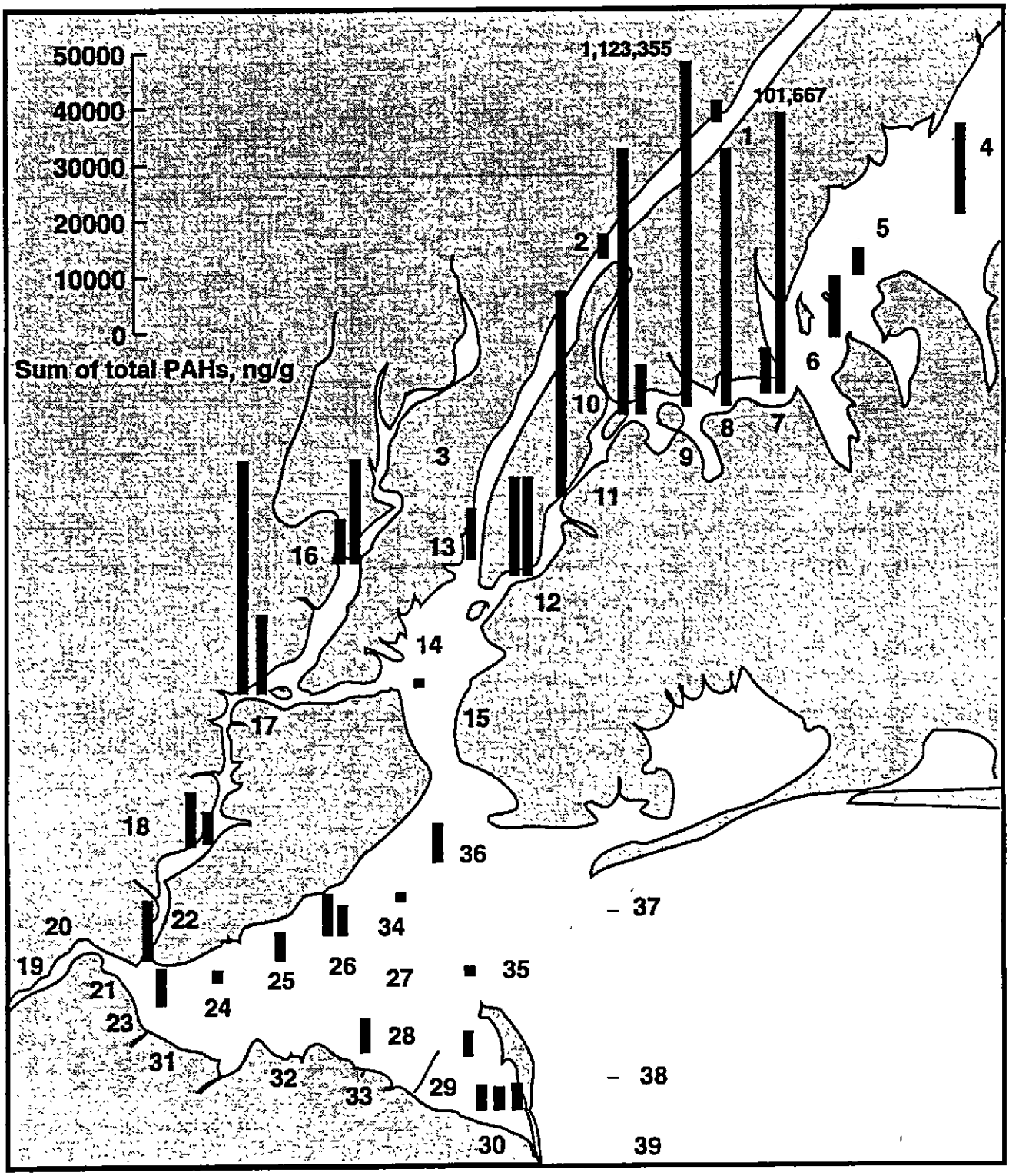

Figure 20. Concentrations of total PAHs (sum of 24 compounds) at selected stations in the Hudson-Raritan Estuary.

compounds, and PAHs were quantified along with dioxins and furans. The 20 samples selected for chemical analyses were chosen before the samples were collected. Samples were chosen to represent suspected pollution gradients based upon data (especially from analyses of dioxins) from previous studies. As expected from the results of the Phase 1 analyses, the sample from station 57 was sandy and had very low concentrations of all substances.

The concentration of cadmium was relatively low in the sample from station 57, a reference station in upper New York Harbor (Figure 21). Also, the cadmium concentration was relatively low in the samples from the Hackensack River and much of Newark Bay. In contrast, the cadmium concentrations in many of the samples from the lower Passaic River were 4 to 6 ppm. In addition, the sample from station 26 midway down Newark Bay had a cadmium concentration of 4.2 ppm.

The concentrations of mercury in the Newark Bay samples followed a distributional pattern similar to that of cadmium (Figure 22). Mercury concentrations were relatively low in the reference sample from upper New York Harbor, in most of the samples from Newark Bay, in two of the Hackensack River samples, and at the upstream station in the Passaic River. In contrast, mercury concentrations were 3-5 ppm in samples from the lower Passaic River, a station in the Hackensack River in the vicinity of Berry's Creek, and at station 26 midway down Newark Bay. At station 14 near Berry's Creek, the mercury concentration was 4.3 ppm.

The SEM/AVS ratios ranged from 0.07 to 2.85 and were less than 1.0 at all but three stations (Figure 23). The sample from station 1 in the Passaic River had the highest ratio, 2.85, followed by station 8 in the lower Passaic River and station 56 in lower Newark Bay, in which the ratios were 1.02 and 1.04, respectively. The total SEM concentrations were based upon sums of the Cd, Cu, Pb, Ni, and Zn concentrations.

The concentrations of total PCBs ranged from 105 ng/g at station 57 in upper New York Harbor to 2318 ng/g at station 26 in Newark Bay and 2850 ng/g at station 3 in the lower Passaic River (Figure 24). Total PCB concentrations exceeded 1,000 ng/g in all of the Passaic River stations except station 1. In contrast, the concentrations of total PCBs ranged from 110 to 671 ng/g at the three stations in the Hackensack River.

The concentrations of 18 dioxins and furans were quantified by NBS. Also, the concentrations of four co-planar PCBs were quantified. Based upon the toxicity equivalency factors (TEF) derived for mammalian systems by Kutz et al. (1990) for the dioxins and furans and by Barnes et al. (1991) for the co-planar PCBs, the cumulative, total 2,3,7,8-tcdd toxicity equivalency quotients (TEQ) were calculated and plotted (Figure 25). Total 2,3,7,8-tcdd TEQs ranged from 13 pg/g at station 57 in upper New York Harbor to 874 pg/g at station 7c in the lower Passaic River. All samples except five from stations in the Hackensack River and Newark Bay had concentrations of 100 pg/g or greater. In addition, sample 26 from Newark Bay had a concentration of 723 pg/g total TEQ.

With funding provided to U.S. EPA Region 2 from the U.S. EPA Office of Science and Technology, the concentrations of 17 dioxin and furan congeners were determined in an additional 35 samples. Twelve samples were analyzed by Pacific Analytical, Inc. and the remaining 23 samples were analyzed by Midwest Research Institute. Both laboratories prepared the samples and conducted the analyses in accordance with EPA Method 1613. However, the comparability of the data from the NBS, Pacific Analytical, Inc., and Midwest Research Institute laboratories was not determined.

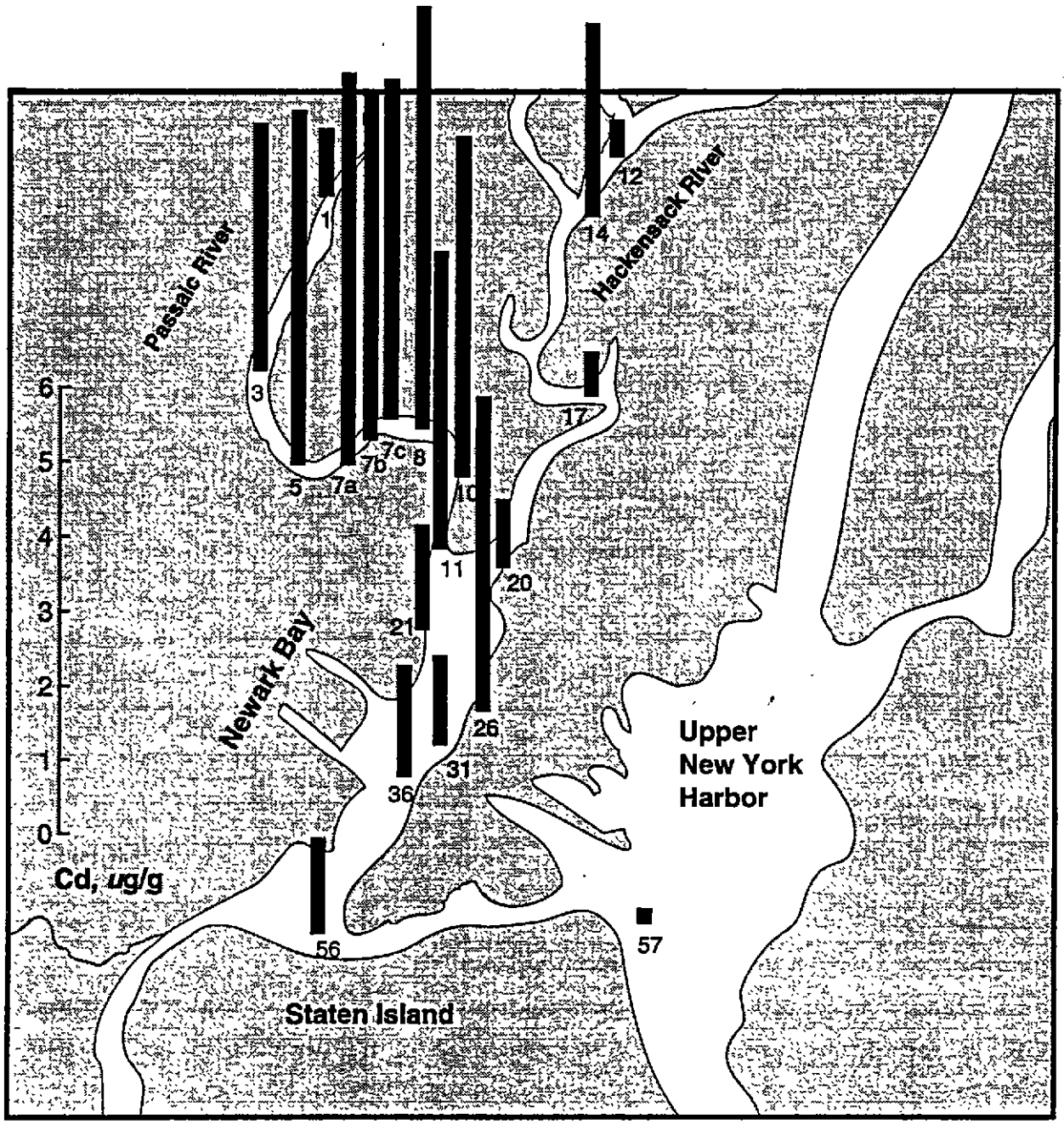

Figure 21. Concentrations of cadmium at selected stations in Newark Bay and vicinity.

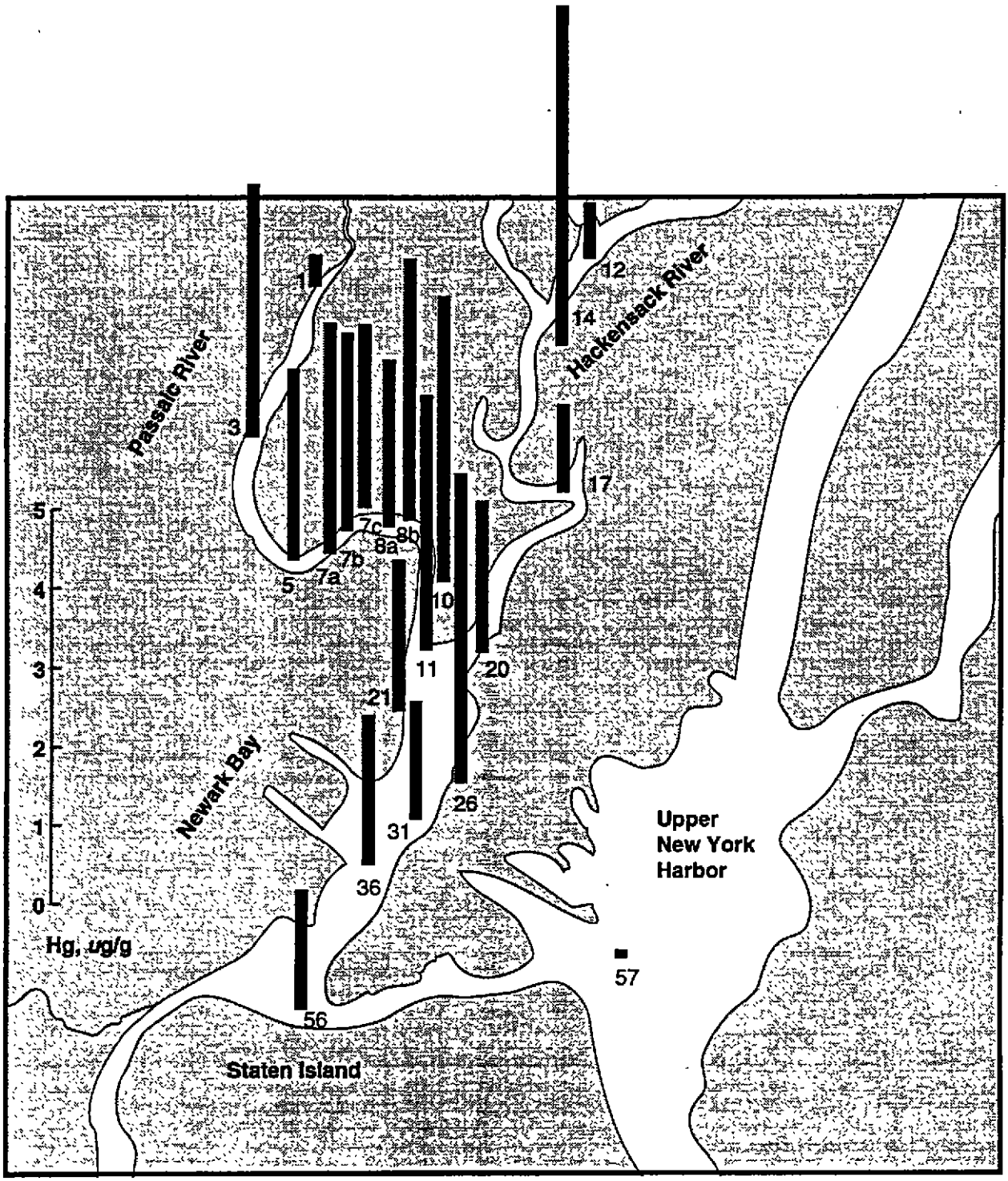

Figure 22. Concentrations of mercury at selected stations in Newark Bay and vicinity.

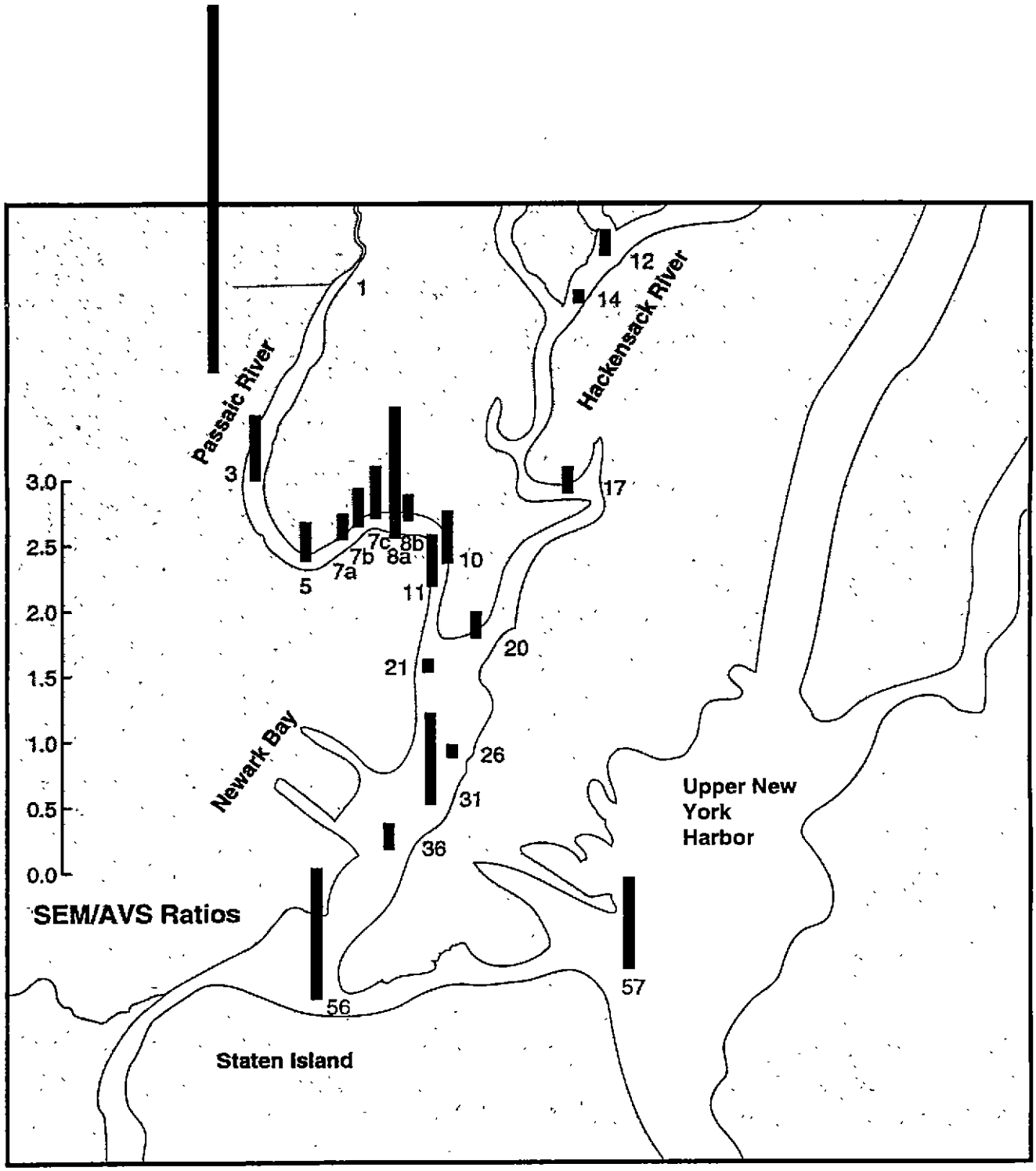

Figure 23. Ratios of total simultaneously-extracted metals(SEM) to total acid-volatile sulfides (AVS) at selected stations in Newark Bay and vicinity.

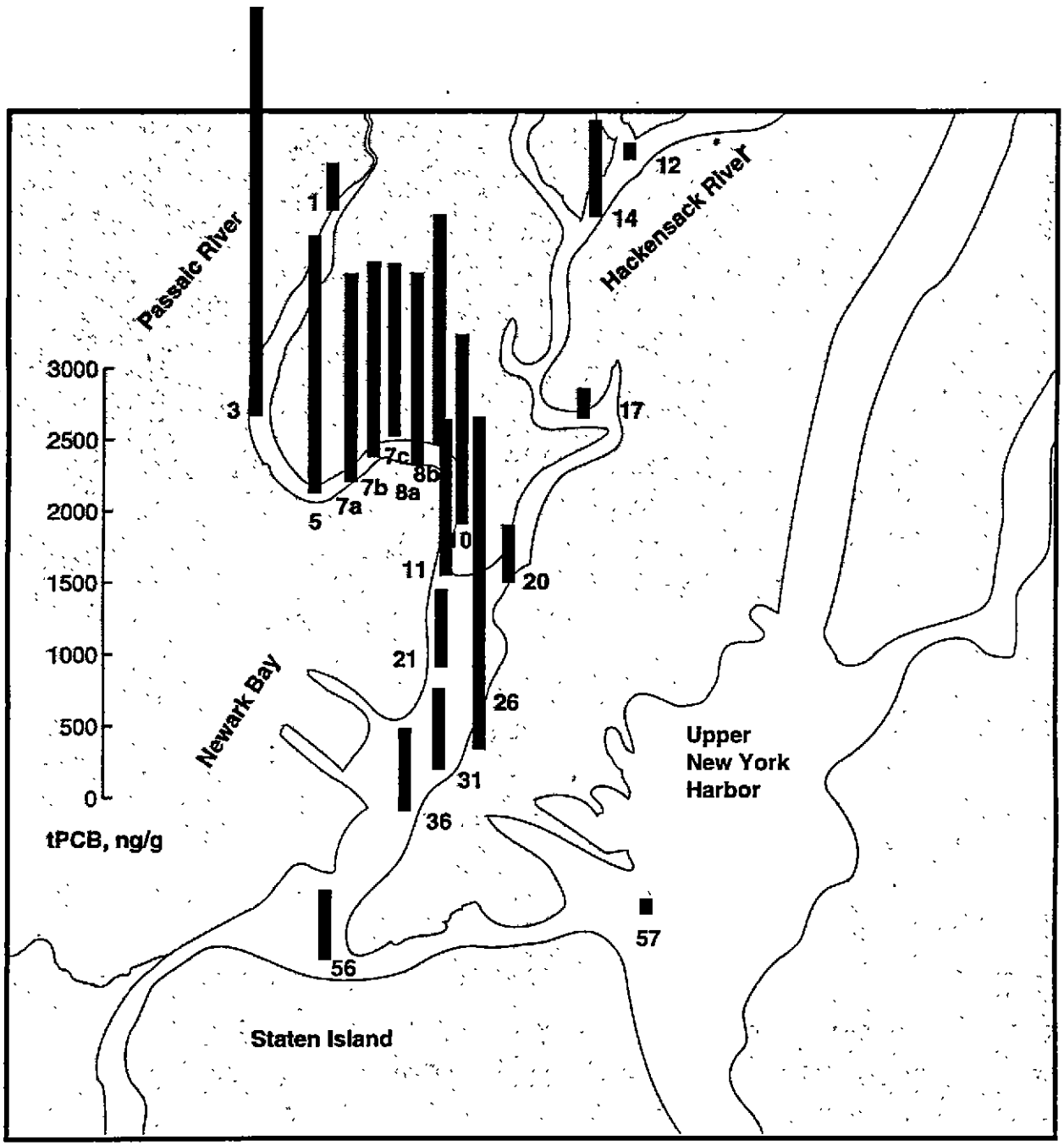

Figure 24. Concentrations of total PCBs at selected stations in Newark Bay and vicinity.

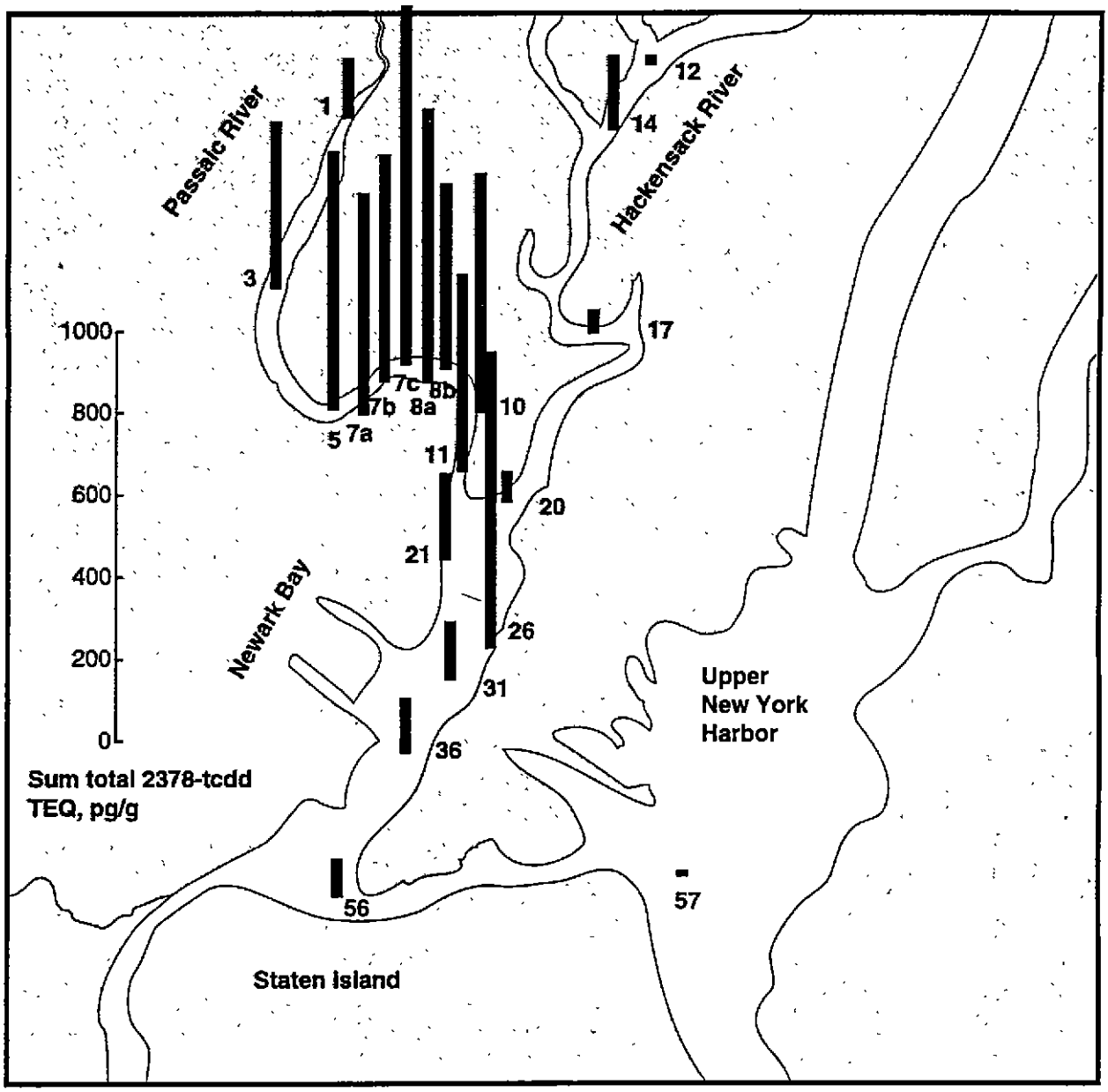

Figure 25. Concentrations of total 2,3,7,8-tcdd toxicity equivalency quotients (TEQ) at selected stations in Newark Bay and vicinity.

The concentrations of 2,3,7,8-tcdd reported by the three laboratories are plotted in Figure 26. Note that the scales in Figures 25 and 26 are different. The spatial pattern in the concentrations of 2,3,7,8-tcdd in all 55 samples corresponded with that for total dioxin equivalents in the 20 samples analyzed by NBS. The relatively high concentrations (280-620 pg/g) of this isomer in the lower Passaic River stations contrasts with the relatively low levels in the Hackensack River (62 pg/g or less). Except for station 26 located in central Newark Bay, the concentrations of 2,3,7,8-tcdd generally decreased down Newark Bay from the mouth of the Passaic River toward Staten Island. The concentrations of this congener were 100-150 pg/g in many of the samples collected near the Port Newark Terminal.

In addition to the chemical analyses of dioxins and furans, the Midwest Science Center of NBS determined the concentrations of these and other compounds in H4IIE rat hepatoma bioassays, following the protocols of Tillitt et al. (1991). The toxicity of whole sediment extracts (F1) and fractions of the extracts were determined and reported in units of 2, 3, 7, 8 -tcdd equivalents (pg/g). Seven fractions, representing dioxins, furans, PCBs, and PAHs, were tested (Table 15). The toxicity of the F5 fraction (PAHs) was considerably greater than that of all of the other fractions. In many of the samples, the tcdd-equivalent concentrations of the PAHs exceeded the concentrations observed in the whole extracts. This observation suggests that the toxicity of these compounds may not be strictly additive, and alternatively, some antagonistic effects may occur, thus reducing the cumulative toxicity of these mixtures. Also, the tcdd equivalent concentrations of the F12 fractions (dioxins, furans) were relatively high. The contributions of the PCB fractions (F7 - F11) to toxicity were relatively minor.

The concentrations of the tcdd equivalents in the whole extracts were highest in the samples from the lower Passaic River, particularly at stations 3, 6, 7, and 8 (Figure 27). Concentrations diminished rapidly down Newark Bay and were relatively low in the Hackensack River. Concentrations were very low in the sample from station 57 in the upper New York Harbor. This distribution pattern differed from that observed in the chemical analyses; specifically, tcdd equivalent concentrations were relatively low at stations 7 and 26, whereas the chemical analyses indicated that dioxin concentrations were relatively high at these stations.

The concordance between the concentrations of the planar hydrocarbons determined in chemical analyses and in the rat hepatoma bioassays was very good for some fractions (Table 16). Spearman-rank correlations were determined for the concentrations of the PCB-TEQs, dioxins/furans-TEQs, and total cumulative TEQs (pg/g) versus the tcdd-eqs (pg/g) determined for each extract fraction in the rat hepatoma bioassays. The correlations between the cumulative TEQs determined in chemical analyses and the tcdd-equivalent concentrations in the F12 fraction (dioxins, furans) were particularly strong.

Table 15. Concentrations of TCDD-equivalents (pg/g) in whole extracts and extract fractions determined in H4IIE rat hepatoma bioassays of sediments from Newark Bay. F 1 fraction = whole extract. F 5 fraction = PAH fraction. F 7 fraction = bulk (>2 - ortho - chloro - substituted) PCB fraction. F 8 = mono - ortho - chloro - substituted PCB fraction. F 9 = non - ortho - chloro - substituted PCB fraction. F 11 = combined total PCB fraction. F 12 = PCDD/PCDF fraction.

Station No.	F1 fraction	F5 fraction	F7 fraction	F8 fraction	F9 fraction	F11 fraction	F12 fraction
1.	380	5800	0.1	2.2	7	82	156
3.	40000	6000	0.1	1.4	20	96	520
5.	42000	22000	0.0	7.4	49	151	856
7a.	12000	19000	0.2	16.8	113	96	762
7b.	8500	5400	0.2	11.3	155	61	806
7c.	6700	5500	1.4	13.3	17	63	1261
8a.	42000	7200	0.1	5.0	85	332	1047
8b.	93000	7000	3.3	18.4	192	391	648
10.	9300	4800	2.0	8.2	2	16	1017
11.	10000	21000	0.3	4.7	68	204	911
12.	500	650	0.2	0.7	1	11	45
14.	650	18000	0.1	4.1	22	42	424
17.	5000	4900	0.2	1.9	5	52	105
20.	710	11000	0.1	5.6	14	80	164
21.	4500	8500	0.1	4.0	18	111	275
26.	3000	7000	0.1	18.1	86	162	857
31.	1700	4500	0.4	3.6	17	19	274
36.	3200	2000	0.2	4.0	10	47	222
56.	7100	2400	0.3	4.7	12	62	130
57.	170	87	0.1	0.3	2	2	15

Based upon means where replicates were tested.

Table 16. Spearman-rank (rho, corrected for ties) correlations between dioxin equivalents determined in chemical analyses and dioxin equivalents (tcdd-eqs) determined in rat hepatoma bioassays of sediment extracts. F 1 fraction = whole extract. F 5 fraction = PAH fraction. F 7 fraction = bulk (>2 - ortho - chloro - substituted) PCB fraction. F 8 = mono - ortho - chloro - substituted PCB fraction. F 9 = non - ortho - chloro - substituted PCB fraction. F 11 = combined total PCB fraction. F 12 = PCDD/PCDF fraction.

Sediment extract fraction	Cumulative PCB TEQs	Cumulative dioxin/furan TEQs	Cumulative total TEQs
F1	+0.633*	+0.605*	+0.616*
F5	+0.428 ns	+0.524*	+0.506*
F7	+0.116 ns	+0.038 ns	+0.053 ns
F8	+0.738*	+0.750*	+0.746*
F9	+0.634*	+0.650*	+0.649*
F11	+0.530*	+0.577*	+0.574*
F12	+0.962***	+0.962***	+0.959***

*p<0.05, **p<0.001, ***p<0.0001

What about PCBs?

This relationship between the total cumulative tcdd equivalents from the chemical analyses and the tcdd equivalents from the H4IIE rat hepatoma bioassays of the F12 fraction is illustrated in Figure 28. The relationship is very strong and nearly linear.

Also, there was a relatively strong correlation and relationship between the concentrations of total PAHs in the sediments and the tcdd equivalents determined in the H4IIE bioassays of the F5 (PAHs) fraction (Figure 29). This relationship was not as strong as that observed with the dioxins and would be improved by deletion of the data from two samples. Nevertheless, a strong pattern was obvious between the chemical estimate and the bioassay estimate of PAH concentrations.

Relationships Between Toxicity and Physical-Chemical Parameters: Phase 1. The relationships between the four measures of toxicity and the concentrations of potential contaminants and other parameters were compared using non-parametric, Spearman-rank correlations (Tables 15-18). Although the correlation analyses cannot be interpreted as evidence of cause-effect relationships, they can identify patterns in co-variance or concordance between dependent variables (i.e., toxicity) and independent variables (i.e., potential toxicants). The correlation coefficients are accompanied by the level of significance of the correlations. To account for Type 1 errors in the correlations, the significance level (p=0.05) should be divided by the number of variables and the adjusted significance level used as the critical p value.

The total concentrations of most trace metals were not significantly correlated with amphipod survival, bivalve survival, or bivalve normal development (Table 17). In contrast, most of the metals were weakly (but significantly) correlated with the microbial bioluminescence EC50s. Only the concentrations of mercury and tin were significantly negatively correlated with amphipod survival. None of the metals or other parameters were correlated with bivalve survival and only the concentration of carbonate was correlated with bivalve normal development. In the microbial bioluminescence test, all of the potentially toxic trace metals (i.e., Ag, Cr, Cd, Cu, Hg, Pb, Sn, and Zn) were significantly (p<0.05) correlated with toxicity. Also, the Microtox test results were correlated with the total organic carbon content (% TOC). Only those correlations shown with "**" would remain significant if the number of variables (18) were taken into account.

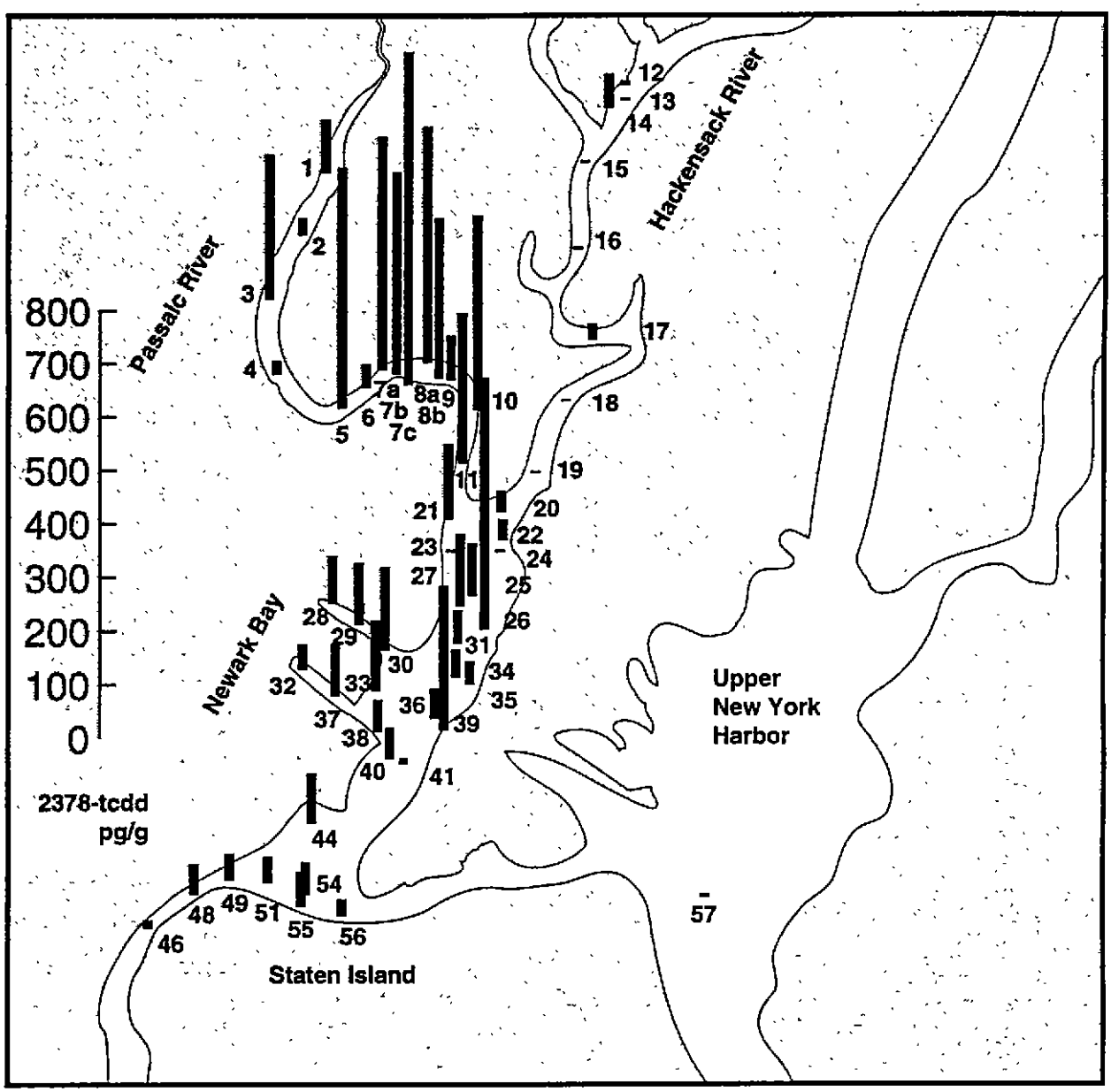

Figure 26. Concentrations of 2,3,7,8-tcdd at 53 selected stations in Newark Bay and vicinity.

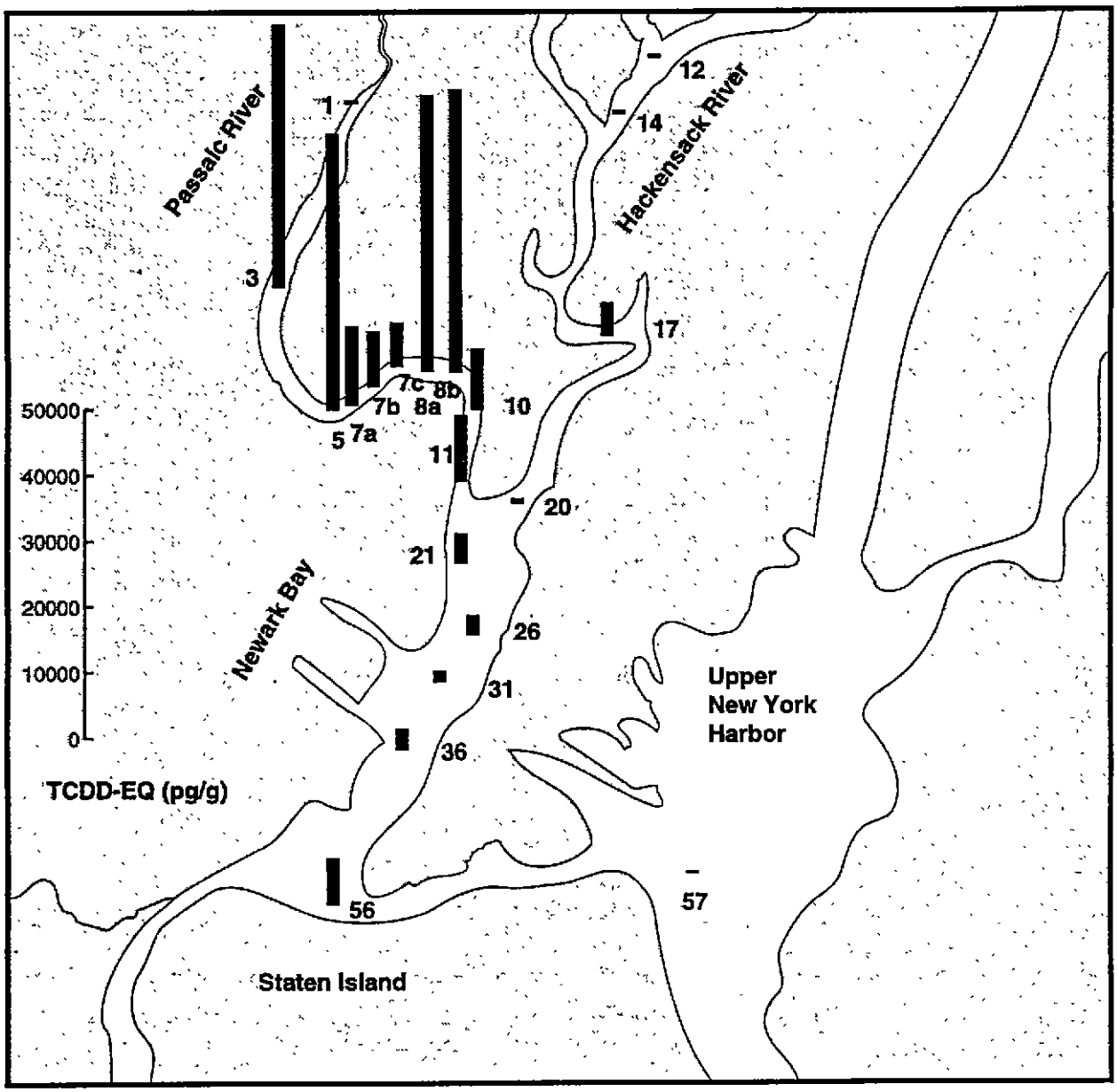

Figure 27. TCDD equivalents (pg/g) from H4IIE bioassays of whole (F1) sediment extracts from selected stations in Newark Bay and vicinity.

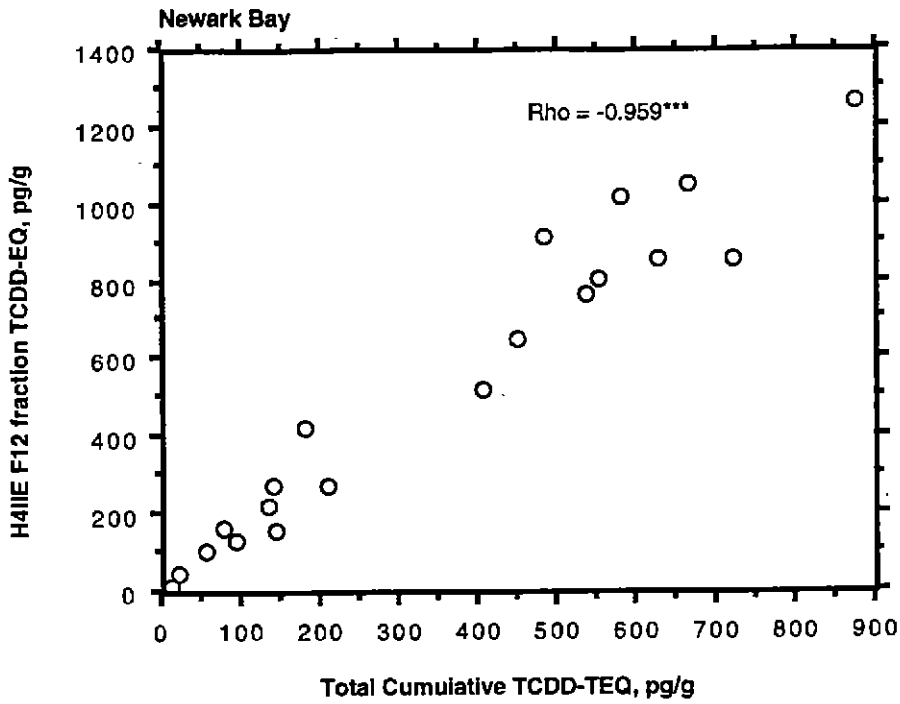

Figure 28. Relationship of total cumulative tcdd toxicity equivalents from chemical analyses and TCDD toxicity equivalents from H4IIE bioassays of the F12 fraction.

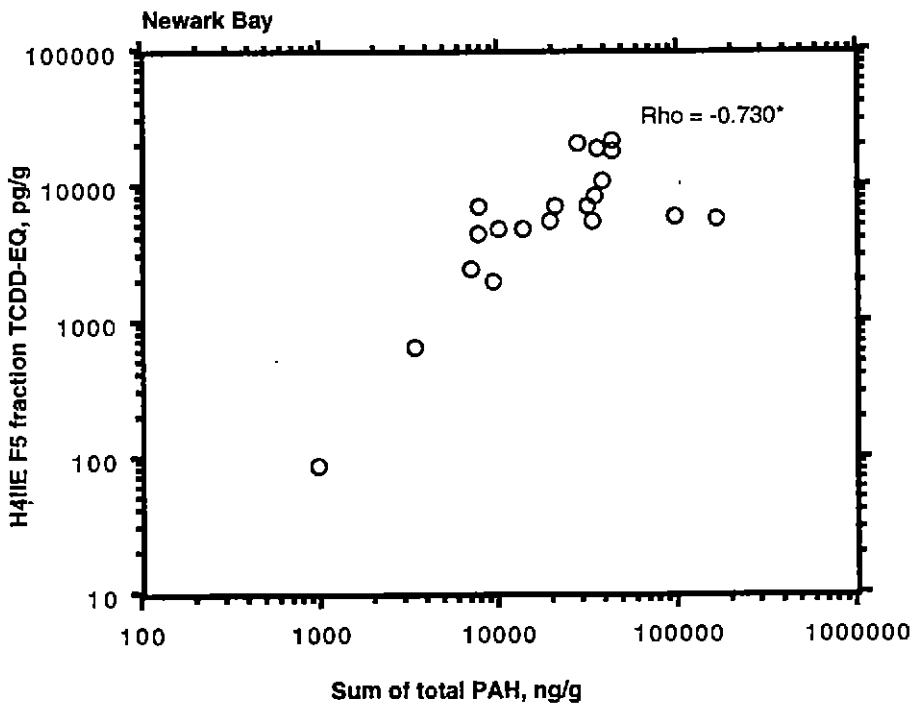

Figure 29. Relationship of the concentrations of total PAHs to the concentrations of the TCDD toxicity equivalents in the H4IIE bioassays of the F5 (PAH) fraction.

Table 17. Spearman-rank correlations (Rho, corrected for ties) between four toxicity end-points (as percent of controls) and the concentrations of trace elements in Hudson-Raritan estuary sediments (n=38).

	Amphipod Survival	Bivalve Survival	Bivalve Development	Microbial Bioluminescence
Silver	+0.206 ns	-0.029 ns	-0.096 ns	-0.363 *
Aluminum	+0.177 ns	+0.245 ns	-0.040 ns	-0.201 ns
Arsenic	-0.153 ns	-0.050 ns	-0.287 ns	-0.305 ns
Chromium	+0.025 ns	+0.207 ns	+0.001 ns	-0.351 *
Cadmium	-0.264 ns	-0.126 ns	-0.205 ns	-0.472 *
Copper	-0.255 ns	-0.048 ns	-0.091 ns	-0.449 *
Iron	+0.233 ns	+0.138 ns	-0.181 ns	-0.320 ns
Mercury	-0.437 *	-0.096 ns	-0.119 ns	-0.377 *
Manganese	+0.494 *	-0.128 ns	-0.142 ns	-0.105 ns
Nickel	-0.095 ns	+0.017 ns	-0.081 ns	-0.451*
Lead	-0.295 ns	-0.068 ns	-0.150 ns	-0.478 *
Antimony	-0.239 ns	+0.013 ns	-0.052 ns	-0.355 *
Selenium	-0.067 ns	+0.010 ns	-0.047 ns	-0.217 ns
Tin	-0.342 *	-0.061 ns	-0.130 ns	-0.427 *
Zinc	-0.134 ns	+0.012 ns	-0.208 ns	-0.433 *
Sum of Cd/Cu Hg/Pb/Zn	-0.240 ns	-0.040 ns	-0.153 ns	-0.465 *
% TOC	-0.151 ns	-0.231 ns	-0.318 ns	-0.581 **
% TIC	-0.281 ns	-0.233 ns	-0.343 *	-0.415 *
% fines	+0.196 ns	+0.063 ns	+0.120 ns	-0.347 *

*p<0.05, **p<0.001, ***p<0.0001

The concentrations of individual and total simultaneously extracted metals (SEM) were not significantly correlated with the results of the tests of amphipod survival, bivalve survival, and bivalve development (Table 18). Similarly, the SEM/AVS ratios were not significantly correlated with any of the tests, and, improbably, a positive association was indicated with amphipod survival, bivalve survival, bivalve development, and microbial bioluminescence. However, the concentrations of many of the individual simultaneously extracted metals, notably lead, were significantly correlated with the Microtox results. Although the correlations between microbial bioluminescence and both total AVS and total SEM concentrations were significantly negative, the correlation with the SEM/AVS ratios was significantly positive. Only those correlations shown with "**" would remain significant if the number of variables (9) were taken into account.

Table 18. Spearman-rank correlations (Rho, corrected for ties) between four toxicity end-points (as percent of controls) and the concentrations of acid-volatile sulfides (AVS) and simultaneously extracted trace metals (SEM) in Hudson-Raritan Estuary sediments (n=38).

	Amphipod Survival	Bivalve Survival	Bivalve Development	Microbial Bioluminescence
Total AVS	-0.150 ns	-0.133 ns	-0.323 ns	-0.544 **
SE Cd	-0.149 ns	-0.113 ns	-0.229 ns	-0.393 *
SE Cu	-0.105 ns	-0.015 ns	-0.096 ns	-0.351 *

Table 18 continued.

	Amphipod Survival	Bivalve Survival	Bivalve Development	Microbial Bioluminescence
SE Hg	+0.292 ns	+0.231 ns	+0.189 ns	+0.309 ns
SE Ni	+0.060 ns	+0.125 ns	+0.075 ns	-0.234 ns
SE Pb	-0.234 ns	+0.001 ns	-0.086 ns	-0.482 *
SE Zn	-0.050 ns	+0.040 ns	-0.216 ns	-0.340 *
Total SEM	-0.130 ns	+0.039 ns	-0.192 ns	-0.417 *
SEM/AVS ratios	+0.197 ns	+0.118 ns	+0.264 ns	+0.454 *

*p<0.05, **p<0.001, ***p<0.0001

Most of the correlations between toxicity and the concentrations of chlorinated organic compounds were not significant (Table 19). Only cis-chlordane, trans-nonachlor, 2,4'-DDD, 4,4'-DDE, 4,4'-DDT, and the sum of total indeno-pesticides were significantly negatively correlated with any of the toxicity tests. These compounds were significantly correlated with the microbial bioluminescence test results. In addition, 4,4'-DDT was significantly correlated with amphipod survival. However, none of these correlations would remain significant if the number of variables (20) were taken into account.

Table 19. Spearman-rank correlations (Rho, corrected for ties) between four toxicity end-points (as percent of controls) and the concentrations of PCBs and pesticides in Hudson-Raritan Estuary sediments (n=38).

	Amphipod Survival	Bivalve Survival	Bivalve Development	Microbial Bioluminescence
HCB	-0.013 ns	+0.281 ns	+0.144 ns	-0.052 ns
Lindane	-0.082 ns	-0.172 ns	-0.062 ns	-0.030 ns
Heptachlor	< mdl	< mdl	< mdl	< mdl
Aldrin	-0.075 ns	-0.004 ns	+0.031 ns	+0.087 ns
Heptachlor epoxide	-0.232 ns	+0.234 ns	+0.031 ns	-0.120 ns
2, 4-DDE	-0.125 ns	-0.157 ns	+0.036 ns	-0.295 ns
Cis-chlordane	-0.204 ns	-0.059 ns	-0.007 ns	-0.384 *
Trans-nonachlor	-0.150 ns	-0.065 ns	-0.018 ns	-0.402 *
Dieldrin	-0.058 ns	+0.285 ns	+0.101 ns	+0.014 ns
4,4-DDE	-0.287 ns	+0.074 ns	+0.105 ns	-0.406 *
2,4-DDD	-0.197 ns	+0.249 ns	+0.286 ns	-0.066 ns
Endrin	< mdl	< mdl	< mdl	< mdl
4,4-DDD	-0.189 ns	-0.019 ns	+0.036 ns	-0.314 ns
2,4-DDT	-0.118 ns	+0.112 ns	+0.189 ns	-0.049 ns
4,4-DDT	-0.476 *	-0.077 ns	+0.069 ns	-0.341 *
Mirex	+0.281 ns	-0.024 ns	-0.033 ns	+0.039 ns
Indeno pesticides	-0.197 ns	-0.054 ns	-0.021 ns	-0.395 *
Total DDTs	-0.311 ns	+0.132 ns	+0.163 ns	-0.271 ns
Total PCBs	-0.124 ns	+0.134 ns	+0.239 ns	-0.306 ns
Total non-DDT pests.	-0.146 ns	+0.130 ns	+0.079 ns	-0.250 ns

*p<0.05, **p<0.001, ***p<0.0001
< mdl = all samples below method detection limit

The correlations between the concentrations of polynuclear aromatic hydrocarbons (PAHs) and both amphipod survival and microbial bioluminescence were very strong and highly significant (Table 20). The PAHs showed consistently negative correlations with these end-points in sharp contrast with the correlations with metals and chlorinated compounds. The correlations with the sum of the low molecular weight (2- and 3-ring) PAHs were particularly significant. Also, the concentrations of petroleum-related compounds and microbial bioluminescence were highly correlated. However, the correlations between the bivalve test results and the PAHs were very weak and frequently not significant. Bivalve survival was correlated with the concentrations of only five low molecular weight compounds. Accounting for the number of variables (32), only those correlations shown with "**" or "***" would remain significant.

National sediment quality criteria (SQC) have been proposed for three aromatic hydrocarbons (U.S. EPA, 1994): fluoranthene, acenaphthene, and phenanthrene expressed in units of organic carbon. The correlations between these three compounds normalized to TOC content and both amphipod survival and microbial bioluminescence were significant (Table 20). The correlation between amphipod survival and acenaphthene improved when the chemical concentrations were normalized to the TOC content (Rho = -0.595** vs. Rho =-0.641***). Otherwise, normalization to TOC content tended to diminish the correlative strength between the concentrations of these three compounds and amphipod survival and microbial bioluminescence.

Table 20. Spearman-rank correlations (Rho, corrected for ties) between four toxicity end-points (as percent of controls) and the concentrations of PAHs in Hudson-Raritan Estuary sediments (n=38).

	Amphipod Survival	Bivalve Survival	Bivalve Development	Microbial Bioluminescence
naphthalene	-0.524*	-0.220 ns	-0.198 ns	-0.577**
2-methylnaph.	-0.512*	-0.289 ns	-0.294 ns	0.653***
1-methylnaph.	-0.552**	-0.306 ns	-0.291 ns	-0.673***
biphenyl	-0.537*	-0.246 ns	-0.263 ns	-0.640***
2,6-methylnaph.	-0.567**	-0.337*	-0.320 ns	-0.695***
acenaphthylene	-0.414*	-0.247 ns	-0.208 ns	-0.652***
acenaphthene	-0.595**	-0.272 ns	-0.224 ns	-0.620**
1,6,7-trimethylnaph.	-0.673***	-0.342*	-0.258 ns	-0.625***
fluorene	-0.623***	-0.310 ns	-0.270 ns	-0.634***
phenanthrene	-0.579**	-0.331*	-0.240 ns	-0.641***
anthracene	-0.576**	-0.321 ns	-0.283 ns	-0.673***
1-methylphenanth.	-0.579**	-0.371*	-0.252 ns	-0.636***
fluoranthene	-0.574**	-0.264 ns	-0.163 ns	-0.608**
pyrene	-0.589**	-0.327*	-0.233 ns	-0.615**
benz(a)anthracene	-0.561**	-0.279 ns	-0.188 ns	-0.604**
chrysene	-0.522*	-0.292 ns	-0.184 ns	-0.526*
benzo(b)fluoranth.	-0.582**	-0.283 ns	-0.215 ns	-0.615**
benzo(k)fluoranth.	-0.464*	-0.160 ns	-0.100 ns	-0.489*
benzo(e)pyrene	-0.592**	-0.262 ns	-0.233 ns	-0.631***
benzo(a)pyrene	-0.538*	-0.279 ns	-0.228 ns	-0.615**
perylene	-0.580**	-0.289 ns	-0.236 ns	-0.563**
indeno(1,2,3)pyrene	-0.549**	-0.207 ns	-0.165 ns	-0.587**

Table 20 continued.

	Amphipod Survival	Bivalve Survival	Bivalve Development	Microbial Bioluminescence
dibenzo(a,h)anth.	-0.549**	-0.291 ns	-0.224 ns	-0.628***
benzo(g,h,i)perylene	-0.480*	-0.249 ns	-0.196 ns	-0.630***
Group A(petroleum)	-0.468*	-0.293 ns	-0.315 ns	-0.625***
Group B(combustion)	-0.576**	-0.294 ns	-0.206 ns	-0.602**
sum low PAHs	-0.592**	-0.320 ns	-0.266 ns	-0.650***
sum high PAHs	-0.471*	-0.128 ns	-0.060 ns	-0.512*
sum total PAHs	-0.495*	-0.312 ns	-0.241 ns	-0.603**
acenaphthene/toc	-0.641***	-0.164 ns	-0.083 ns	-0.437*
phenanthrene/toc	-0.571**	-0.178 ns	-0.055 ns	-0.398*
fluoranthene/toc	-0.559**	-0.139 ns	-0.022 ns	-0.418*

*p<0.05, **p<0.001, ***p<0.0001

The concentrations of some substances equalled or exceeded the respective ERM guideline values of Long et al. (1995) or Long and Morgan (1990), or the proposed National SQC of U.S. EPA (1994) in some of the samples. The ERM guidelines are the concentrations above which toxicity or other effects frequently occurred in previous studies (Long et al., 1995). The SQCs are the concentrations determined by equilibrium-partitioning models to be protective of benthic organisms. In this study, it was assumed that substances that were correlated with toxicity and equalled or exceeded either the respective ERM or SQC values may have contributed to the observed toxicity. Table 19 summarizes the frequency of guideline exceedances for those chemicals or classes of chemicals that indicated a significant negative correlation with toxicity in at least one of the tests.

None of the samples had concentrations of silver, arsenic, or cadmium that equalled or exceeded the respective ERM values (Table 21). The ERM value for chromium was exceeded only in one sample (12a from the East River). The guideline values for mercury, p,p'-DDT, p,p'-DDE, fluoranthene, phenanthrene, and total high molecular weight PAHs were equalled or exceeded most frequently. Although the ERM value for mercury was exceeded in 30 samples, Long et al. (1995) reported only a moderate degree of confidence in this guideline. The SQC values for fluoranthene and phenanthrene were exceeded in many samples, often by a considerable amount. Many of the chemicals quantified in samples 7b, 9b, 11b, 12a, 17c, and 18c equalled or exceeded their respective guideline concentrations, often by a factor of 2x or greater.

Table 21. Samples from the Hudson-Raritan estuary (Phase 1) stations that equalled or exceeded the respective ERM or SQC guideline concentrations for each major substance or class of compounds. Stations in which the concentration exceeded the guideline by >2x are listed in bold (n=38).

Chemical substance	Number of samples in which ERM or SQC values were exceeded	Samples in which the ERM or SQC was exceeded
Silver (ERM=3.7[a])	0	
Arsenic (ERM=70[a])	0	
Cadmium (ERM=9.6[a])	0	
Chromium (ERM-370[a])	1	12a

Table 21 continued.

Chemical substance	Number of samples in which ERM or SQC values were exceeded	Samples in which the the ERM or SQC was exceeded
Copper (ERM = 270[a])	2	12a, 18c
Mercury (ERM = 0.71[a])	30	1a, 6c, **7b, 8c, 9b, 10a, 10b, 11b, 12a, 12b,13a**, 16a, **16b, 17b, 17c, 18a, 18c, 22c, 23a, 24c, 25a, 26a, 26c, 29a**, 30a, 30b, **30c, 33b**, 36c
Nickel (ERM = 51.6[a])	3	11b, **12a**, 17c
Lead (ERM = 218[a])	8	8c, 9b, **12a,** 10b, 11b, 12b, 17c, 18c
Zinc (ERM = 410[a])	5	9b, **12a**, 18c, 30a, 33b
p,p'-DDE (ERM = 27[a])	12	**9b**, 11b, **12a**, 12b, **17b, 17c, 18a,** 18c, 22c, 23a, 24c, 33b
p,p'-DDT (ERM = 7[b])	14	**9b**, 11b, 12a, **12b, 16a, 16b, 17b, 17c, 18a, 18c, 22c, 23a, 29a, 36c**
total PAHs (ERM = 44792[a])	4	**7b**, 8c, **9b**, 10b
total Low PAHs (ERM = 3160[a])	9	**7b, 8c, 9b, 10b, 11b**, 12a, 12b, 16a, 17c
total High PAHs (ERM = 9600[a])	14	**7b, 8c, 9b, 10b, 11b, 12a**, 12b, 14a, 16a, **16b**, 17b, **17c**, 23a, 26c
Fluoranthene/toc (SQC = 300[c])	20	**7b**, 7c, **8c, 9b, 10b, 11b**, 12a, 12b, 13a, **14a, 16a, 16b**, 17b, **17c, 18a, 18c**, 22c, **23a**, 35a, 36c
Acenaphthene/toc (SQC = 240[c])	2	**9b, 10b**
Phenanthrene/toc (SQC = 240[c])	14	7b, 8c, 9b, **10b**, 11b, **16a**, 17c

[a]Effects Range-Median values from Long et al. (1995)
[b]Effects Range-Median values from Long and Morgan (1990)
[c]Sediment Quality Criteria from U.S. EPA (1994)

Mercury was among the few trace elements that were correlated with amphipod survival. Also, many of the samples exceeded the ERM value for mercury. The relationship between amphipod survival and mercury concentrations in the sediments is illustrated in Figure 30. Amphipod survival decreased relatively steadily with increasing mercury concentrations, especially when the levels exceeded the ERM value of 0.71 (Long et al., 1995).

Microbial bioluminescence EC50s were very low in all of the samples in which the concentrations of 4,4'-DDE were above the ERM value of Long and Morgan, 1990 (Figure 31). Although the Microtox test results and the DDE concentrations were significantly correlated (Rho = -0.405, $p<0.05$), the pattern in response was not nearly as clear as with other toxicity tests and chemicals (i.e., amphipod survival correlated with the PAHs).

The correlations between amphipod survival and the concentrations of all the PAHs were consistent and clear. Also, the concentrations of these compounds often exceeded their respective guidelines. The relationships between amphipod survival and selected PAHs are illustrated in Figures 32-35. At concentrations of total low molecular weight PAHs below the ERM value of Long et al. (1995), amphi-

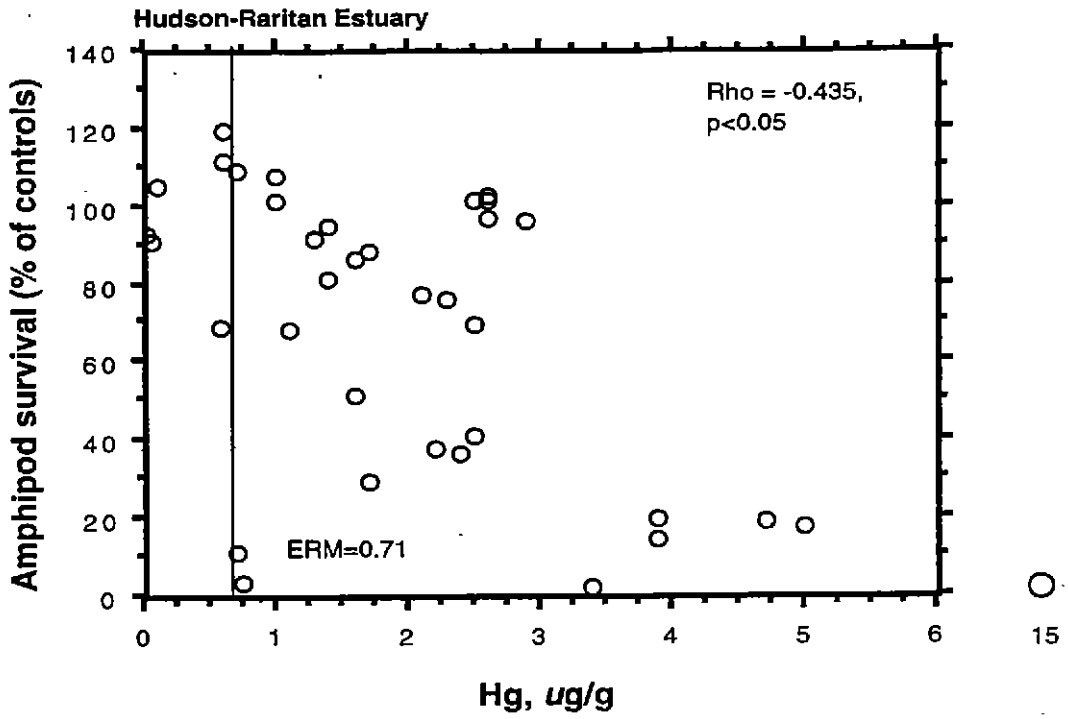

Figure 30. Relationship of amphipod survival to mercury concentrations in sediments.

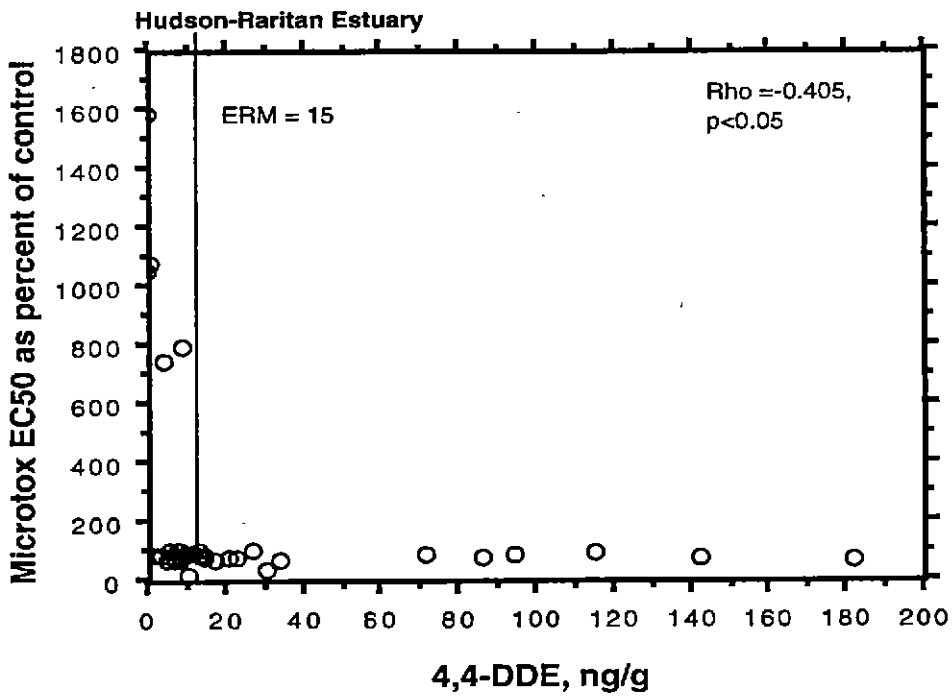

Figure 31. Relationship of microbial bioluminescence EC50s to 4,4-DDE concentrations in sediments.

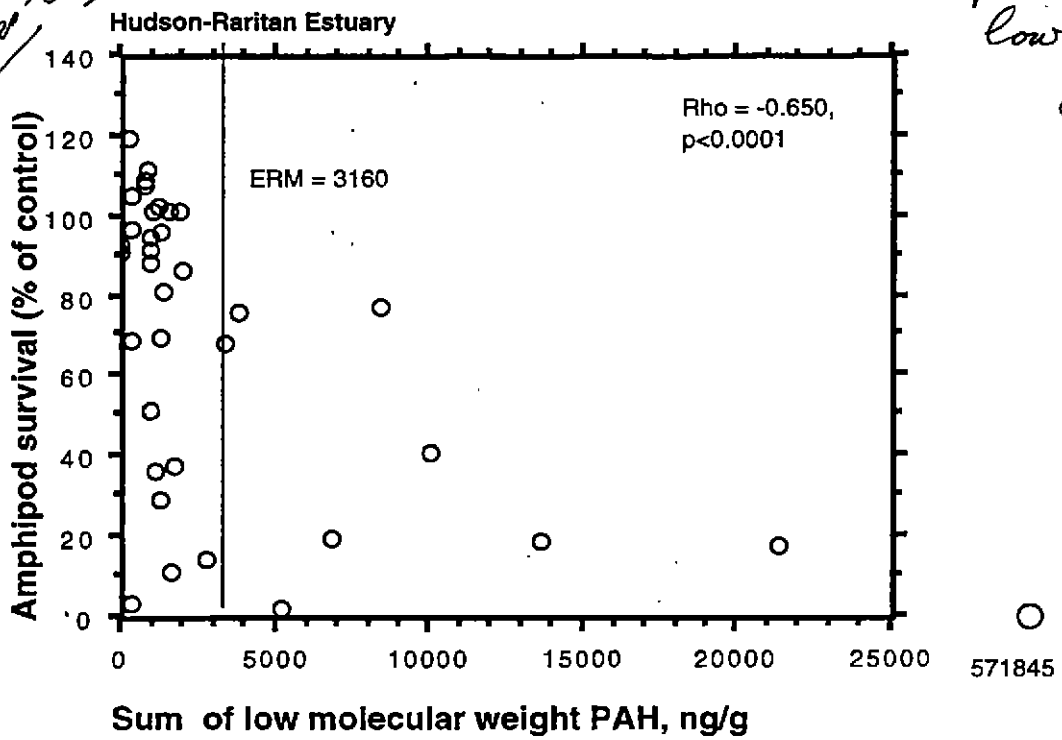

Figure 32. Relationship of amphipod survival to total low molecular weight PAH concentrations in sediments.

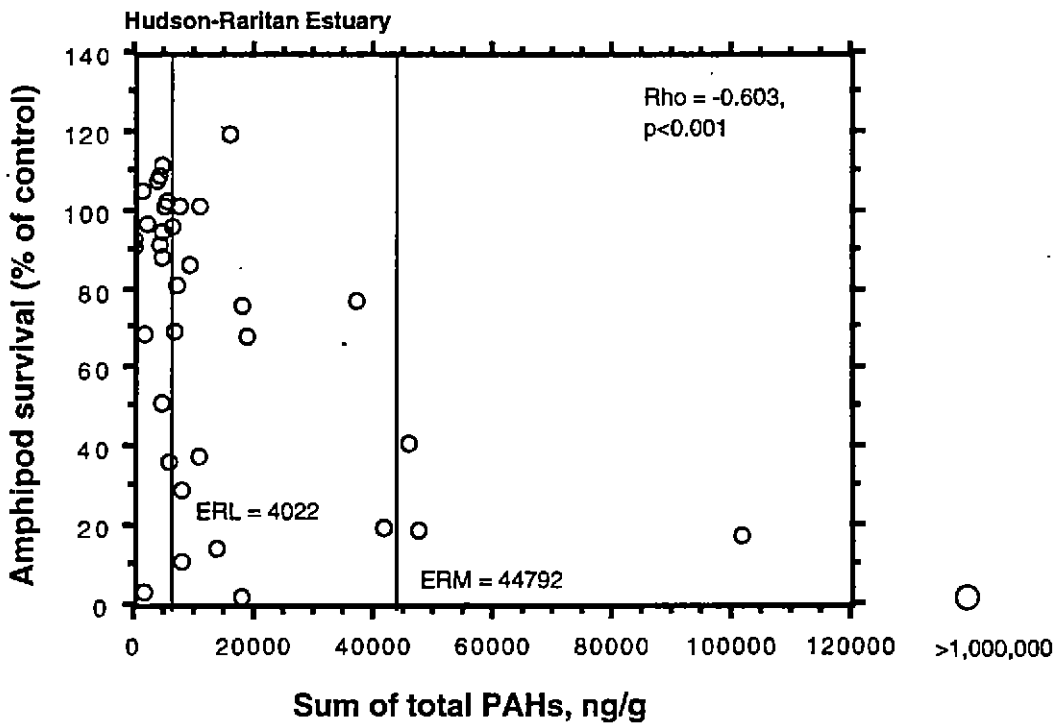

Figure 33. Relationship of amphipod survival and total PAH concentrations in sediments.

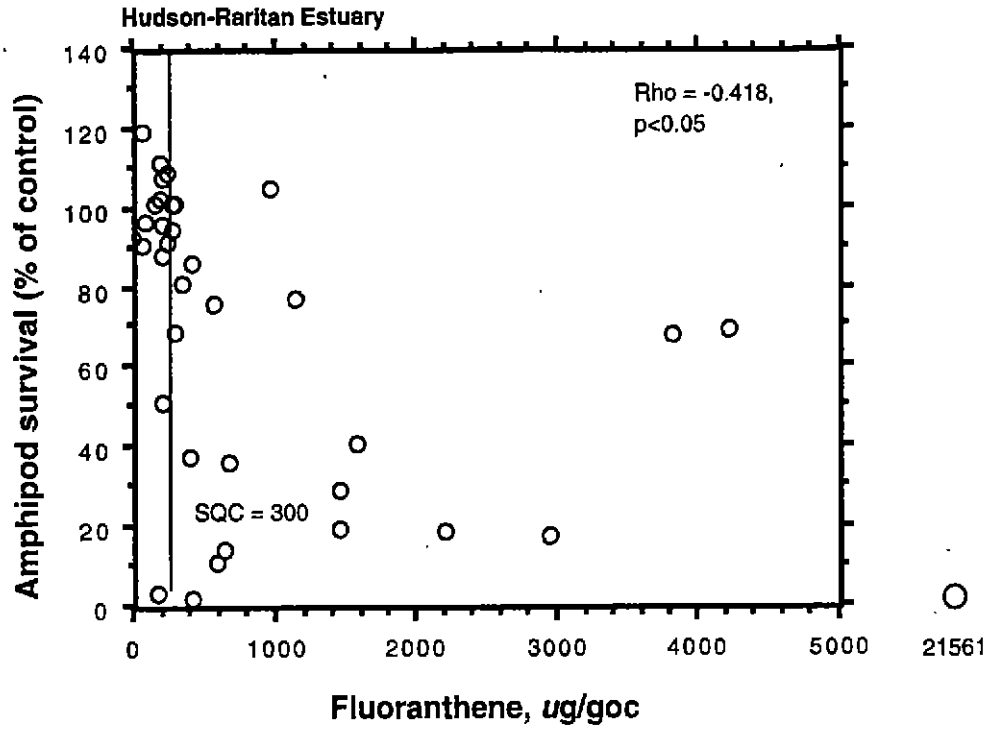

Figure 34. Relationship of amphipod survival to fluoranthene concentrations (ug/goc) in sediments.

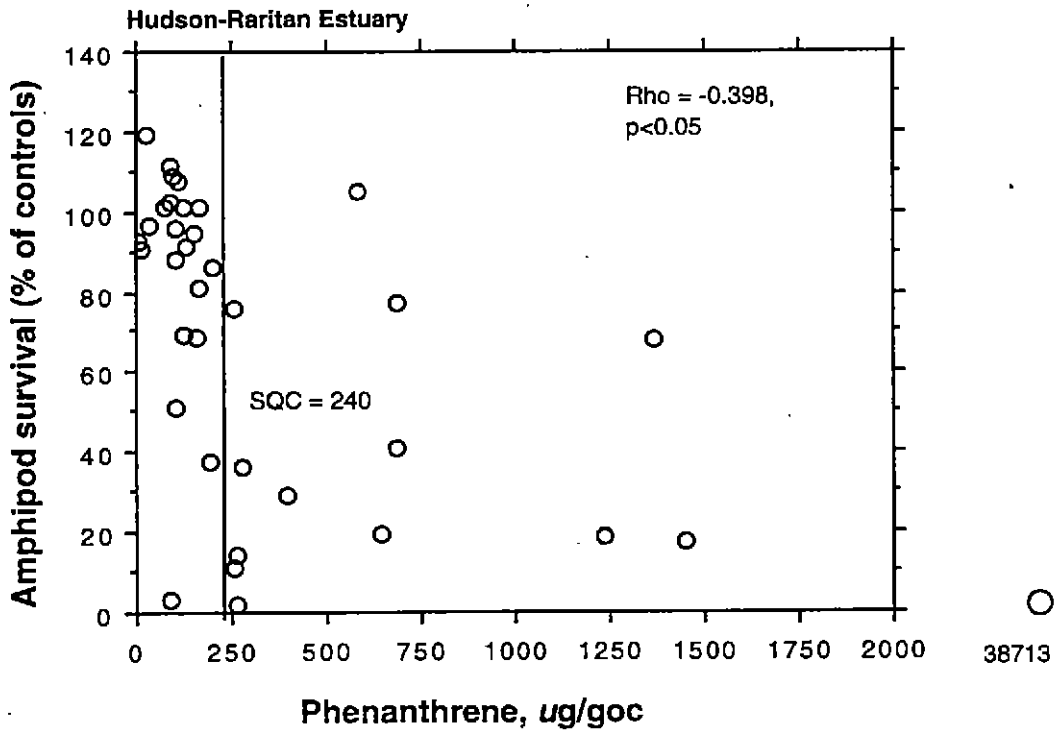

Figure 35. Relationship of amphipod survival to phenanthrene concentrations (*ug*/goc) in sediments.

Too strong of a statement

pod survival was highly variable (Figure 32). Relatively high survival occurred in many of the samples. In the samples in which these compounds equalled or exceeded the ERM value, however, amphipod survival was universally low and significantly different from controls. Amphipod survival was 0.0% in one sample from the East River that had extremely high concentrations of PAHs.

Amphipod survival was very high in all except two samples in which the total PAH concentrations were below the ERL value of Long et al. (1995). Amphipod survival was relatively low in many of the samples with total PAH concentrations above the ERL. Amphipod survival ranged from 0.0% to 40% in the four samples with total PAH concentrations above the ERM guideline. The data in Figure 30 illustrate a relatively consistent decrease in amphipod survival with increasing concentrations of total PAHs, in agreement with the significant correlation (Rho = -0.603, $p<0.001$).

No way!

The concentrations of both fluoranthene and ~~phenanthrene normalized to TOC content~~ were significantly correlated with amphipod survival ~~and the concentrations in many~~ samples equalled or exceeded their respective proposed National SQC (U.S. EPA, 1994). The relationships between these two compounds and amphipod survival are illustrated in Figures 34 and 35. In both cases amphipod survival was relatively high in most samples with chemical levels below the SQC, and decreased steadily as the concentrations exceeded the respective SQCs.

In tables 22-24 the average concentrations of toxicants in the samples that were toxic to amphipod survival are compared to those in the samples that were not toxic. Also, the average concentrations in the toxic samples were divided by the average concentrations in the nontoxic samples and these ratios were compared among chemicals. Finally, the average concentrations in the toxic samples were compared with the sediment quality guidelines (SQG) of Long et al. (1995), or Long and Morgan (1990), or the proposed National SQC (EPA, 1994). No SQG were available for substances such as aluminum and iron. We assumed that chemicals that contributed substantially to the observed toxicity would be correlated with toxicity and highly elevated in concentration in the toxic samples, and the average concentrations in the highly toxic samples would exceed applicable ERM or SQC values. In the amphipod tests 17 samples analyzed for chemical substances were not significantly toxic (i.e., different from controls), 2 were significantly different from controls (but survival exceeded 80% of controls), and 19 samples caused amphipod survival in less than 80% of controls. Average amphipod survival was 98.4% in the nontoxic samples and 30.1% in the highly toxic samples.

The average concentrations of all the trace metals were very similar in the nontoxic, significantly toxic, and highly toxic samples, ~~based upon the results of the~~ amphipod tests (Table 22). The ratios in average concentrations between the nontoxic samples and either the significantly toxic or highly toxic samples ranged from 0.1 to 2.2. Most ratios were 1.0 or thereabouts. The concentrations of mercury in the highly toxic samples were the most elevated of the metals, exceeding the concentrations in the nontoxic samples by a factor of 2.2, and exceeding the ERM value of 0.71 ppm (Long et al., 1995) by a factor of 4.5. The average concentrations of most metals exceeded the ERL values in both the nontoxic and the toxic samples, illustrating the relative similarity in concentrations among the samples. The mean total SEM concentrations exceeded the total AVS concentrations only in the nontoxic samples (a result of two nontoxic, sandy samples). Most of the variability in the SEM/AVS ratios was contributed by the concentrations of zinc in the samples.

The average concentrations of chlorinated organic compounds (PCBs and pesticides) in the toxic samples often were ~~very similar (i.e., ratios of about 1.0)~~ to the concentrations in the significantly toxic samples (Table 23). However, the ratios in ~~chemical concentrations between nontoxic and highly toxic samples~~ often exceeded 2.0 and ranged upwards to 20.3 ~~in the highly toxic samples.~~ The average concentra-

Table 22. Average trace metal concentrations (ppm, dry wt. or *u*mole/g ± s.d.) in samples that were not toxic, significantly toxic (p<0.05), and highly toxic (percent survival < 80% of controls) in amphipod tests, ratios between the averages, and ratios of highly toxic averages to SQGs.

	Non-toxic (98.4±11.1% survival, n=17)	Significantly toxic (86.2±5.0% survival, n=2)	Ratio of toxic to non-toxic averages	Highly toxic (30.1±26.3% survival, n=19)	Ratio of toxic to non-toxic averages	Ratio of highly toxic avg. to SQG
Silver	2.0±1.0*	2.1±0.05*	1.1	1.9±0.7*	0.9	0.5
Aluminum (%)	5.7±2.2	5.4±0.1	0.9	5.1±1.1	0.9	
Arsenic	18.6±10.3*	24.5±3.5*	1.3	20.7±12.0*	1.1	0.3
Chromium	116.1±50.2*	115.0±5.0*	1.0	128.7±81.6*	1.1	0.3
Cadmium	1.2±0.6*	1.7±0.4*	1.4	2.2±1.7*	1.9	0.2
Copper	111.3±62.8*	88.5±9.5*	0.8	174.4±139.0*	1.6	0.6
Iron (%)	3.7±1.4	4.2±0.7	1.1	3.3±1.0	0.9	
Mercury	1.4±1.0**	1.3±0.05**	0.9	3.2±3.1**	2.2	4.5
Manganese	849.4±344.4	610.0±50.0	0.7	556.5±178.8	0.7	
Nickel	34.9±14.2*	32.0±3.0*	0.9	41.0±24.7*	1.2	0.8
Lead	131.4±67.6*	110.0±10.0*	0.8	191.4±123.8*	1.5	0.9
Antimony	1.5±1.0	1.4±0.0	0.9	2.5±2.1	1.6	
Selenium	1.0±0.4	0.7±0.2	0.8	1.1±1.0	1.1	
Tin	16.3±9.3	15.0±2.0	0.9	27.2±21.5	1.7	
Zinc	264.6±123.1*	285.0±65.0*	1.1	330.9±278.8*	1.2	0.8
SE molar Cd	0.007±0.005	0.009±0.003	1.2	0.010±0.008	1.5	
SE molar Cu	0.593±0.337	0.597±0.009	1.0	0.633±-0.528	1.1	
SE molar Hg	<0.0001±0.0	<0.0001±0.0	1.0	<0.0001±0.0	0.5	
SE molar Ni	-0.05±0.055	0.100±0.004	1.0	0.094±0.067	1.0	
SE molar Pb	0.418±0.228	0.396±0.037	1.0	0.542±0.330	1.3	
SE molar Zn	2.185±1.181	2.641±0.920	1.2	2.102±0.936	1.0	
Total SEM	3.299±1.683	3.74±0.87	1.1	3.380±1.643	1.0	
SEM/AVS ratios	1.21±2.41***	0.16±0.06	0.1	0.16±0.15	0.1	
Total molar AVS	25.4±22.6	24.3±5.8	1.0	31.6±20.4	1.2	

*Concentration equals or exceeds ERL value (Long et al., 1995). **Concentrations equals or exceeds ERM value (Long et al., 1995). *** Exceeds ratio of 1.0.

Table 23. Average pesticide and PCB concentrations (ppb, dry wt. ± s.d.) in samples that were not toxic, significantly toxic (p<0.05), and highly toxic (percent survival < 80% of controls) in the amphipod tests, ratios between the averages, and ratios of highly toxic averages to SQGs.

	Non-toxic (98.4±11.1% survival, n=17)	Significantly toxic (86.2±5.0% survival, n=2)	Ratio of toxic to non-toxic averages	Highly toxic (30.1±26.3% survival, n=19)	Ratio of toxic to non-toxic averages	Ratio of highly toxic avg. to SQG
Hexachlorobenzene	4.8±4.8	3.6±2.9	0.7	5.0±5.9	1.0	
Lindane	0.099±0.0	0.099±0.0	1.0	0.16±0.25	1.6	
Heptachlor	0.271±0.0	0.271±0.0	1.0	0.271±0.0	1.0	
Aldrin	0.9±2.0	3.2±3.0	3.4	1.2±3.2	1.3	
Heptachlor epoxide	0.23±0.0	0.23±0.0	1.0	0.52±1.22	2.3	
2,4-DDE	4.7±4.2	4.1±2.7	0.9	17.3±23.2	3.7	
Cis-chlordane	3.3±2.0	2.8±0.1	0.9	6.4±5.6	2.0	
Trans-nonachlor	2.5±1.5	2.1±0.3	0.8	5.0±4.7	2.0	
Dieldrin	2.8±2.6	2.8±0.9	1.0	3.4±3.8	1.2	
4,4-DDE	10.8±8.9*	11.5±3.4*	1.1	43.7±53.5**	4.0	1.6
2,4-DDD	6.1±7.0	6.6±1.4	1.1	28.8±43.6	4.7	
Endrin	0.6±0.0	0.6±0.0	1.0	0.6±0.0	1.0	
4,4-DDD	17.5±19.2*	14.9±2.6*	0.8	86.4±131.2**	4.9	4.3
2,4-DDT	1.8±2.4	1.6±0.8	0.9	13.6±31.3	7.7	
4,4-DDT	7.4±19.0**	7.6±6.9**	1.0	151.2±370.8**	20.3	21.6
Mirex	0.5±1.0	0.2±0.0	0.5	0.2±0.0	0.5	
Sum indeno-pesticides	6.3±3.5	5.5±0.3	0.9	12.2±10.7	1.9	
Sum DDTs	48.4±43.6**	46.3±17.8**	1.0	231.8±312.6**	4.8	5.0
Sum PCB congeners	195.7±131.9	173.1±59.9	0.9	370.0±436.3	1.9	
Total PCBs	391.4±263.8**	346.2±119.8**	0.9	740.0±872.6**	1.9	4.1
Sum non-DDT pesticides	16.0±9.3	16.0±0.5	0.9	22.8±17.7	1.4	

*Concentration equals or exceeds ERL value (Long et al., 1995 or Long and Morgan, 1990). **Concentration equals or exceeds ERM value (Long et al., 1995 or Long and Morgan, 1990).

tions of parent 4,4'-DDT in the highly toxic samples exceeded the average concentration in the nontoxic samples by a factor of 20.3 and exceeded the ERM value of Long and Morgan (1990) by a factor of 21.6. The other isomers of DDT were highly elevated in the highly toxic samples and often exceeded respective ERM guideline values. The sums of the quantified PCB congeners were multiplied by 2.0 to estimate the concentration of total PCB (NOAA, 1989). The average concentrations of total PCBs in the highly toxic samples exceeded the average concentration in the nontoxic samples by a factor of 1.9 and exceeded the ERM value of Long et al. (1995) by a factor of 4.1.

The concentrations of all categories of PAHs were considerably elevated in the samples that were highly toxic to the amphipods relative to the samples that were not toxic (Table 24). The concentrations of organic carbon, inorganic carbon, and fine-grained sediment particles were not elevated in the highly toxic samples to the same degree as the PAHs. The average concentrations of total low molecuar weight PAHs in the toxic samples (34,672 ppb) exceeded the average concentrations in the nontoxic samples (922 ppb) by a factor of 37.6 and exceeded the ERM value for LPAH of Long et al. (1995) by a factor of 11.0. Also, both the high molecular weight compounds and total PAHs were elevated in concentration in the toxic samples relative to the nontoxic samples. The concentrations of both fluoranthene and phenanthrene in the highly toxic samples exceeded both the average concentrations in the nontoxic samples and the respective SQC concentrations by a considerable amount. Although the average concentration of acenaphthene in the toxic samples exceeded the nontoxic average by a factor of 58.7, it exceeded the SQC by a factor of only 2.8.

In tables 25-27 the average concentrations of chemicals in samples that were toxic to microbial bioluminescence were compared with those that were not toxic. As observed in the amphipod tests, the average trace metals concentrations were relatively similar in the toxic and nontoxic samples, as indicated by ratios between the averages of 1.0 or therabouts (Table 25). Among the metals that were quantified, the concentrations of zinc were most elevated in the highly toxic samples; the average concentration of 442 ppm in the highly toxic samples exceeded the average in the nontoxic samples (240.7 ppm) by a factor of 1.8. Also, the concentration of lead in the highly toxic samples (average of 224 ppm) exceeded the average concentration in the nontoxic samples (132.4 ppm) by a factor of 1.7. The average concentrations of both lead and zinc in the highly toxic samples were very similar to the ERM values (218 and 410 ppm, respectively). The average concentrations of mercury in all three categories were very similar (2.0-2.4 ppm) and exceeded the ERM value of 0.71 ppm. The concentrations of trace elements simultaneously extracted with the acid-volatile sulfides were very similar among the three toxicity categories. The SEM/AVS ratios averaged 1.0 in the nontoxic samples and 0.1 in the significantly toxic and highly toxic samples.

Again, as observed in the amphipod tests, most of the pesticides and other chlorinated organics occurred in similar concentrations in both the toxic and nontoxic samples (Table 26). The concentrations of some compounds, such as heptachlor were below the detection limits in all samples, as indicated by standard deviations of 0.0 in all categories. The average concentrations of many compounds (e.g., 4,4'-DDE, 4,4'-DDT) actually were considerably lower in the highly toxic samples than in the nontoxic samples, despite the significant Spearman-rank correlations observed with these data. However, the concentrations in the highly toxic samples often exceeded the respective ERM values. The average concentrations of total PCBs were relatively high, exceeding the ERM value of 180 ppb, in all categories. One highly toxic sample from site 12 in the East River had a detectable concentration of heptachlor epoxide, thus driving up the average for that compound.

Table 24. Average PAH concentrations (ppb, dry wt. ± s.d.) in samples that were not toxic, significantly toxic (p<0.05), and highly toxic (percent survival < 80% of controls) in the amphipod tests, ratios between the averages, and ratios between highly toxic averages and respective SQGs.

	Non-toxic (98.4±11.1% survival, n=17)	Significantly toxic (86.2±5.0% survival, n=2)	Ratio of toxic to non-toxic averages	Highly toxic (30.1±26.3% survival, n=19)	Ratio of toxic to non-toxic averages	Ratio of highly toxic avg. to SQG
Sum petroleum-related	2057±6659	448±125	0.2	12858±46456	6.3	
Sum combustion-related	3526±2257	4214±1158	1.2	44715±118799	12.7	
Sum LPAH	922±583*	1167±220*	1.3	34672±126721**	37.6	11.0
Sum HPAH	6808±8278*	4379±1202*	0.6	48142±120134**	7.1	5.0
Sum total PAH	5427±3838*	5547±1422*	1.0	80270±246981**	14.8	1.8
Percent TOC	2.4±1.1	2.2±0.3	0.9	2.8±1.4	1.2	
Percent TIC	0.2±0.3	0.05±0.02	0.2	0.7±0.8	2.9	
Percent fines	41.4±24.2	41.3±14.6	1.0	37.2±18.8	0.9	
Fluoranthene/toc	474.0±956.3***	299.9±54.9	0.6	2161.7±4672.8***	4.6	7.2
Acenaphthene/toc	11.4±7.1	12.9±4.3	1.1	667.5±2489.8***	58.7	2.8
Phenanthrene/toc	123.1±125.0	151.1±16.4	1.2	2491.1±8548.2***	20.2	10.4

*Concentration equals or exceed ERL value (Long et al., 1995). **Concentrations equals or exceeds ERM value (Long et al., 1995). ***Concentration equals or exceeds proposed SQC (EPA, 1994).

Table 25. Average trace metal concentrations (ppm, dry wt. or *u*mole/g ± s.d.) in samples that were not toxic, significantly toxic (p<0.05), and highly toxic (percent survival < 80% of controls) in Microtox tests, ratios between the averages, and ratios of highly toxic averages to SQGs.

	Non-toxic (EC50s 6.3±8.8, n=22)	Significantly toxic (EC50s 1.7±0.04, n=6)	Ratio of toxic to non-toxic averages	Highly toxic (EC50s 1.3±0.4, n=10)	Ratio of toxic to non-toxic averages	Ratio of highly toxic avg. to SQG
Silver	1.8±0.9*	2.0±0.7*	1.1	2.4±0.1*	1.4	0.6
Aluminum (%)	5.1±2.0	5.4±0.7	1.1	6.0±1.1	1.2	
Arsenic	18.0±11.2*	23.1±13.5*	1.3	22.5±7.7*	1.2	0.3
Chromium	108.0±54.1*	107.0±16.9*	1.0	163.1±90.7*	1.5	0.4
Cadmium	1.6±1.5*	1.6±0.8*	1.0	2.1±1.3*	1.3	0.2
Copper	123.7±112.7*	124.5±42.7*	1.0	191.4±123.5*	1.5	0.7
Iron (%)	3.1±1.3	3.7±1.0	1.2	4.3±0.7	1.3	
Mercury	2.4±3.1**	2.0±1.4**	0.8	2.2±1.2**	0.9	3.1
Manganese	626±275	730±298	1.2	808±333	1.3	
Nickel	32.3±15.4*	35.7±6.2*	1.1	51.3±27.4*	1.6	1.0
Lead	132.4±80.5*	156.5±84.3*	1.2	224.0±127.9**	1.7	1.0
Antimony	1.9±1.7	1.3±0.6	0.7	2.7±2.0	1.4	
Selenium	1.1±0.9	0.8±0.4	0.7	1.1±0.5	1.0	
Tin	18.6±13.1	19.3±8.2	1.0	30.1±25.2	1.6	
Zinc	240.7±131.5*	273.3±89.8*	1.1	442.0±327.3**	1.8	1.1
SE molar Cd	0.0100±0.0100	0.0102±0.0062	1.0	0.0103±0.0062	1.0	
SE molar Cu	0.5800±0.5000	0.5539±0.3818	1.0	0.7117±0.2783	1.2	
SE molar Hg	<.0001±0.0001	<.0001±0.0001	1.0	<.0001±0.0001	1.0	
SE molar Ni	0.1000±0.0700	0.0768±0.0351	0.8	0.0972±0.0297	1.0	
SE molar Pb	0.4100±0.2500	0.3494±0.1530	0.9	0.7065±0.2985	1.7	
SE molar Zn	1.9900±1.0900	1.7569±0.7411	0.9	2.7930±0.8585	1.4	
Total SEM	3.1±1.8	2.7±1.2	0.9	4.3±1.0	1.4	
SEM/AVS ratios	1.0±2.2	0.1±0.1	0.1	0.1±0.1	0.1	
Total molar AVS	22.1±18.4	33.1±27.4	1.5	39.7±16.6	1.8	

*Concentration equals or exceeds ERL value (Long et al., 1995). **Concentrations equals or exceeds ERM value (Long et al., 1995).

Table 26. Average pesticide and PCB concentrations (ppb, dry wt. ± s.d.) in samples that were not toxic, significantly toxic (p<0.05), and highly toxic (percent survival < 80% of controls) in the Microtox tests, ratios between the averages, and ratios of highly toxic averages to SQGs.

	Non-toxic (EC50s 6.3±8.8, n=22)	Significantly toxic (EC50s 1.6±0.04, n=6)	Ratio of toxic to non-toxic averages	Highly.toxic (EC50s 1.3±0.4, n=10)	Ratio of toxic to non-toxic averages	Ratio of highly toxic avg. to SQG
hexachlorobenzene	4.8±5.1	1.9±1.8	0.4	6.6±6.3	1.4	
lindane	0.1±0.0	0.3±0.4	2.9	0.1±0.0	1.0	
heptachlor	0.3±0.0	0.3±0.0	1.0	0.3±0.0	1.0	
aldrin	1.6±3.3	0.2±0.0	0.1	0.9±2.0	0.5	
heptachlor epoxide	0.2±0.0	0.2±0.0	1.0	0.8±1.6	3.4	
2,4'-DDE	12.8±19.0	3.1±1.1	0.2	11.6±19.3	0.9	
cis-chlordane	4.9±5.2*	2.9±1.5*	0.6	5.7±3.4*	1.1	
trans-nonachlor	3.7±4.1	2.4±0.6	0.6	4.6±3.4	1.2	
dieldrin	2.8±2.2*	1.7±2.2*	0.6	4.6±4.7*	1.7	
4,4'-DDE	34.3±50.9**	6.4±4.5*	0.2	24.2±22.6*	0.7	0.9
2,4'-DDD	25.5±41.2	2.6±2.9	0.1	8.9±9.7	0.3	
endrin	0.6±0.0*	0.6±0.0*	1.0	0.6±0.0*	1.0	
4,4'-DDD	71.8±124.7**	8.4±5.0*	0.1	33.7±36.1**	0.5	1.7
2,4'-DDT	12.5±29.2	0.5±0.4	<0.1	1.4±1.5	0.1	
4,4'-DDT	129.5±349.0**	7.8±14.2**	0.1	11.8±12.8**	0.1	1.7
mirex	0.2±0.0	0.9±1.5	3.6	0.2±0.0	1.0	
total indeno- pesticides	9.2±9.3	5.8±2.0	0.6	11.3±8.3	1.2	
total DDTs	192.3±299.9**	28.8±23.4*	0.1	91.7±84.6**	0.5	2.0
total PCB congeners	258.0±215.8	116.8±37.0	0.5	432.4±527.5	1.7	
total PCBs	516.0±431.6**	233.6±74.0**	0.5	864.8±1055.0**	1.7	4.8
total non-DDT pesticides	19.4±14.8	11.3±4.6	0.6	24.3±15.1	1.3	

*Concentration equals or exceeds ERL value (Long et al., 1995 or Long and Morgan, 1990). **Concentration equals or exceeds ERM value (Long et al., 1995 or Long and Morgan, 1990).

Table 27. Average PAH concentrations (ppb, dry wt. ± s.d.) in samples that were not toxic, significantly toxic (p<0.05), and highly toxic (percent survival < 80% of controls) in the Microtox tests, ratios between the averages, and ratios between highly toxic averages and respective SQGs.

	Non-toxic (EC50s 6.3±8.8, n=22)	Significantly toxic (EC50s 1.7±0.04, n=6)	Ratio of toxic to non-toxic averages	Highly toxic (EC50s 1.3±0.4, n=10)	Ratio of toxic to non-toxic averages	Ratio of highly toxic avg. to SQG
Sum petroleum-related	845±1380	6701±10076	7.9	22135±62558	26.2	
Sum combustion-related	9332±16650	13910±14373	1.5	62917±160149	6.7	
Sum LPAH	2337±4389*	4518±5300**	1.9	59824±170688**	25.6	18.9
Sum HPAH	10311±17071**	18502±15735**	1.8	70134±160861**	6.8	7.3
Sum of total PAH	11948±21406*	21146±18495*	1.8	123875±333291**	10.4	2.8
percent TOC	2.2±1.2	2.7±0.8	1.2	3.6±1.0	1.6	
percent TIC	0.4±0.6	0.3±0.3	0.8	0.7±0.8	1.9	
percent fines	34.3±24.0	47.4±13.5	1.4	45.2±15.0	1.3	
fluoranthene/toc	672.3±927.1***	951.9±829.8***	1.4	2922.7±6319.5***	4.3	9.7
acenaphthene/toc	33.6±48.1	110.6±151.8	3.3	1149.9±3357.7***	34.2	4.8
phenanthrene/toc	293.6±385.9***	422.6±427.9***	1.4	4073.2±11548.0***	13.9	17.0

*Concentration equals or exceed ERL value (Long et al., 1995). **Concentrations equals or exceeds ERM value (Long et al., 1995). ***Concentration equals or exceeds proposed National SQC (EPA, 1994).

All of the classes of PAHs were considerably elevated in concentration in the samples that were highly toxic to microbial bioluminescence (Table 27). The average concentration of LPAH in the highly toxic samples exceeded the average concentration in the nontoxic samples by a factor of 25.6 and exceeded the ERM value by a factor of 18.9. Also, the concentrations of petroleum-related compounds, acenaphthene, and phenanthrene were very high in the highly toxic samples. All three of the individual PAHs exceeded the proposed National SQCs (U.S. EPA, 1994) in the highly toxic samples. The concentrations of organic carbon, inorganic carbon, and fine-grained sediments were slightly higher in the highly toxic samples relative to the nontoxic samples.

Relationships between Toxicity and Physical-Chemical Parameters: Phase 2. The Spearman-rank correlations between amphipod survival in the Phase 2 samples and the concentrations of trace metals are compared in Table 28. The correlations were performed for the concentrations of total individual metals, total acid-volatile sulfides (AVS), and the SEM/AVS ratios. The correlations between percent amphipod survival and total metals concentrations were significant for all elements except arsenic, aluminum, iron, nickel, and antimony. The concentrations of total cadmium were most strongly correlated with amphipod survival. Also, amphipod survival was significantly correlated with increasing concentrations of AVS. However, the ratios of total SEM to total AVS were not correlated with amphipod survival. If the number of variables (16) were taken into account, only correlations listed as "**" would remain significant.

Table 28. Spearman-rank correlations (Rho, corrected for ties) between percent amphipod survival and the concentrations of total trace metals and with the ratios of simultaneously extracted metals (SEM) to acid-volatile sulfides (AVS) in Phase 2 sediments (n=20).

	Total metals (ug/g dry wt.)	SEM/AVS (u moles/g)
Silver	-0.585*	
Arsenic	-0.332 ns	
Aluminum	-0.095 ns	
Cadmium	-0.777**	
Chromium	-0.673*	
Copper	-0.723*	
Iron	-0.209 ns	
Mercury	-0.612*	
Nickel	-0.137 ns	
Lead	-0.681*	
Antimony	-0.378 ns	
Tin	-0.734*	
Selenium	-0.647*	
Zinc	-0.534*	
Total AVS		-0.565*
SEM/AVS ratios		+0.248 ns

ns = not significant (p>0.05). * p<0.05 ** p<0.001
SEM = (sum of Cd, Cu, Pb, Ni, Zn)

The Spearman-rank correlation coefficient for amphipod survival and the concentration of un-ionized ammonia in the overlying water in the amphipod test chamber was not significant (Rho = -0.105,

p>0.05, n=50). The concentration of un-ionized ammonia exceeded the detection limit (0.35 *ug*/l) in seven of the samples and the maximum recorded concentration was 620 *ug*/l. Three of the samples exceeded the no- observed-effects concentration and none equalled or exceeded the unionized ammonia LC50 for *A. abdita* (Figure 36) reported by Kohn et al. (1994).

The correlations between amphipod survival and the concentrations of chlorinated organic compounds and total organic carbon are listed and compared in Table 29. Nearly all of the pesticides and PCB groups were significantly correlated with toxicity to the amphipods. Compounds that were very highly correlated with amphipod survival included dieldrin (expressed both in dry weight and organic carbon), p, p'-DDE, and total PCBs (estimated by GC, as the total of quantified congeners, and by GC/MS). Amphipod survival was more highly correlated with the DDE isomers than with the DDT isomers. The correlations with endrin were not significant. The correlations with total organic carbon also were not significant. If the number of variables tested (18) were accounted for, only those correlations shown with "**" would be significant.

Table 29. Spearman-rank correlations (Rho, corrected for ties) between percent amphipod survival and the concentrations of chlorinated organic compounds in Newark Bay sediments (n=20).

Chemical name	Correlation coefficient	Chemical name	Correlation coefficient
hexachlorobenzene	-0.633*	pentachloro anisole	-0.599*
alpha-BHC	-0.234 ns	lindane	-0.242 ns
beta-BHC	+0.174 ns	heptachlor	-0.100 ns
delta-BHC	-0.487*	dacthal	-0.289 ns
oxychlordane	-0.633*	heptachlor epoxide	-0.680*
trans-chlordane	-0.705*	trans-nonachlor	-0.699*
cis-chlordane	-0.677*	o, p'-DDE	-0.707*
dieldrin	-0.848**	p, p'-DDE	-0.800**
o, p'-DDD	-0.629*	endrin	-0.437 ns
cis-nonachlor	-0.707*	o, p'-DDT	-0.576*
p, p'-DDD	-0.597*	p, p'-DDT	-0.253 ns
mirex	-0.569*	total GC PCBs	-0.802**
total DDTs	-0.576*	sum of total PCBs	-0.783**
percent TOC	-0.205 ns	endrin/toc	-0.253 ns
dieldrin/toc	-0.841**		

ns = not significant (p>0.05). *p<0.05, **p<0.001

The correlations between amphipod survival and the concentrations of nearly all the dioxin and furan compounds were highly significant (Table 30). The concentrations were expressed as units of dry weight for individual compounds. Also, the concentrations of selected compounds were multiplied by the respective 2,3,7,8-tcdd toxicity equivalency factors of Barnes et al. (1991) for co-planar PCBs and Kutz et al. (1990) for dioxins and furans and summed to estimate the total toxicity equivalency quotients (TEQ). The correlations were particularly strong for 2,3,7,8-tcdd, 2,3,7,8-tcdf, the cumulative 2,3,7,8-tcdd TEQ for total PCBs, and the total cumulative TEQ for dioxins, furans, and PCBs. Amphipod survival was significantly correlated with tcdd-equivalent concentrations determined in H4IIE rat hepatoma bioassays of the whole F1 extract and several of the extract fractions, but not with the F5 fraction (PAHs). If the number of variables tested (28) were accounted for, only those correlations shown with "**" would be significant.

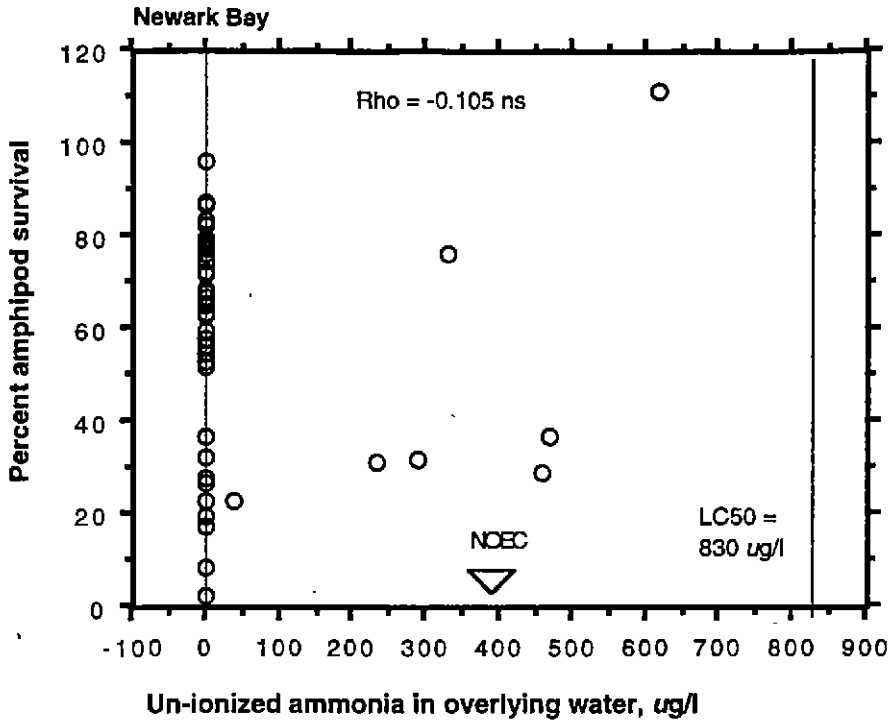

Figure 36. Relationship of amphipod survival to the concentrations of un-ionized ammonia (*ug/l*) in the overlying water of the test chambers.

Table 30. Spearman-rank correlations (Rho, corrected for ties) between percent amphipod survival and the concentrations of chlorinated dibenzo dioxin and dibenzo furan compounds in Newark Bay sediments (n=20).

Chemical name	Correlation coefficient	Chemical name	Correlation coefficient
✓ 2378-tcdd	-0.868**	12378-pcdd	-0.683*
12478-pcdd	-0.539*	123478-hcdd	-0.725*
✓ 123678-hcdd	-0.761**	123789-hcdd	-0.684*
1234678-hcdd	-0.734*	octodichloro-dd	-0.675*
✓ 2378-tcdf	-0.863**	12378-pcdf	-0.714*
23478-pcdf	-0.731*	123478-hcdf	-0.639*
123678-hcdf	-0.677*	123789-hcdf	-0.584
234678-hcdf	-0.558*	1234678-hcdf	-0.618*
1234789-hcdf	-0.654*	octochloro-df	-0.613*
✓ total dioxins TEQ	-0.866**	✓ total PCBs TEQ	-0.850**
✓ total cumulative TEQ	-0.865**	✓ total F1 extract	-0.614**
F5 fraction	-0.393 ns	F7 fraction	-0.128 ns
✓ F8 fraction	-0.659**	✓ F9 fraction	-0.599**
✓ F11 fraction	-0.630**	✓ F12 fraction	-0.815***

ns = not significant (p>0.05), *p<0.05, **p<0.001

None of the correlations between amphipod survival and the concentrations of PAHs were statistically significant (Table 31). These results are in sharp contrast with those from the Phase 1 samples, in which the PAHs were highly correlated with toxicity to amphipods.

Table 31. Spearman-rank correlations (Rho, corrected for ties) between percent amphipod survival and the concentrations of polynuclear aromatic hydrocarbons (PAHs) in Newark Bay sediments (n=20).

Chemical name	Correlation coefficient	Chemical name	Correlation coefficient
naphthalene	-0.149 ns	benzo(b)thiophene	-0.394 ns
2-methyl naphthalene	-0.313 ns	1-methyl naphthalene	-0.262 ns
biphenyl	-0.131 ns	2,6/2,7 dimethyl naphthalene	+.023 ns
acenaphylene	-0.212 ns	acenapthene	-0.162 ns
fluorene	-0.131 ns	dibenzothiophene	-0.402 ns
phenanthrene	-0.212 ns	anthracene	+0.013 ns
fluoranthene	-0.244 ns	pyrene	-0.359 ns
benzo(a)anthracene	-0.145 ns	chrysene	-0.209 ns
benzo(b)fluoranthene	-0.138 ns	benzo(k)fluoranthene	-0.206 ns
benzo(e)pyrene	-0.186 ns	benzo(a)anthracene	-0.147 ns
perylene	-0.122 ns	indeno(1,2,3)pyrene	-0.185 ns
dibenzo(a,h)anthracene	-0.188 ns	benzo(g,h,i)perylene	-0.203 ns
total LPAH	-0.098 ns	total HPAH	-0.203 ns
sum total PAH	-0.194 ns	acenaphthene/toc	-0.152 ns
phenanthrene/toc	-0.241 ns	fluoranthene/toc	-0.346 ns

ns = not significant (p>0.05)

The concentrations of many of the chemicals quantified in Phase 2 equalled or exceeded respective guideline values (Table 32). In particular, the concentrations of many chlorinated organic compounds, such as 2,3,7,8-tcdd, the isomers of DDT, and total PCBs, equalled or exceeded the respective guidelines in many of the samples. The concentrations of 2,3,7,8-tcdd exceeded the proposed sediment guideline (100 pg/g, parts per trillion) for the protection of benthic organisms (U.S. EPA, 1993) and human health receptors (New York Sate Department of Environmental Conservation, 1993) by more than two fold in many samples. The cumulative 2378-tcdd toxicity equivalency quotients (TEQ) for all of the dioxins, furans, and PCBs also exceeded the guideline value by factors of up to four fold. All three p,p- isomers of DDE, DDD, and DDT equalled or exceeded the respective ERM values (Long et al., 1995; Long and Morgan, 1990) in many samples. However, the authors of these reports expressed only a moderate degree of confidence in these guidelines. The concentrations of total PCB congeners exceeded the ERM value of 180 ppb in most of the samples.

The concentrations of many of the chlorinated organic compounds were elevated, frequently by >2X, in many of the Phase 2 samples. In comparison, the concentrations of most trace elements were not particularly elevated in these samples (Table 32). None of the samples had concentrations of arsenic, cadmium, copper, or chromium that exceeded the respective ERM values. Although many of the samples had mercury concentrations that exceeded the ERM value of 0.71 ppm, Long et al. (1995) had only a moderate degree of confidence in this ERM value. Lead and zinc concentrations equalled or exceeded the respective ERM values in 10 samples, but never by a factor of two fold or greater. The

concentrations of both low and high molecular weight PAHs were elevated in many samples; however, the concentrations of total PAHs exceeded the ERM value in only two samples. The PAH concentrations were particularly high in the sample from station 1 in the Passaic River. The samples collected in the Passaic River (stations 1-11) and the sample from station 26 (central Newark Bay) had elevated concentrations of many chemicals.

Table 32. Samples from the Phase 2 stations that equalled or exceeded the respective ERM or SQC values for each major substance or class of compounds. Stations in which the concentration exceeded the guideline by >2x are listed in bold (n=20).

Chemical substance	Number of samples in which guideline values were exceeded	Samples in which the ERM or SQC was exceeded
2378-tcdd (SQG = 100 ppt[a])	11	**3, 5, 7a, 7b, 7c, 8a, 8b, 10, 11,** 21, **26**
total cum. PCB TEQ (SQG = 100 ppt[a])	2	7c, 26
total dioxins TEQ ppt[a])	14	1, **3, 5, 7a, 7b, 7c, 8a, 8b, 10,** 11, (SQG = 100 **11,** 14, 21, **26,** 31
total cumulative TEQ ppt[a])	15	1, **3, 5, 7a, 7b, 7c, 8a, 8b, 10,** 11, (SQG = 100 **11,** 14, **21, 26,** 31, 36
p,p' - DDE (ERM = 27 ppb[b])	13	3, **5,** 7a, 7b, **7c, 8a,** 8b, **10,** 11, **26,** 31, 36, 56
total PCBs (ERM = 180 ppb[b])	16	**1, 3, 5, 7a, 7b, 7c, 8a, 8b, 10, 11,** 14, 21, **26,** 31, 36, 56
p, p' - DDD (ERM = 20 ppb[c])	15	1, **3, 5, 7a, 7b, 7c, 8a, 8b, 10, 11,** 14, 26, 31, 36, 56
p, p' - DDT (ERM = 7 ppb[c])	14	1, **3, 5, 7a, 7b, 7c, 8a, 8b, 10, 11, 14, 31, 36, 56**
total DDTs (ERM = 46.1 ppb[b])	15	1, **3, 5, 7a, 7b, 7c, 8a, 8b, 10, 11, 14, 26, 31, 36, 56**
dieldrin/oc (SQC = 20 *u*g/goc[d])	0	none
endrin/oc (SQC = 0.76 *u*g/goc[d])	0	none
silver (ERM = 3.7 ppm[b])	7	5, 7a, 7b, 7c, 8a, 8b, 10
arsenic (ERM = 70 ppm[b])	0	none
cadmium (ERM = 9.6 ppm[b])	0	none
chromium (ERM = 370 ppm[b])	0	none
copper (ERM = 270 ppm[b])	0	none
mercury (ERM = 0.71 ppm[b])	17	**3, 5, 7a, 7b, 7c, 8a, 8b, 10, 11, 14,** 17, **20, 21, 26, 31, 36, 56**
nickel (ERM = 51.6 ppm[b])	3	10, 11, 56
lead (ERM = 218 ppm[b])	10	3, 5, 7a, 7b, 7c, 8a, 8b, 10, 11, 14
zinc (ERM = 410 ppm[b])	10	3, 5, 7a, 7b, 7c, 8a, 8b, 10, 11, 20
total LPAH (ERM = 3160 ppb[b])	9	**1, 3,** 5, 7a, 7b, 8b, 14, 20, 21
total HPAH (ERM - 9600 ppb[b])	13	**1, 3, 5, 7a, 7b,** 7c, 8a, **8b, 11, 14,** 17, **20, 21**

Table 32 continued.

Chemical substance	Number of samples in which guideline values were exceeded	Samples in which the ERM or SQC was exceeded
total PAH (ERM = 44792 ppb[b])	2	**1, 3**
acenaphthene (SQC = 230 *ug*/goc[d])	0	none
phenanthrene (SQC = 240 *ug*/goc[d])	1	**1**
fluoranthene (SQC = 300 *ug*/goc[d])	3	**1**, 20, 21

[a]Sediment Quality Guidelines from U.S. EPA (1993).
[b]Effects Range Median values from Long et al. (1995)
[c]Effects Range Median values from Long and Morgan (1990)
[d]Sediment Quality Criteria from U.S. EPA (1994)

The relationships between amphipod toxicity and the concentrations of a number of toxic chemicals in the samples are plotted in the following graphs (Figures 37-45). In addition, each graph includes the Spearman-rank correlation coefficient for that particular chemical and the respective sediment quality guideline value.

Amphipod survival decreased steadily with increasing concentrations of p,p'-DDE in the samples (Figure 37). In the two samples with very high amphipod survival, the concentrations of p,p'-DDE were very low (<10 ng/g). In the sample that caused zero amphipod survival, the concentration of p,p'-DDE was the highest among the 20 samples (>70 ng/g). In most of the samples in which p,p'-DDE concentrations were less than the ERM value (27 ng/g, Long et al., 1995), amphipod survival was relatively high (>70% in all but one sample). In contrast, amphipod survival was relatively low (<70%) in all but one sample in which the concentrations of p,p'-DDE exceeded the ERM value. However, MacDonald (1994) estimated a Sediment Effect Concentration (SEC) of 6.58 mg/kg dry wt. (6580 ng/g) for the sum of DDEs, two orders of magnitude greater than the highest concentrations observed in the Phase 2 samples. Based upon a database compiled from studies focused upon the effects of the DDTs, the SEC of MacDonald (1994) probably is more reliable than the ERM of Long et al. (1995). Therefore, although amphipod survival was strongly correlated with the concentrations of p,p'-DDE, this compound probably contributed minimally to the toxicity since the concentrations were far below a reliable threshold concentration.

Although the correlation between amphipod survival and the concentrations of the sum of the six DDT isomers was significant (Rho = -0.576, $p<0.05$), the concentrations of these compounds were relatively low. Total DDT concentrations ranged from 9.5 to 287.4 ng/g (median = 169.0 ng/g), considerably lower than the estimated SEC of 7120 ng/g (MacDonald, 1994). Expressed in units of organic carbon, total DDT concentrations ranged from 0.6 to 12.0 *ug*/goc (median = 4.4 *ug*/goc); again well below the 10-day toxicity threshold in laboratory bioassays (300 *ug*/goc) and the 10-day LC50 (2500 *ug*/goc) in field-collected sediments for the amphipod *Eohaustorius estuarius* (Swartz et al., 1994).

There was a very strong relationship between amphipod survival and the concentrations of total PCB congeners, as illustrated by a Spearman-rank correlation of 0.802. The concentrations of total PCBs

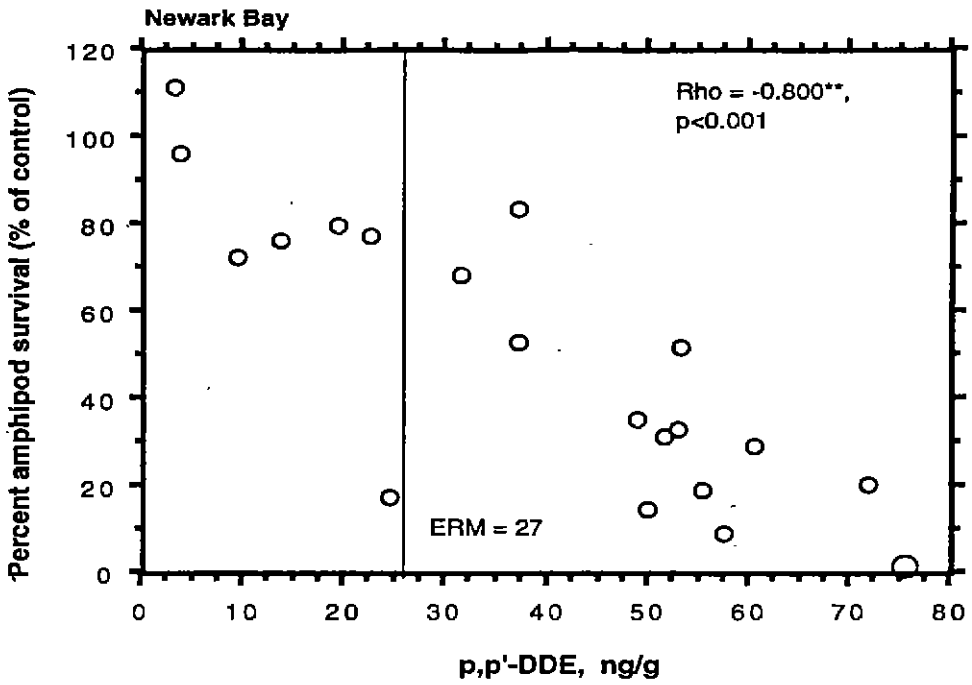

Figure 37. Relationship of amphipod survival to the concentrations of p, p' - DDE in Newark Bay sediment samples.

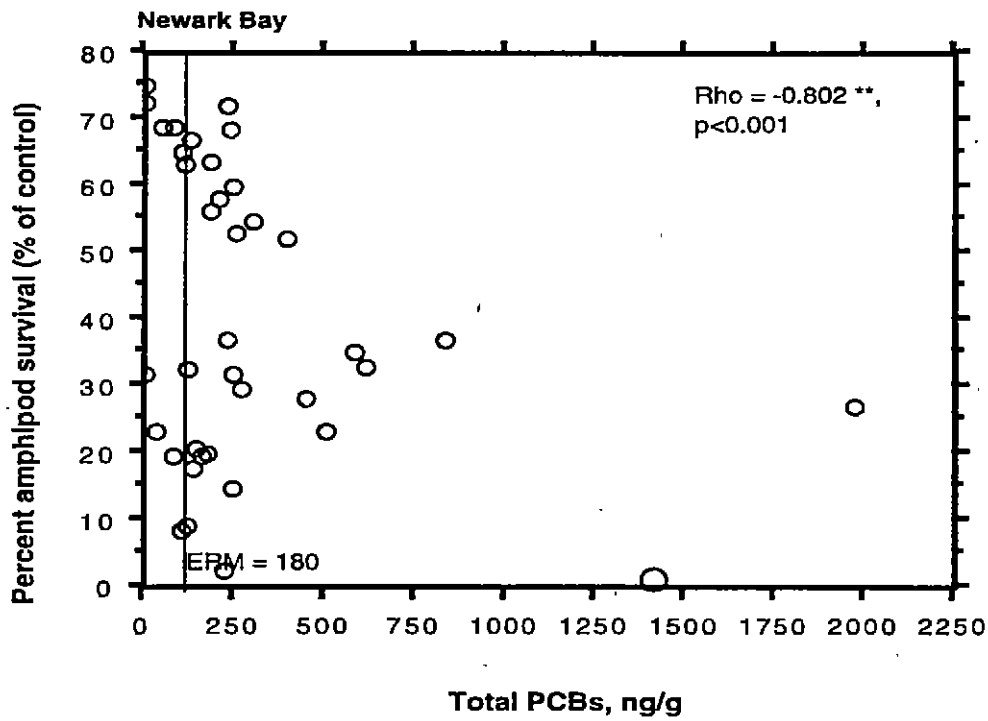

Figure 38. Relationship of amphipod survival to the concentrations of total PCB congeners in Newark Bay sediment samples.

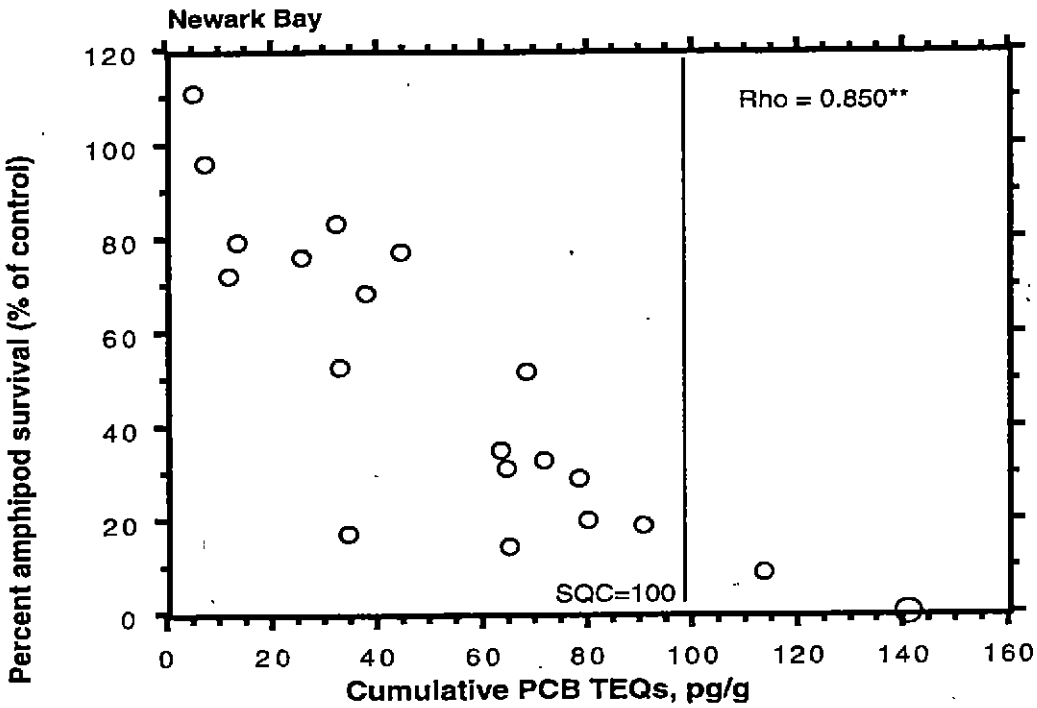

Figure 39. Relationship between amphipod survival and the concentrations of 2,3,7,8-TCDD toxicity equivalency quotients for the co-planar PCB congeners in Newark Bay sediments.

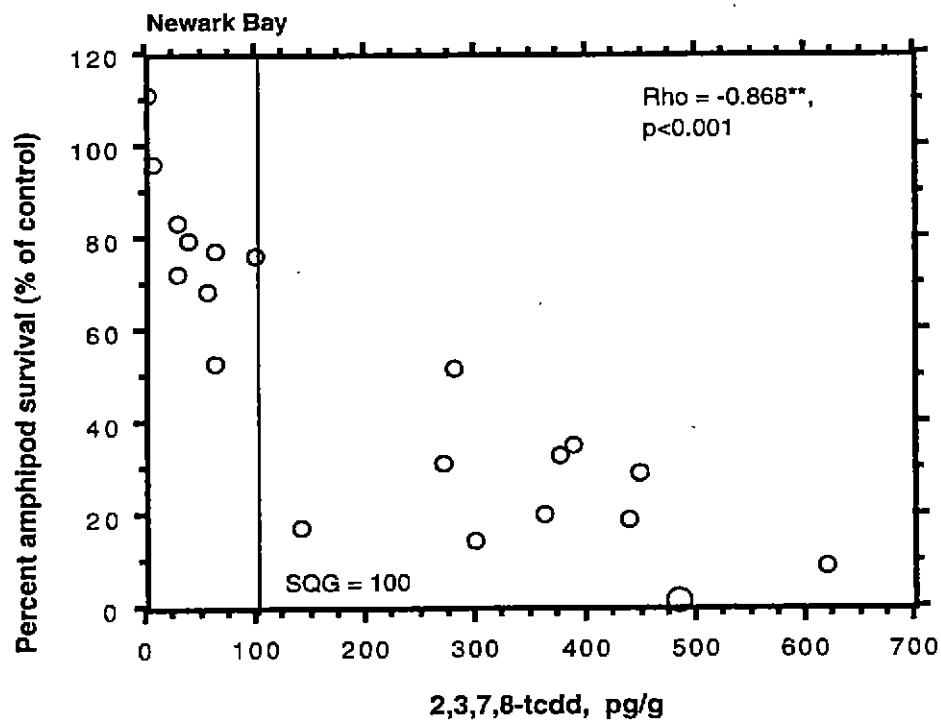

Figure 40. Relationship of amphipod survival to the concentrations of 2,3,7,8-TCDD in Newark Bay sediment samples.

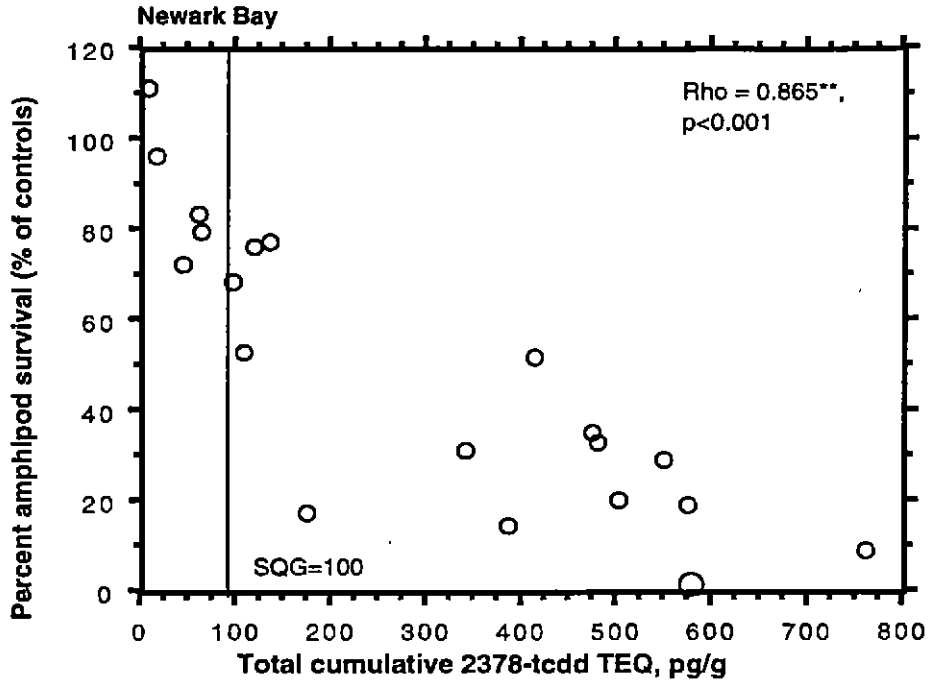

Figure 41. Relationship between amphipod survival and the concentration of total cumulative 2,3,7,8-TCDD toxicity equivalency quotients in Newark Bay sediments.

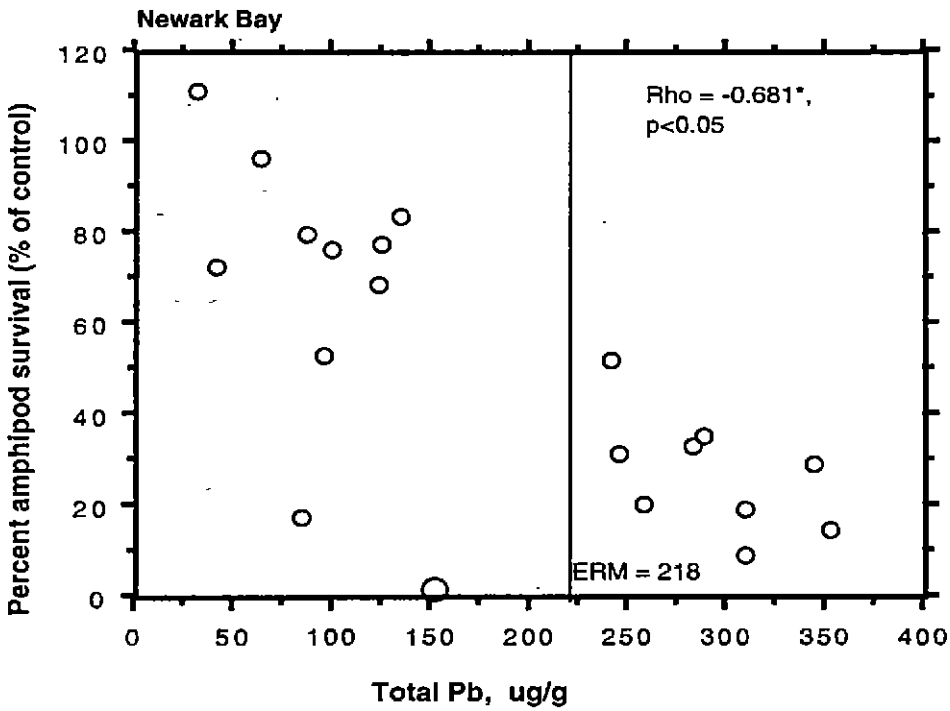

Figure 42. Relationship of amphipod survival to the concentrations of total lead in Newark Bay sediment samples.

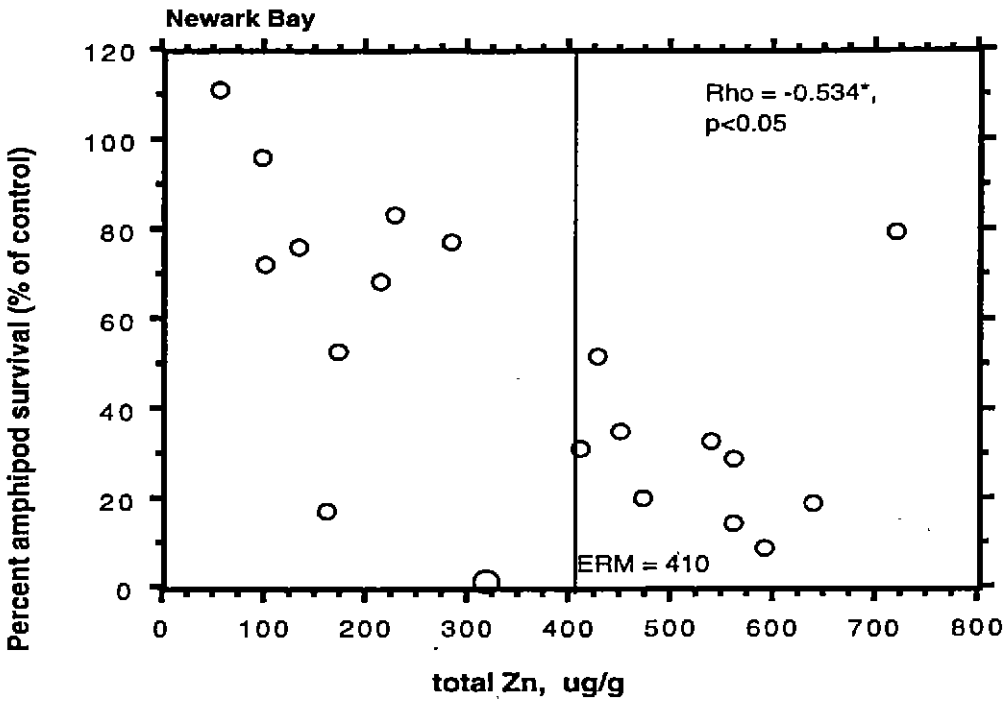

Figure 43. Relationship of amphipod survival to the concentrations of total zinc in Newark Bay sediment samples.

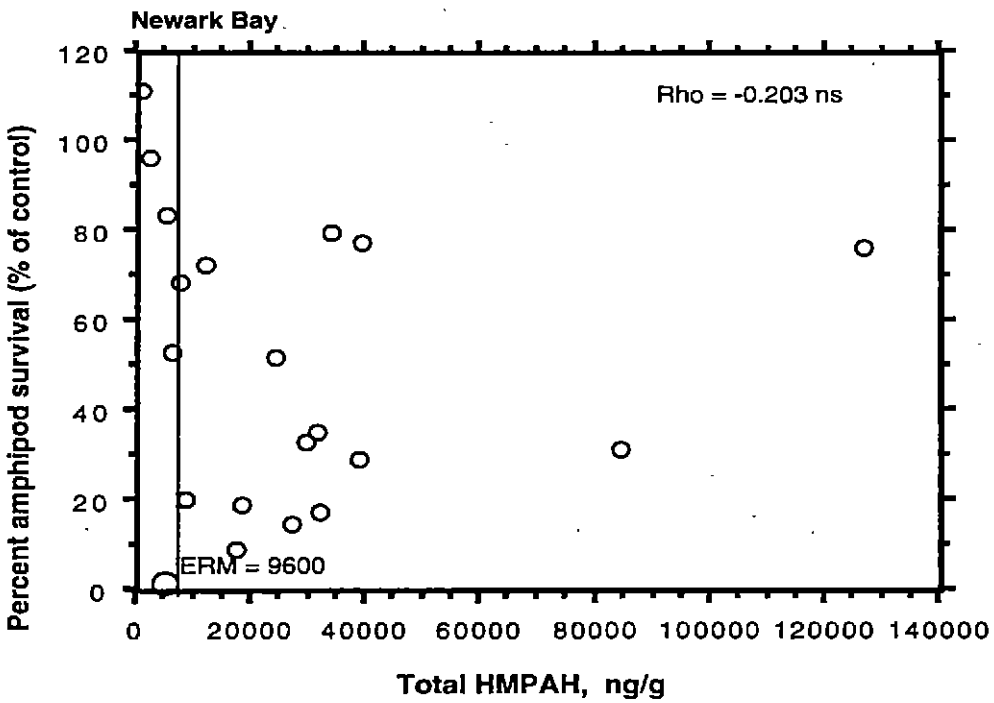

Figure 44. Relationship of amphipod survival to the concentrations of total high molecular weight PAHs in Newark Bay sediment samples.

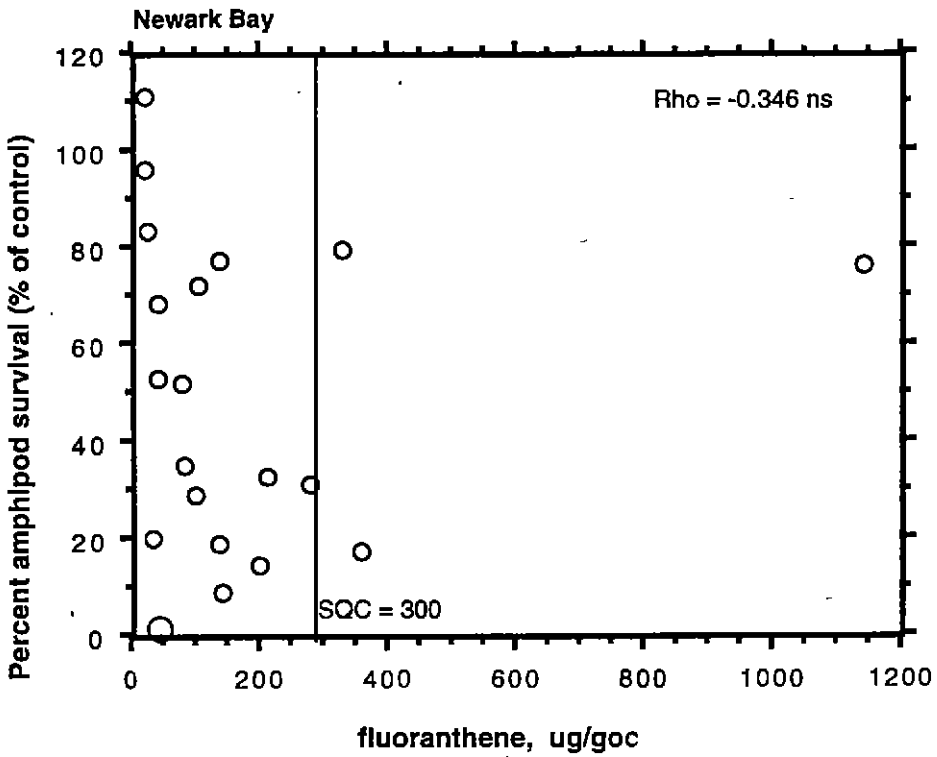

Figure 45. Relationship of amphipod survival to the concentrations of fluoranthene in Newark Bay sediment samples.

exceeded the ERM value of 180 ng/g (Long et al., 1995) in all except three samples, and most of these samples were highly toxic to the amphipods (Figure 38). Total PCB concentrations ranged from 105.5 to 2,850.2 ng/g (median = 879.2 ng/g). Amphipod survival was zero in a sample with approximately 1,400 ng tPCB/g. MacDonald (1994) estimated the SEC for total PCBs as 0.592 mg/kg dry wt (592 ng/g). All of the samples that equalled or exceeded a total PCB concentration of 592 ng/g caused 50% or less amphipod survival. One sample had over 2,800 ng tPCB/g and caused less than 40% amphipod survival. It appears that the PCBs may have made a major contribution to the toxicity to the amphipods.

The concentrations of four co-planar PCBs were normalized to (multiplied by) the toxicity equivalency factors (TEFs) (Barnes et al., 1991) for each congener and the sums of those quotients were calculated. The cumulative toxicity equivalency quotients (TEQ) for the co-planar PCBs were highly correlated with amphipod survival (Figure 39). There is no consensus toxicity threshold value for these quotients. Many different estimates have been made of critical or threshold values and they differ from each other by many orders of magnitude (Iannuzzi et al., 1995). In two samples the cumulative TEQs for the PCB congeners were higher than one estimate of a threshold, 100 pg/g for fish and human receptors (U.S. EPA, 1993; New York State DEC, 1993, respectively), but the reliability of this threshold value is unknown. The sample from station 26 caused 100% amphipod mortality and had about 140 pg/g cumulative TEQs for the co-planar PCBs. Among all the chemicals quantified, only the concentrations of these compounds and p,p'-DDE were highest in the sample from station 26 where amphipod survival was zero.

Another source of variability in results among the tests is the exposure medium that was tested. The amphipods are tube-dwelling, epifaunal organisms and were exposed to solid phase sediments for 10 days. The clam larvae were planktonic and exposed to liquid phase samples for 48 hours. The bacteria were cultured in laboratory equipment and exposed for 5 minutes to an organic extract of the sediments. The solvent extraction elutes potentially toxic contaminants from the sediments, and, therefore, enhances their apparent availability. The Microtox tests probably provide an estimate of the toxicity potential of the total bulk contaminant content of the sediments, instead of the biologically available fraction.

Summary of Chemistry/Toxicity Relationships. The data from Phase 1 of the Hudson-Raritan Estuary survey were examined to determine (1) which chemicals were correlated significantly with the measures of toxicity; (2) which chemicals also were elevated in concentration in the highly toxic samples versus the nontoxic samples; and (3) which chemicals in the highly toxic samples also were elevated in concentration above applicable, effects-based, sediment quality guidelines. A summary of the data from these three tiers of analyses are listed in Table 40. The substances included in Table 40 are those that were significantly correlated with two measures of toxicity: amphipod survival and microbial bioluminescence. There were no strong, significant correlations between toxicity to the bivalve embryos and any of the chemicals or chemical classes, so the data from those tests were not included in Table 40.

Amphipod survival was significantly correlated with two metals, mercury and tin, in the sediments. Microtox test results were significantly correlated with 10 metals. Generally, the average concentrations of all 10 trace metals in the highly toxic samples were slightly higher than in the nontoxic samples in both of the toxicity tests. For most of the metals, the average concentrations in the highly toxic samples were lower than the respective ERM values of Long et al. (1995). The concentrations of mercury, lead, and zinc in the highly toxic samples either equalled or slightly exceeded the applicable ERM values. Thirty of the 38 samples equalled or exceeded the mercury ERM concentration. However, Long et al. (1995) reported that they had only a moderate degree of confidence in the ERM value for mercury, whereas they reported a relatively high degree of confidence in the values for lead and zinc. Therefore, the exceedances of the mercury ERM concentration in most samples probably were not very meaningful.

Four chlorinated organic compounds were significantly correlated with microbial bioluminescence and one was correlated with amphipod survival (Table 40). No applicable guidelines were available for cis-chlordane and trans-nonachlor. Both of these isomers of chlordane were slightly elevated in the highly toxic samples relative to the nontoxic samples. The concentrations of p,p'-DDT were significantly correlated with both measures of toxicity. However, the average concentrations of this isomer of DDT were much more elevated in the samples that were toxic to the amphipods (exceeded the ERM by a factor of 21.6) than in those that were toxic to microbial bioluminescence (exceeed the ERM by a factor of 1.7). Long et al. (1995) reported a moderate degree of confidence in the ERM values for total DDT and p,p'-DDE and Long and Morgan (1990) reported a low degree of confidence in the ERM for p,p'-DDT. Therefore, the slight exceedance of the ERM value for p,p'-DDT in the samples that were highly toxic to microbial bioluminescence probably is meaningless. The concentrations of the DDT isomers in these samples were one to two orders of magnitude lower than the respective Sediment Effect Concentrations (SECs) of MacDonald (1994).

All of the compounds and classes of PAHs were significantly correlated with the results of the amphipod and Microtox tests the concentrations in the highly toxic samples exceeded the concentrations in

Based upon all of the data from both phases and all four test end-points, there are several patterns in toxicity in the study area. First, toxicity was very high in the upper and lower East River samples, and generally (but not consistently) diminished eastward into western Long Island Sound and southward into the New York Harbor. Second, toxicity was relatively high in the lower Passaic River, Newark Bay, and Arthur Kill, gradually diminished somewhat into western Raritan Bay, and diminished additionally into north-central Raritan Bay and the mouth of the estuary. Third, toxicity was high in the inner portions of Sandy Hook Bay, diminished into lower New York Harbor, the outer bay, and the mouth of the estuary.

Areas in which the sediments were toxic in the present survey also were toxic in one or more historical surveys in which sediments were tested with either amphipods or nematodes (Tietjen and Lee, 1984; Schimmel et al., 1994; Scott et al., 1990; Brosnan and O'Shea, 1993; Aqua Survey, 1990a, 1990b; Tatem et al., 1991). These areas included the lower East River, Newark Bay, Arthur Kill, Kill van Kull, lower Passaic River, western Raritan Bay, and Sandy Hook Bay.

Correlations Among Toxicity Tests. It was apparent from these data that the four test end-points did not always agree on the relative toxicity of all the samples. While some stations and sites were toxic in more than one test, there were many cases where the tests did not agree as to which samples were toxic. Table 39 summarizes the Spearman-rank correlations (Rho) among the four test end-points. All except the correlations between amphipod survival and bivalve normal development were significant. The strongest relationship, as expected, was between normal development and survival of the bivalve larvae (Rho = 0.741, $p<0.0001$). The results of the Microtox test were correlated with the results of the three other tests. These data indicate that, while the four tests suggested different patterns in toxicity, they did overlap to a significant degree.

These correlation coefficients illustrate the advantage of determining toxicity with a battery of tests and end-points. The spatial pattern of toxicity indicated with one assay may not necessarily represent patterns in toxicity to other organisms and/or end-points. The study area has many different sources of contamination, the mixtures and concentrations of contaminants differ remarkably from place to place, and the relative bioavailability of the different chemicals probably varies spatially. The different toxicity tests, therefore, would be expected to differ spatially in their responses to the various sources of contamination.

Table 39. Spearman rank correlation coefficients (Rho) for the four toxicity test end-points tested in Phase 1 as percent of controls (n=117).

	Amphipod survival	Bivalve survival	Bivalve development
Bivalve survival	0.368*		
Bivalve development	0.252^{ns}	0.741***	
Microbial bioluminescence	0.377*	0.432**	0.496**

*p<0.05, **p<0.01, ***p<0.001

ures depict the presence/absence of toxicity, not the relative degree of toxicity, based upon statistical differences from the controls.

Based upon the data depicted in Table 37 and Figures 46 and 47, it appears that the spatial limits of toxicity were not determined. Toxicity to at least one of the tests was evident throughout most of the study area and extended to its outer limits. There were no clear limits or boundaries beyond which only nontoxic sediments were consistently encountered. All of the samples from western Long Island Sound, the upper East River, the lower East River, Newark Bay, Arthur Kill, and inner-most Sandy Hook Bay were toxic in at least one of the tests. Also, many of the samples from the lower Raritan River and western Raritan Bay were toxic in at least one test. In contrast, only two of the 15 samples in the lower Hudson River/upper New York Harbor area were toxic in any of the tests. In addition, only two of the stations in sites 31, 32, and 33 in southern Raritan Bay were toxic in all tests. All three samples from site 39 in New York Bight were significantly different from controls in at least one test, but the site mean was not significantly different from controls in any of the tests.

The spatial pattern in toxicity illustrated by the site means (Figure 47) is similar to that identified by the station means (Figure 46). Figure 47 illlustrates the sites in which the mean toxicity results for any of the tests were significantly different from the respective controls. As observed with the station means, these data indicate that the sites in western Long Island Sound, upper East River, lower East River, Newark Bay, Arthur Kill, much of western Raritan Bay, and Sandy Hook Bay were different from controls. However, these data also suggest that site 13 in the lower Hudson River; sites 31 and 33 in southern Raritan Bay; and sites 36, 37, and 38 in the mouth of the estuary were significantly different from controls in at least one test. As observed with the station means, the site means indicated that sites 1-3 in the lower Hudson River, site 14 in upper New York Harbor, and several sites in north-central Raritan Bay were not toxic in any of the tests.

Figure 48 depicts the relative toxicity of the sites, based upon the number of significant toxic responses determined at each site, using the tests of statistical differences from controls. Sites are identified in which there was no toxic response relative to controls among the four test end-points, and sites in which there was one response, two, three, or four. It was assumed that sediments that caused four significantly elevated toxic responses were more degraded than those that elicited, say, one or two significant responses.

The site means for all four tests were significantly different from the controls only at site 7 (Figure 48). Note: based upon a critical value of <80% of controls, three sites were indicated as toxic in all tests in the calculations of the spatial extent of toxicity (Table 13). However, based upon the statistical tests of significance, only one site (site 7) was different from controls in all four tests. That is, in all four test end-points, the measures of toxicity were sufficiently high and consistent to provide mean results that were significantly different from the controls. In addition, the numerical results of the three invertebrate tests were 80% or less than the controls. Among the 17 samples tested with the polychaete growth test, sediments from site 7 were the most toxic. This site was clearly the most toxic among all 39 sites sampled during Phase 1.

Sites 11, 15, 17, 18, and 30 located in lower East River, upper New York Harbor, Newark Bay, Arthur Kill, and Sandy Hook Bay, respectively, were highly toxic in three of the four test end-points (Figure 48). Sites 1-3, 14, 19, 21, 24-26, 32, 34, and 39 were not toxic to any of the tests.

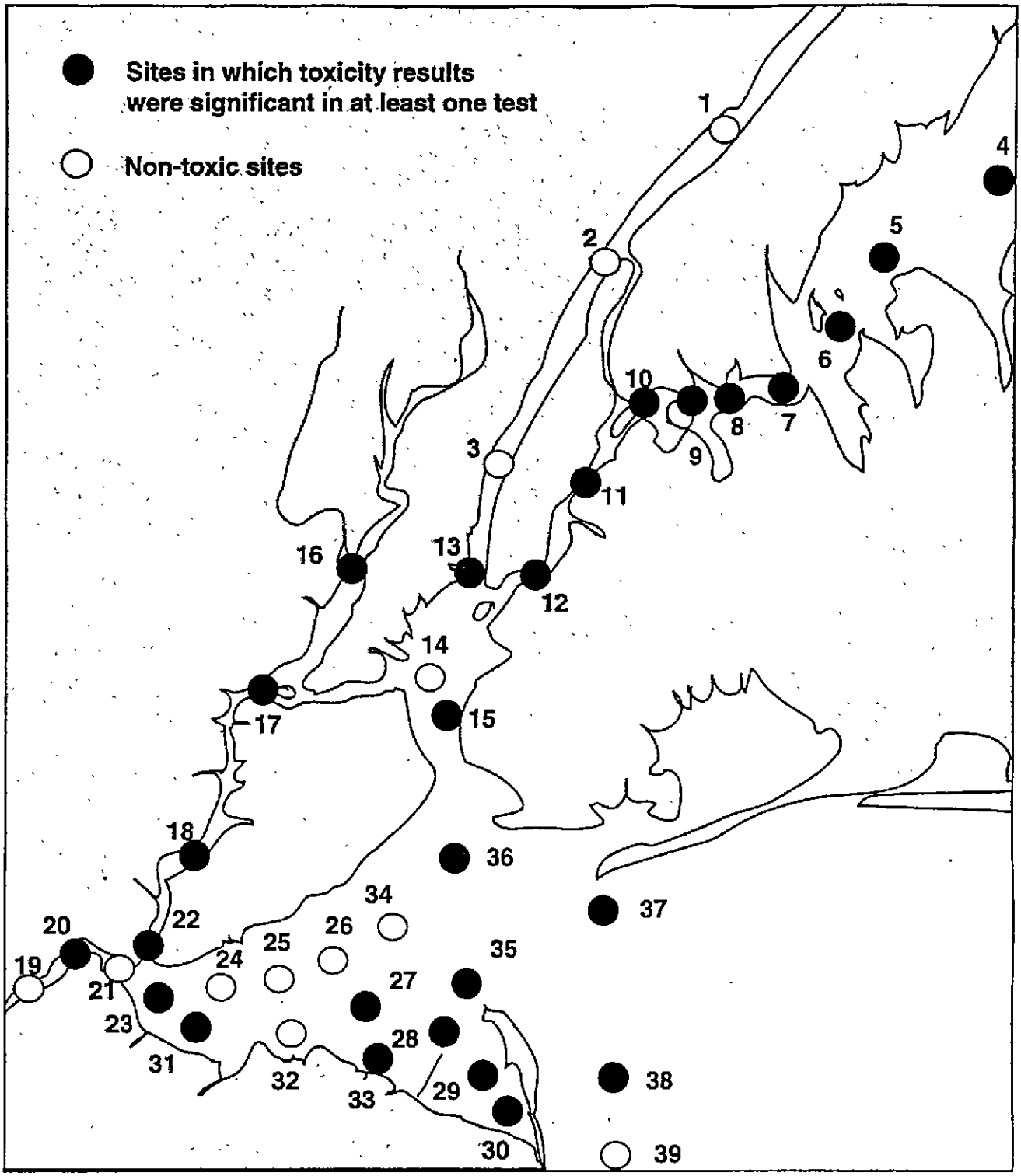

Figure 47. Sampling sites in which the mean toxicity test results were significantly different from controls in at least one of the four tests or not toxic in any test (average of three stations).

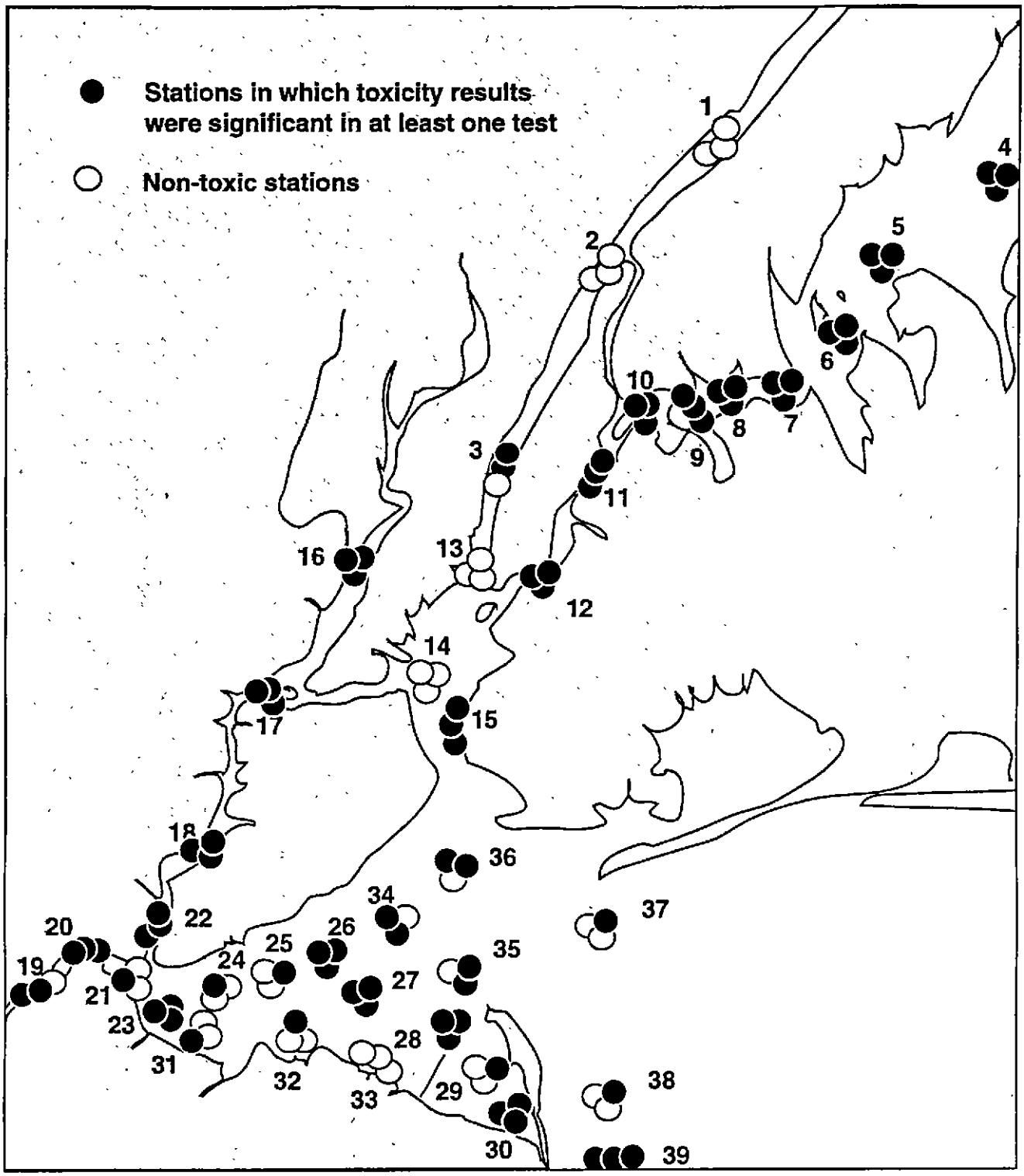

Figure 46. Sampling stations in which the toxicity test results were significantly different from controls in at least one of the four toxicity tests or not toxic in any tes

Table 38 continued.

Toxicity Test/Endpoint	Number of Stations: Statistically[a] Significant	Number of Stations: Numerically[b] Significant	Number of Sites: Statistically[a] Significant	Number of Sites: Numerically[b] Significant
Mulinia lateralis				
• survival (n=109)	23	21	6	4
• normal (n=109) development	21	19	6	4
Microtox™				
• Inhibition of bioluminescence (n=116)	47	32	19	14
All tests combined	81	54	27	19

[a] Statistically significantly different from controls (alpha=0.05).
[b] Significantly different from controls (alpha=0.05) and mean value 80% or less of the control response.

Spatial Extent of Toxicity. Using test results of <80% of control responses as a critical value, the spatial extent of toxicity was estimated. Approximately 25% of the study area exhibited toxic samples in the bivalve survival tests, 30% was toxic in the bivalve embryo development tests, 38% was toxic in the amphipod tests, and approximately 39% of the area was toxic to microbial bioluminescence. Approximately 5.7% of the area was toxic in all four of these tests. These estimates are similar to the estimate of the spatial extent of sediment toxicity to amphipod survival (21%) for the entire Virginian province of EMAP, which includes the present study area (Schimmel et al., 1994). However, the estimated spatial extent of toxicity to amphipods within the Newark Bay region of the study area (85%) was much higher than that for the remainder of the study area or the Virginian province.

These calculations of the spatial extent of toxicity must be viewed as rough estimates, since a number of factors could have contributed to bias in the analyses. Although the Phase 1 survey area was stratified *a priori*, the selection of the boundaries for each stratum could have affected the results. Since many of the sampling sites were selected with some knowledge of the site from previous studies, there may have been some bias in the site selection. Each station within a site was chosen by the vessel operator with no attempt to sample near known sources; nevertheless, there could have been bias in the station selections. The coordinates for each sampling station were not selected with a probabalistic, random method (Schimmel et al., 1994). On the other hand, there was no attempt to bias the site and station selections to over- or under estimate the toxicity of the area.

During Phase 2 of the survey, the samples were chosen randomly with a probabalistic, random-stratified sampling design similar to that used by the EMAP. As a consequence, the estimate of the spatial extent of toxicity (85%) within the Newark Bay area should be more accurate than that calculated for the entire survey area.

Spatial Patterns in Toxicity. The area-wide patterns in toxicity, as determined by the four test endpoints measured in Phase 1, collectively, are illustrated for the station means in Figure 46 and for the site means in Figure 47. Stations and sites were depicted as toxic when at least one of the four test endpoints indicated a statistically significant elevation in toxicity relative to the controls. These two fig-

Table 37 continued.

Regional zone	Sampling site/station	Amphipod survival	Bivalve survival	Bivalve development	Microbial bioluminescence
	36-A	-	-	-	-
	36-B	*	-	-	**
	36-C	*	-	-	-
	Site 36 mean	-	-	-	**
Zone M	37-A	-	**	-	-
	37-B	-	-	-	-
	37-C	-	-	-	-
	Site 37 mean	*	*	-	-
	38-A	-	-	-	-
	38-B	-	-	-	-
	38-C	*	-	-	-
	Site 38 mean	*	-	-	-
	39-A	**	**	**	-
	39-B	**	**	**	-
	39-C	*	-	-	-
	Site 39 mean	-	-	-	-

* Significantly different from controls (alpha=0.05).
** Significantly different from controls and 80% or less of controls.
- Not significantly different from controls.
nd - No data.

Significantly elevated toxicity was observed in samples from 54 stations and 16 sites in the amphipod survival test; 23 stations and 6 sites in the bivalve larvae survival test; 21 stations and 6 sites in the bivalve larvae development test; and 47 stations and 19 sites in the Microtox test (Table 38). Test results were significantly different from controls and 80% or less of the control in samples from 42 stations and 10 sites in the amphipod tests; in 21 stations and 4 sites in the bivalve survival tests; in 19 stations and 4 sites in the bivalve development tests; and in 32 stations and 14 sites in the Microtox tests. A total of 81 stations out of 117 (69%) and 27 sites out of 39 (69%) were indicated as significantly toxic in at least one of the test end-points during Phase 1. A total of 54 stations (46%) and 19 sites (49%) were significantly toxic and indicated responses of 80% or less than the controls in at least one of the tests. During the Phase 2 tests, amphipod survival was significantly lower than controls in 48 of 57 samples (84.2%).

Table 38. Summary of the numbers of Phase 1 stations and sites indicated as significantly toxic (different from controls) and numerically significant (80% controls or less) in each of four sediment toxicity test endpoints.

	Number of Stations		Number of Sites	
Toxicity Test/Endpoint	Statistically[a] Significant	Numerically[b] Significant	Statistically[a] Significant	Numerically[b] Significant
Ampelisca abdita				
• survival (n=117)	54	42	16	10

Table 37 continued.

Regional zone	Sampling site/station	Amphipod survival	Bivalve survival	Bivalve develop-ment	Microbial bioluminescence
Zone I	25-A	-	-	-	-
	25-B	-	-	-	-
	25-C	-	-	-	*
	Site 25 mean	-	-	-	-
	26-A	-	**	**	*
	26-B	-	-	-	*
	26-C	-	-	-	*
	Site 26 mean	-	-	-	-
	27-A	-	-	-	*
	27-B	-	-	-	*
	27-C	-	-	-	*
	Site 27 mean	-	-	-	**
Zone J	28-A	-	-	-	**
	28-B	**	nd	nd	**
	28-C	**	nd	nd	**
	Site 28 mean	*	-	-	**
	29-A	-	-	-	-
	29-B	-	-	**	-
	29-C	-	-	-	-
	Site 29 mean	*	-	-	-
	30-A	-	**	**	**
	30-B	*	**	**	*
	30-C	**	nd	nd	*
	Site 30 mean	-	**	**	**
Zone K	31-A	-	-	-	*
	31-B	-	-	-	-
	31-C	-	-	-	-
	Site 31 mean	-	-	-	**
	32-A	-	-	-	-
	32-B	-	-	-	*
	32-C	-	-	-	-
	Site 32 mean	-	-	-	-
	33-A	-	-	-	-
	33-B	-	-	-	-
	33-C	-	-	-	-
	Site 33 mean	*	-	-	-
Zone L	34-A	-	nd	nd	-
	34-B	**	**	**	-
	34-C	**	-	-	-
	Site 34 mean	-	-	-	-
	35-A	**	-	-	-
	35-B	-	nd	nd	nd
	35-C	**	-	-	-
	Site 35 mean	**	-	-	*

Table 37 continued.

Regional zone	Sampling site/station	Amphipod survival	Bivalve survival	Bivalve develop-ment	Microbial bioluminescence
	14-A	-	-	-	-
	14-B	-	-	-	-
	14-C	-	-	-	-
	Site 14 mean	-	-	-	-
	15-A	**	-	-	-
	15-B	*	-	-	-
	15-C	**	-	-	*
	Site 15 mean	**	*	-	*
Zone F	16-A	**	-	-	-
	16-B	**	-	-	*
	16-C	**	-	-	*
	Site 16 mean	**	-	-	-
	17-A	**	-	-	-
	17-B	**	**	-	-
	17-C	**	**	-	-
	Site 17 mean	**	**	-	**
	18-A	**	-	-	-
	18-B	**	-	-	*
	18-C	**	-	-	-
	Site 18 mean	**	-	*	*
Zone G	19-A	-	-	-	-
	19-B	-	-	-	*
	19-C	*	-	-	*
	Site 19 mean	-	-	-	-
	20-A	*	-	-	-
	20-B	*	-	-	-
	20-C	**	*	-	-
	Site 20 mean	-	*	-	-
	21-A	-	-	-	*
	21-B	-	-	-	-
	21-C	-	-	-	-
	Site 21 mean	-	-	-	-
Zone H	22-A	**	-	-	*
	22-B	**	-	-	-
	22-C	**	**	-	-
	Site 22 mean	**	-	-	*
	23-A	-	-	-	**
	23-B	-	-	-	**
	23-C	**	-	-	-
	Site 23 mean	**	-	-	**
	24-A	*	-	-	*
	24-B	-	nd	nd	-
	24-C	-	-	-	-
	Site 24 mean	-	-	-	-

Table 37 continued.

Regional zone	Sampling site/station	Amphipod survival	Bivalve survival	Bivalve develop-ment	Microbial bioluminescence
	3-A	-	-	-	-
	3-B	**	-	-	-
	3-C	**	-	-	-
	Site 3 mean	-	-	-	-
Zone B	4-A	-	-	-	*
	4-B	-	-	-	*
	4-C	-		-	*
	Site 4 mean	-	-	*	*
	5-A	-	-	**	**
	5-B	-	-	**	*
	5-C	-	**	**	*
	Site 5 mean	-	-	**	**
	6-A	-	**	*	-
	6-B	-	**	**	**
	6-C	-	**	**	**
	Site 6 mean	-	**	**	-
Zone C	7-A	**	**	**	-
	7-B	**	**	**	-
	7-C	**	**	**	-
	Site 7 mean	**	**	**	**
	8-A	*	*	-	-
	8-B	**	-	**	**
	8-C	**	**	-	*
	Site 8 mean	-	-	-	**
	9-A	**	-	-	*
	9-B	**	-	-	**
	9-C	**	-	-	-
	Site 9 mean	**	-	-	**
Zone D	10-A	**	**	**	**
	10-B	**	**	**	*
	10-C	**	-	-	*
	Site 10 mean	-	-	-	**
	11-A	*	-	-	-
	11-B	**	**	-	*
	11-C	**	-	*	*
	Site 11 mean	**	**	-	*
	12-A	**	-	-	*
	12-B	**	-	-	*
	12-C	-	-	**	*
	Site 12 mean	-	-	-	**
Zone E	13-A	-	-	-	-
	13-B	-	nd	nd	-
	13-C	-	-	-	-
	Site 13 mean	*	-	-	-

toxic (Brosnan and O'Shea, 1993). In 18 samples tested in 1990 from the Arthur Kill and vicinity, amphipod mortality ranged from 18 to 61% (Aqua Survey, 1990a, 1990b). Five of nine samples collected in 1990 were toxic to amphipods during the first phase of the EMAP survey conducted by U.S. EPA (Schimmel et al., 1994).

During Phase 1 of this survey, toxicity in 117 sediment samples was determined with three complimentary tests performed in the laboratory. Four toxicity end-points were determined among the three tests. Toxicity end-points included survival of amphipods, survival of bivalve larvae, morphological development of bivalve larvae, and metabolic activity of a bioluminescent bacterium. During Phase 2, 57 additional samples from Newark Bay and vicinity were tested with the amphipod survival test.

All four test end-points provided a wide range in response from the least toxic to the most toxic station. In Phase 1, amphipod survival ranged from 0.0% in three samples to 99.0%. In Phase 2, amphipod survival ranged from 0.0% in two samples to 100%. Bivalve embryo survival ranged from 16.1% to over 100% relative to controls. Bivalve normal development ranged from 0.0% in two samples to 100% in many samples. The Microtox EC50s ranged from 0.30 mg/ml to over 32.6 mg/ml. All four end-points indicated that some of the stations and some of the sites were significantly more toxic than the control sediments.

The toxicity data developed for each station and site during Phase 1 are summarized in Table 37. A single asterisk was assigned to those stations and sites that were significantly different from controls in each test. Two asterisks were assigned where the numerical results were significantly different from controls and were less than or equal to 80% of the control response.

Based upon the results of all four test end-points combined, the samples from zones A (lower Hudson River), G (lower Raritan River), I (central Raritan Bay), K (southern Raritan Bay), and M (outer bay, New York Bight) were among the least toxic. Samples from these areas often were not toxic in any of the tests, or in only one or two of them. Furthermore, toxicity test results rarely were less than 80% of the control responses. Among the most toxic samples were those from zones B (western Long Island Sound), C (upper East River), D (lower East River), and F (Newark Bay/Arthur Kill). Samples from these areas often were highly toxic as indicated by toxicity in multiple tests and responses less than 80% of the control response.

Table 37. Summary of toxicity test results for each station and site sampled during Phase 1.

Regional zone	Sampling site/station	Amphipod survival	Bivalve survival	Bivalve development	Microbial bioluminescence
Zone A	1-A	-	-	-	-
	1-B	-	-	-	-
	1-C	-	-	-	-
	Site 1 mean	-	-	-	-
	2-A	-	-	-	-
	2-B	-	-	-	-
	2-C	-	nd	nd	-
	Site 2 mean	-	-	-	-

Table 36. Average concentrations of PAHs (ng/g, dry wt.) in highly toxic (<80% survival) and nontoxic samples from Phase 2, ratios between the averages, and ratios between the highly toxic averages and the respective SQGs.

	Nontoxic (91.9 ± 13.0% survival, n = 4)	Highly toxic (38.0 ± 24.7% survival, n = 16)	Ratio of highly toxic nontoxic averages	Ratio of highly toxic avg. to the SQG
sum of LPAH	1736±1730	5822±9350	3.4	1.8[a]
sum of HPAH	12100±15868	31709±30761	2.6	3.3[a]
sum of PAH	13836±17576	37532±39671	2.7	0.8[a]
acenaphthene (ug/goc)	2.4±1.7	12.5±20.7	5.3	0.05[b]
phenanthrene (ug/goc)	17.0±12.8	123.0±294.6	7.2	0.5[b]
fluoranthene (ug/goc)	51.0±49.8	208.9±260.2	4.1	0.7[b]

[a] Long et al. (1995)
[b] U.S. EPA (1994)

DISCUSSION

Incidence and Severity of Toxicity. In previous studies and surveys of the Hudson-Raritan Estuary, many investigators have reported that portions of this area were highly contaminated with a variety of potentially toxic chemicals (O'Connor and Ehler, 1991; Breteler, 1984; Squibb et al., 1991; Long and Morgan, 1990; Schimmel et al., 1994). The concentrations of many substances equalled or exceeded known toxicity thresholds and exceeded concentrations observed in many other estuaries in the USA. Therefore, based upon these historical chemical data, there was a potential for contaminant-induced toxicity in water, sediments, and resident biota.

The spatial patterns in chemical concentrations compiled by Squibb et al. (1991) suggested that Newark Bay and Arthur Kill would be highly toxic. Based upon the data from the present survey, many of the samples from these two areas, indeed, appeared to be toxic. The data assembled by Squibb et al. (1991) also suggested that the following areas would be moderately toxic: East River bays, East River in the vicinity of Ward's Island, upper New York Harbor, Gowanus Canal, lower Hackensack River, and lower Jamaica Bay. Among these areas, samples were collected in the present survey in the upper East River near Ward's Island, upper New York Harbor, and the lower Hackensack River. The samples collected in the East River were highly toxic, those from the lower Hackensack River were moderately toxic, and those from the upper New York Harbor were not toxic at one site and moderately toxic at another site. The northern and southern portions of Raritan Bay, which were highly sandy, were expected to be among the least toxic areas according to the data compiled by Squibb et al. (1991), and that was confirmed in the present survey. Although conditions in all of these areas were heterogeneous, the overall patterns in toxicity suggested by the chemical data from previous surveys generally were confirmed by the toxicity tests in the present survey.

Previous investigators have documented toxicity in sediment samples collected throughout the estuary. The toxicity of sediments to nematode growth (Tietjen and Lee, 1984) was reported in all ten samples that were tested. Toxicity to amphipods was reported in 8% of 10% samples tested in 1990 (Scott et al., 1990). Nine of 20 samples collected in 1992 and tested in flow-through tests with amphipods were

Table 35. Average concentrations of total extractable and AVS simultaneously extracted trace metals (ppm, dry wt.) in highly toxic (<80% survival) and nontoxic samples from Phase 2, ratios between the averages, and ratios between the highly toxic averages and the respective SQGs.

	Nontoxic (91.9 ± 13.0% survival, n = 4)	Highly toxic (38.0 ± 24.7% survival, n = 16)	Ratio of highly toxic to nontoxic averages	Ratio of highly toxic avg. to the SQG
total silver	2.4±1.1	3.6±1.6	1.5	1.0[a]
total arsenic	10.7±3.3	10.4±3.9	1.0	0.15[a]
total cadmium	1.1±0.9	3.3±1.8	2.9	0.3[a]
total chromium	102.9±68.1	141.1±56.3	1.4	0.4[a]
total copper	68.9±46.5	142.6±67.0	2.1	0.5[a]
total mercury	1.6±1.6	2.4±0.9	1.4	3.4[a]
total nickel	45.1±17.9	39.7±11.8	0.9	0.8[a]
total lead	88.8±42.9	208.0±102.9	2.3	0.9[a]
total tin	16.5±9.6	46.4±24.2	2.8	na
total selenium	0.5±0.4	0.9±0.3	1.7	na
total zinc	166.2±93.1	403.9±191.9	2.4	1.0[a]
total AVS (*u*mol/g)	2.2±1.4	3.1±1.5	1.4	na
SE silver	0.4±0.3	0.4±0.2	1.0	na
SE arsenic	2.0±1.2	1.6±0.6	0.8	na
SE cadmium	0.9±0.7	2.7±1.4	2.9	na
SE chromium	33.4±28.0	67.4±35.8	2.0	na
SE copper	26.5±24.2	36.9±20.2	1.4	na
SE mercury	0.06±0.0	0.06±0.0	1.0	na
SE nickel	6.3±3.1	8.6±3.6	1.4	na
SE lead	69.0±41.1	164.7±81.5	2.4	na
SE zinc	147.3±55.8	293.6±161.2	2.0	na
SEM/AVS ratios (*u*mol/g)	0.5±0.4	0.5±0.7	1.0	na
Un-ionized ammonia (ug/l)	155.3±268.3	102.7±164.4	0.7	na

[a] Long et al. (1995)
na = no applicable guidelines

The concentrations of the classes of PAHs and three individual hydrocarbons were higher in the toxic samples than in the nontoxic samples, but not to a great degree (Table 36). Also, the average concentrations of the sums of both the low and high molecular weight compounds exceeded the respective ERM values, but again; not by a large amount. Among the three compounds for which there are proposed criteria, phenanthrene was most elevated in concentration in the toxic samples, but the average concentrations of all three compounds were considerably lower than the respective SQGs.

Table 34 contd.

	Nontoxic (91.9 ± 13.0% survival, n = 4)	Highly toxic (38.0 ± 24.7% survival, n = 16)	Ratio of highly toxic to nontoxic averages	Ratio of highly toxic avg. to the SQG
oxychlordane	0.2±0.1	0.5±0.3	2.6	na
heptachlor epoxide	1.4±1.0	6.6±4.4	4.9	na
trans-chlordane	3.8±3.0	23.4±16.0	6.2	na
trans-nonachlor	2.8±2.1	13.5±8.8	4.9	na
cis-chlordane	4.7±3.7	28.2±20.6	6.0	na
o, p' - DDE	3.4±3.3	8.3±4.3	2.5	na
dieldrin	2.7±1.9	10.6±5.9	3.9	1.3[a]
p, p' - DDE	16.8±14.1	44.4±19.0	2.7	1.6[b]
o, p' - DDD	6.8±6.5	21.5±12.5	3.2	na
endrin	0.4±0.2	0.9±0.7	2.2	0.02[a]
cis-nonachlor	1.3±0.9	6.2±4.2	4.8	na
o, p' - DDT	1.2±0.8	5.3±3.4	4.6	na
p, p' - DDD	15.8±14.1	45.9±22.2	2.9	2.3[a]
p, p' - DDT	31.5±40.6	40.7±35.0	1.3	5.8[a]
mirex	2.4±1.3	10.8±7.2	4.6	na
sum of DDTs	75.2±65.7	166.2±73.7	2.2	3.6[b]
sum of PCB congeners	148.1±123.0	757.8±527.4	5.1	4.2[b]
percent TOC	2.2±1.4	3.1±1.5	1.4	na
dieldrin (*ug*/goc)	0.1±0.1	0.4±0.2	2.7	0.02[c]
endrin (*ug*/goc)	0.3±0.3	0.3±0.4	1.1	0.4[c]
p, p' - DDE (*ug*/goc)	0.7±0.5	1.6±0.8	2.1	na
sum of DDTs (*ug*/goc)	2.9±1.6	5.8±2.8	2.0	0.03[d]
sum of PCBs (*ug*/goc)	5.6±2.2	25.1±16.2	4.5	na

[a] Long and Morgan (1990)
[b] Long et al. (1995)
[c] U.S. EPA (1994)
[d] Swartz et al. (1994)

na = no applicable guidelines

The average concentrations of the trace metals in the toxic samples rarely exceeded the averages in the nontoxic samples by a great degree, and, except for mercury, were lower than the respective ERM value (Table 35). The toxic/nontoxic ratios ranged from 0.8 to 2.9 for the metals. The toxic/nontoxic ratios for each element were similar whether quantified as total extractable metal or as AVS simultaneously extracted metal. Although the average concentration of mercury in the toxic samples was elevated relative to the ERM value, Long et al. (1995) reported only a moderate degree of confidence in this guideline, suggesting that it should be higher. The concentrations of un-ionized ammonia were lower in the toxic samples than in the nontoxic samples.

toxic samples by factors of 6.5, 2.8, and 5.4, respectively. In addition, the average concentrations of the dioxin TEQs and the total cumulative TEQs in the toxic samples exceeded the guideline value of 100 pg/g by factors of 3.5 and 4.2, respectively.

Table 33. Average concentrations (pg/g, dry wt.) of 2,3,7,8-tcdd and total cumulative dioxin TEQs in highly toxic (<80% survival) and nontoxic samples from Newark Bay, ratios between the averages, and ratios between the highly toxic averages and the respective SQG*.

	Nontoxic (91.9 ± 13.0% survival, n = 4)	Highly toxic (38.0 ± 24.7% survival, n = 16)	Ratio of highly toxic to nontoxic averages	Ratio of highly toxic avg. to the SQG
2378-tcdd	25.8±23.2	273.9±177.9	10.6	2.7
cum. dioxins TEQ	55.0±50.8	355.1±217.1	6.5	3.5
cum. PCB TEQ	22.1±16.6	62.0±34.5	2.8	<1.0
total cum. TEQ	77.2±66.9	417.1±249.0	5.4	4.2

*SQG = 100 pg/g (U.S. EPA, 1993)

The average concentrations of pesticides and total PCBs in the toxic and nontoxic samples are compared in Table 34. The average concentrations of nearly all of these compounds were higher in the toxic samples than in the nontoxic samples. The ratios of the averages ranged from 0.9 to 6.2. The concentrations of some chlordane isomers, hexachlorobenzene, and the sum of the PCB congeners were elevated to the greatest degree (>5.0X) in the toxic samples. Sediment guidelines were not available for most compounds. Among those substances for which guidelines exist, the average concentrations in the toxic samples often were lower than the guidelines. However, the concentrations of p,p'-DDE and total PCB congeners were highly elevated relative to the ERM values (Long et al., 1995). Also, the average concentration of total PCBs (758 ng/g) in the toxic samples exceeded the SEC (562 ng/g) calculated by MacDonald (1994). However, the average concentration of total DDTs in the toxic samples (5.8 *ug*/goc) was far lower than the toxicity threshold (300 *ug*/goc) identified by Swartz et al. (1994) for the amphipod *R. abronius*.

Table 34. Average concentrations (ng/g, dry wt.) of pesticides and PCBs in highly toxic (<80% survival) and nontoxic samples from Newark Bay, ratios between the averages, and ratios between the highly toxic averages and the respective SQGs.

	Nontoxic (91.9 ± 13.0% survival, n = 4)	Highly toxic (38.0 ± 24.7% survival, n = 16)	Ratio of highly toxic to nontoxic averages	Ratio of highly toxic avg. to the SQG
hexachlorobenzene	1.0±1.0	4.8±2.4	5.0	na
pentachloro-anisole	0.3±0.2	0.6±0.2	2.2	na
alpha-BHC	1.1±0.5	0.7±0.5	1.6	na
lindane	0.2±0.2	0.3±0.3	1.3	na
beta-BHC	0.4±0.3	0.3±0.3	0.9	na
heptachlor	0.1±0.0	0.2±0.3	2.0	na
delta-BHC	1.3±0.7	2.4±1.1	1.9	na
dacthal	1.7±0.5	2.3±0.7	1.4	na

Among all of the substances quantified in Phase 2, the concentrations of the dioxins were most highly correlated with amphipod survival. The scatterplot of the data showed a consistent pattern of decreasing survival with increasing 2,3,7,8-tcdd concentrations (Figure 40). All of the samples that were highly toxic to the amphipods had 2,3,7,8-tcdd concentrations that exceeded the 100 pg/g guideline proposed by the U.S. EPA (1993).

The concentrations of all the dioxin, furan, and PCB congeners for which toxicity equivalency factors were available (Barnes et al., 1991; Kutz et al., 1990) were normalized to (multiplied by) the appropriate TEFs and the total cumulative TEQs were determined. Amphipod survival was highly correlated with the total cumulative TEQs (Figure 41). Also, all of the samples that exceeded the U.S. EPA (1993) guideline of 100 pg/g were highly toxic to the amphipods. Amphipod survival dropped to 50% or less in samples with total dioxins TEQs of 150 pg/g or more. However, the sample with the highest TEQ concentration was not sample 26, in which amphipod survival was zero.

The relationships between amphipod survival and the concentrations of both lead and zinc were relatively strong and consistent (Figures 42-43). All of the samples with lead concentrations that exceeded the ERM value (Long et al., 1995) were highly toxic (survival <80%). Also, all except one sample with zinc concentrations above the ERM value were highly toxic. Long et al. (1995) reported relatively high confidence in the ERM values for both of the elements. However, two samples in which survival was 0.0% and 20% had relatively low concentrations of both lead and zinc. The very high concentrations of PCBs, dioxins, and other chlorinated hydrocarbons probably were more important in these samples than the trace elements. Also, one sample with a very high concentration of zinc (>700 ug/g) had relatively high amphipod survival (80%). Based upon these data, lead and zinc may have contributed to the observed toxicity in some of the samples.

The correlations between the concentrations of PAHs and amphipod survival were relatively poor, especially when compared to the strong correlations observed in the data from Phase 1. The concentrations of high molecular weight PAHs were relatively high in the samples that caused low amphipod survival; however, this pattern was not consistent (Figure 44). For example, the HPAH concentration in sample 26 was relatively low (less than the ERM value of 9600 ng/g) and one sample in which amphipod survival was relatively high had the highest concentration of these compounds. Among the three compounds for which EPA has developed SQCs, fluoranthene was most strongly correlated with amphipod survival. However, the correlation between amphipod survival and fluoranthene concentrations was not significant and the pattern was inconsistent (Figure 45). Three samples had fluoranthene concentrations that either equalled or exceeded the SQC; amphipod survival was relatively high in one and very low in the other. Based upon these data, it does not appear that the PAHs contributed substantially to the observed toxicity in many of the Newark Bay samples.

Of the 20 samples that were subjected to chemical analyses, 4 were not significantly different from controls in the tests of amphipod survival, whereas 16 were significantly different from controls and amphipod survival was less than 80% of the control survival. The average concentrations of the 2,3,7,8-tcdd and dioxin TEQs that co-occurred with the nontoxic and the toxic samples are compared in Table 33. In addition, the average concentrations of these compounds in the toxic samples were compared with the sediment guideline proposed by the U.S. EPA (1993). The average concentration of 2,3,7,8-tcdd in the toxic samples exceeded the average concentration in the nontoxic samples by a factor of 10.6 and exceeded the guideline by a factor of 2.7. The concentrations of the dioxin TEQs, co-planar PCB TEQs, and total cumulative TEQs in the toxic samples exceeded the concentrations in the non-

This is not a sed. tox. guideline

Table 40. Summary of toxicity/chemistry relationships for those chemicals that were significantly correlated with toxicity in the Phase 1 samples.

	Spearman rank correlation coefficients		Ratio of highly toxic averages to non-toxic averages		Ratio of highly toxic averages to respective SQGs		No. of samples that equalled or exceeded SQGs
	Amphipod	Microtox	Amphipod	Microtox	Amphipod	Microtox	
silver	ns	-0.363*	0.9	1.4	<1.0	<1.0	0
chromium	ns	-0.351*	1.1	1.5	<1.0	<1.0	1
cadmium	ns	-0.472*	1.9	1.3	<1.0	<1.0	0
copper	ns	-0.449*	1.6	1.5	<1.0	<1.0	2
mercury	-0.437*	-0.377*	2.2	0.9	4.5	3.1	30
nickel	ns	-0.451*	1.2	1.6	<1.0	<1.0	3
lead	ns	-0.478*	1.5	1.7	<1.0	1.0	8
antimony	ns	-0.355*	1.6	1.4	na	na	na
tin	-0.342*	-0.427*	1.7	1.6	na	na	na
zinc	ns	-0.433*	1.2	1.8	<1.0	1.1	5
cis-chlordane	ns	-0.384*	2.0	1.1	na	na	na
trans-nonachlor	ns	-0.402*	2.0	1.2	na	na	na
4,4'-DDE	ns	-0.406*	4.0	0.7	1.6	<1.0	12
4,4'-DDT	-0.476*	-0.341*	20.3	0.1	21.6	1.7	14
total indeno- pesticides	ns	-0.395*	1.9	1.2	na	na	na
petroleum PAHs	-0.468*	-0.625***	6.3	26.2	na	na	na
combustion PAHs	-0.576**	-0.602**	12.7	6.7	na	na	na
sum of LPAHs	-0.592**	-0.650***	37.6	25.6	11.0	18.9	9
sum of HPAHs	-0.471*	-0.512*	7.1	6.8	5.0	7.3	14
sum of total PAHs	-0.495*	-0.603**	14.8	10.4	1.8	2.8	4
fluoranthene/toc	-0.559**	-0.418*	4.6	4.3	7.2	9.7	20
acenaphthene/toc	-0.641***	-0.437*	58.7	34.2	2.8	4.8	2
phenanthrene/toc	-0.571**	-0.398*	20.2	13.9	10.4	17.0	14

*p<0.05, **p<0.001, ***p<0.0001

the nontoxic samples (often by a considerable amount), and they exceeded the applicable guidelines (Table 40). The concentrations of the low molecular weight PAHs, in particular, corresponded very well with the toxicity results. The concentrations of the petroleum-related compounds were very high in the samples that were toxic in the Microtox tests, whereas the combustion-related compounds were relatively high in the samples that were toxic in the amphipod tests. The concentrations of acenaphthene were correlated with toxicity, and were highly elevated in the toxic samples, but they exceeded the applicable SQC by only a factor of 2.8 and 4.8, respectively, in the two tests. Also, phenanthrene was correlated with toxicity and elevated in concentration in the toxic samples; in addition, it was elevated relative to the applicable SQC by factors of 10.4 and 17.0, respectively, in the two tests.

In summary, these data from the Phase 1 portion of the survey suggest that the toxicity observed in the samples was in strong correspondence with the concentrations of the PAHs in the samples. To a considerably lesser degree, toxicity corresponded with the concentrations of some trace metals and chlorinated organic compounds.

In the samples analyzed during Phase 2 of the survey, a considerable number of chemicals co-varied with amphipod survival (Table 41). Nine trace elements were correlated with toxicity to the amphipods; however, the concentrations of most of these metals were not highly elevated relative to applicable guidelines. For example, cadmium, chromium, and copper were correlated with amphipod survival, but the concentrations of these substances were below the ERM values. The concentrations of mercury were elevated relative to the ERM values, but Long et al. (1995) reported only a moderate degree of confidence in the guidelines for mercury.

Whereas the concentrations of PAHs were highly correlated with amphipod survival in Phase 1, the concentrations of PCBs, 2,3,7,8-tcdd, and many other chlorinated hydrocarbons were highly correlated with amphipod survival in Phase 2 (Table 41). The strong correlations with are particularly interesting since dioxins generally are not especially toxic to invertebrates in short-term acute exposures. No applicable guidelines are available for many of these compounds. The concentrations of dieldrin were far below the applicable sediment guideline values, whereas the concentrations of the p,p'-DDE and total DDT isomers were high relative to the ERM values of Long et al (1995), but were far below the respective SECs of MacDonald (1994).

The PAH concentrations in some samples exceeded the sediment guidelines of Long et al. (1995) or the U.S. EPA (1994) and the average concentrations in the toxic samples exceeded the average in the nontoxic samples. However, amphipod survival was not correlated with those compounds, and, therefore, they were not included in Table 41. Nevertheless, they may have been important in contributing to toxicity in some specific samples in which the PAH concentrations were particularly high.

In previous studies conducted within this study area, measures of sediment toxicity were highly correlated with a number of different chemicals. Scott et al. (1990) reported that amphipod mortality in samples from the Hudson-Raritan Estuary was correlated with the concentrations of total PCBs, total PAHs, several pesticides, copper, zinc, chromium, lead, nickel, and cadmium. Also, the concentrations of many of these chemicals in the highly toxic samples equalled or exceeded the respective ERM values. The correlations between amphipod mortality and the concentrations of trace metals normalized to the aluminum content were highly significant in the EMAP samples (Schimmel et al., 1994). In samples collected by the City of New York (Brosnan and O'Shea, 1994), amphipod mortality was correlated with total SEM/AVS ratios.

Table 41. Summary of toxicity/chemistry relationships for those chemicals that were significantly correlated with toxicity in the Phase 2 samples.

	Spearman rank correlation coefficients	Ratio of highly toxic averages to non-toxic averages	Ratio of highly toxic averages to SQGs	Number of samples that equalled or exceeded SQGs
Trace elements				
silver	-0.585*	1.5	1.0	7
cadmium	-0.777**	2.9	0.3	0
chromium	-0.673*	1.4	0.4	0
copper	-0.723*	2.1	0.5	0
mercury	-0.612*	1.4	3.4	17
lead	-0.681*	2.3	0.9	10
tin	-0.734*	2.8	na	na
selenium	-0.647*	1.7	na	na
zinc	-0.534*	2.4	1.0	10
Chlorinated hydrocarbons				
sum of PCB congeners	-0.783*	5.1	4.2	16
cumulative PCB TEQ	-0.850**	2.8	<1.0	2
2378-tcdd	-0.868**	10.6	2.7	11
cumulative dioxin TEQ	-0.866**	6.5	3.5	14
total cumulative TEQ	-0.865**	5.4	4.2	15
Pesticides				
hexachlorobenzene	-0.633*	5.0	na	na
delta-BHC	-0.487*	1.9	na	na
oxychlordane	-0.633*	2.6	na	na
trans-chlordane	-0.705*	6.2	na	na
cis-chlordane	-0.677*	6.0	na	na
dieldrin (dry wt.)	-0.848**	3.9	na	na
dieldrin (oc)	-0.841**	2.7	0.02	0
o,p' - DDD	-0.629*	3.2	na	na
pentachloro anisole	-0.599*	2.2	na	na
heptachlor epoxide	-0.680*	4.9	na	na
trans-nonachlor	-0.699*	4.9	na	na
o,p' - DDE	-0.707*	2.5	na	na
p,p' - DDE	-0.800**	2.7	1.6	13
cis-nonachlor	-0.707*	4.8	na	na
o,p' - DDT	-0.576*	4.6	na	na
p,p' - DDD	-0.597*	2.9	na	na
mirex	-0.569*	4.6	na	na
sum of total DDTs	-0.576*	2.2	3.6	15

*p<0.05, **p<0.001. na = no applicable SQGs available.

As observed in this survey, many contaminants co-vary with each other in the sediments. Therefore, correlation analyses alone do not provide great insight into the potential causes of toxicity. A much stronger weight of evidence is provided by the complementary measures of correlative strength, concentrations gradients between toxic and nontoxic samples, and comparisons with applicable effects-based, numerical guidelines.

CONCLUSIONS

This survey was intended to provide information on the possible biological effects of toxic chemicals in the sediments of the Hudson-Raritan estuary. Standardized laboratory toxicity tests were performed on 174 samples collected throughout the study area. Some of the important conclusions derived from this survey follow:

Potential for Toxicity

- The concentrations and mixtures of toxicants quantified in previous studies differed among the many different waterways, tributaries, harbors, and basins of this study area.
- The concentrations of many substances quantified during previous studies exceeded the concentrations previously associated with toxicity, occasionally by a great amount, and therefore, suggested that sediments in this area may be toxic.
- The concentrations of polynuclear aromatic hydrocarbons (PAHs) were extremely high in some samples from the East River collected during the present survey. The concentrations of chlorinated hydrocarbons, such as PCBs, pesticides, and dioxins, were very high in some samples from the lower Passaic River and Newark Bay. The concentrations of total simultaneously extracted metals exceeded the acid-volatile sulfide concentrations in a few of the samples.
- Based upon historical data, those areas included in the present survey in which the highest toxicity was predicted included Newark Bay and Arthur Kill. As expected, many samples from these two adjacent areas were highly toxic. Portions of the East River and lower Passaic River, which were expected to be moderately toxic, often were moderately to highly toxic in the laboratory tests.

Incidence of Toxicity

The significance of the toxicity data was determined in statistical comparisons of the test results with the respective controls.

- Out of 58 sediment samples tested in previous studies, 45 (77.6%) were highly toxic to either nematode growth or amphipod survival.
- All four test end-points measured in the present survey indicated results significantly different from controls in samples collected throughout the estuary.
- Of the 117 stations that were sampled in Phase 1 of the present survey, test results for 81 stations (69% of the total tested) were significantly different from controls in at least one of the test end-points.
- Of the 117 samples, 46% were significantly different from controls in the amphipod survival tests.
- Of 109 samples tested, 27% were significantly different from controls in the tests of bivalve embryo survival or normal development.
- Of 116 samples tested, 41% were significantly different from controls in the bacterial bioluminescence tests.
- Of 57 samples from Newark Bay and vicinity tested during Phase 2, 48 (84%) were significantly toxic to amphipod survival.

• In tests of growth, 13 of 17 samples were toxic to the polychaete *Armandia brevis* and 8 of 17 samples were toxic to the sand dollar *Dendraster excentricus*. Also, 8 of 9 samples were toxic in tests of survival with the freshwater amphipod *Diporeia* spp.

Spatial Patterns in Toxicity

• Toxicity extended throughout much of the study area and no clear boundary or limit to toxicity was apparent.

• The data from each of the individual tests were correlated with each other to different degrees and indicated overlap in the patterns of toxicity.

• 100% mortality of amphipods was observed in samples from Newark Bay, Arthur Kill, and the East River.

• Regions of the study area in which highly toxic sediments were collected included the East River, the vicinity of the Verrazano Narrows Bridge, Kill van Kull near Shooter's Island, Arthur Kill, central Newark Bay, lower Passaic River, and Sandy Hook Bay.

• Sediments that were consistently not toxic or the least toxic in all tests were collected in the lower Hudson River off Manhattan Island, in the center of upper New York Harbor, in southern Raritan Bay, and in some regions of north-central Raritan Bay.

• Based upon the distance from the metropolitan New York City area, the sediments collected in the mouth of the estuary and New York Bight were expected not to be toxic or among the least toxic. However, some of the samples from these areas were toxic in some of the tests.

• The relatively high toxicity observed in the East River generally diminished eastward into Long Island Sound and southward into upper New York Harbor.

• The relatively high toxicity in the lower Passaic River, Newark Bay, and Arthur Kill generally diminished into central Raritan Bay.

• The relatively high toxicity in innermost Sandy Hook Bay generally diminished into central Raritan Bay and the mouth of the estuary.

Spatial Extent of Toxicity.

• Approximately 25% of the study area exhibited toxicity in the bivalve embryo survival tests; 30% was toxic in the bivalve embryo development tests; 38% was toxic in the amphipod survival tests; and approximately 39% of the area was toxic to microbial bioluminescence. Approximately 5.7% of the area was toxic in all four of these tests. Since a probabalistic, random-stratified sampling design was not used in Phase 1, the estimates of the spatial extent of toxicity may not be accurate.

•Within the Newark Bay/lower Passaic River/lower Hackensack River/northern Arthur Kill region, however, 85% of the area was toxic to amphipod survival. Since a probabalistic, random-stratified sampling was used in Phase 2, the estimate of the spatial extent of toxicity in the Newark Bay area may be much more accurate that the estimate for the entire survey area.

Chemistry/Toxicity Relationships.

• The chemistry/toxicity relationships differed among regions of the study area.

• Toxicity to amphipod survival and microbial bioluminescence in samples from the East River and vicinity was highly correlated with the concentrations of polynuclear aromatic hydrocarbons (PAHs). The concentrations of these compounds in highly toxic samples often exceeded effects-based guidelines or toxicity thresholds.

• Toxicity to amphipod survival in samples from the lower Passaic River, Newark Bay and vicinity was highly correlated with the concentrations of PCBs, dioxins, and pesticides, the concentrations of which often exceeded effects-based guidelines or toxicity thresholds. In this area, toxicity was not correlated with the concentrations of PAHs.

• Toxicity to amphipod survival was not highly correlated with the concentrations of ammonia in the samples.

• Toxicity to amphipod survival was not significantly correlated with total SEM:AVS ratios.

• Toxicity to amphipod survival and microbial bioluminescence were moderately correlated with some trace metals, such as lead and zinc.

• Generally, the correlations between the results of the bivalve embryo tests and the concentrations of all chemicals were poor.

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REFERENCES

Aqua Survey, Inc. 1990a. Solid phase 10-day static sediment tests for control, reference and test sediments. Job #9094. August 17, 1990. Prepared for Exxon Company, U.S.A., Linden, NJ. 112 pp.

Aqua Survey, Inc. 1990b. Solid phase 10-day static sediment tests for control, reference and test sediments. Job #9205. November 30, 1990. Prepared for Exxon Company, USA, Linden, NJ. 84 pp.

ASTM. 1990. Standard guide for conducting 10-day static sediment toxicity tests with marine and estuarine amphipods. Guide E, pp. 1367-90. American Society for Testing Materials, Philadelphia, PA. 9 pp.

Barnes, D., A. Alford-Stevens, L. Birnbaum, F.W. Kutz, W. Wood and D. Patton. 1991. Toxicity equivalency factors for PCBs? Quality Assurance: Good Practice, Regulation and Law 1(1):70-81.

Belin, J. S. and D. G. Barnes. 1989. Interim procedures for estimating risks associated with exposures to mixtures of chlorinated dibenzo-p-dioxins and -dibenzofurans (CDDs and CDFs) and 1989 update. U.S. EPA/625/3-89/016. U.S. Environmental Protection Agency, Washington, DC. 29 pp.

Belton, T.J., R. Hazen, B.E. Ruppel, K. Lockwood, R. Mueller, E. Stevenson, and J.J. Post. 1985. A study of dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin) contamination in select finfish, crustaceans and sediments of New Jersey Waterways. New Jersey Dept. of Environmental Protection, Trenton, NJ. 102 pp.

Bonnevie, N.L., R.J. Wenning, S.L. Huntley and H. Bedbury. 1993. Distribution of inorganic compounds in sediments from three waterways in northern New Jersey. *Bulletin of Environmental Contamination and Toxicology* 51:672-680.

Bopp, R.F. and H.J. Simpson. 1989. Contamination of the Hudson River - The sediment record. In: Contaminated marine sediments - assessment and remediation: 401-416. National Academy of Sciences, Washington, DC. 493 pp.

Bopp, R.F., M.L. Gross, H. Tong, H.J. Simpson, S.J. Monson, B.L. Deck and F.C. Moser. 1991. A major incident of dioxin contamination: Sediments of New Jersey estuaries. *Environmental Science Technology* 25:951-956.

Breteler, R.J. (ed.) 1984. Chemical pollution of the Hudson-Raritan Estuary. NOAA Tech. Memo. NOS OMA 7. National Oceanic and Atmospheric Administration, Rockville, MD. 72 pp.

Brosnan, T.M. and M.L. O'Shea. 1993. New York Harbor Water Quality Survey: 1991-1992. Executive summary. New York City Dept. of Environmental Protection, Wards Island. New York, NY. 29 pp.

City of New York. 1987. New York Harbor Water Quality Survey, 1987. New York City, , Dept. of Environmental Protection, New York, NY. 19 pp.

Crecelius, E., C. Apts, L. Bingler, O. Cotter, S. Kiesser and R. Sanders. 1993. Analysis of marine sediment and bivalve tissue by x-ray fluorescence, atomic absorption, and inductively coupled plasma

mass spectrometry. In: Sampling and analytical methods of the National Status and Trends Program National Benthic Surveillance and Mussel Watch Projects 1984-1992. Vol 3: III.187-III.212. Comprehensive descriptions of elemental analytical methods. National Oceanic and Atmospheric Administration, Silver Spring, MD.

DeMuth, S., E. Casillas, D.A. Wolfe and B. B. McCain. 1993. Toxicity of saline and organic solvent extracts of sediments from Boston Harbor, Massachusetts and the Hudson-Raritan Estuary, New York using the Microtox bioassay. *Archives of Environmental Contamination Toxicology* 25:377-386.

Folk, 1974. Petrology of Sedimentary Rocks. Hemphill Publishing Company, Austin, TX. 184 pp.

Gottholm, B.W., M.R. Harmon and D.D. Turgeon. 1993. Assessment of chemical contaminants in the Hudson-Raritan Estuary and coastal New Jersey area. National Oceanic and Atmospheric Administration, Silver Spring, MD. 19 pp.

Gunster, D.G., C.A. Gillis, N.L. Bonnevie, T.B. Abel and R. J. Wenning. 1993. Petroleum and hazardous chemical spills in Newark Bay, New Jersey, USA from 1982-1991. *Environmental Pollution* 82:245-253.

Huntley, S. L., N. L. Bonnevie, R. J. Wenning. 1993. Distribution of polycyclic aromatic hydrocarbons (PAHs) in three northern New Jersey waterways. *Bulletin of Environmental Contamination and Toxicology* 51: 865-872.

Iannuzzi, T.J., N.L. Bonnevie, and R.J. Wenning. 1995. An evaluation of current methods for developing sediment quality guidelines for 2,3,7,8 tetrachlorodibenzo-p-dioxin. *Archives of Environmental Contamination and Toxicology* 28: 366-377.

Kohn, N.P., J.Q. Word, D.K. Niyogi, L.T. Ross, T. Dillon and D.W. Moore. 1994. Acute toxicity of ammonia to four species of marine amphipod. *Marine Environmental Research* 38:1-15.

Kutz, F.W., D.G. Barnes, D.P. Bottimore, H. Greim and E. W. Bretthauer. 1990. The International toxicity equivalency factor (I-REF) method of risk assessment for complex mixtures of dioxins and related compounds. *Chemosphere* 20(7-9):751-757.

Long, E.R. and L.G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Tech. Memo. NOS OMA 52. National Oceanic and Atmospheric Administration, Seattle, WA. 175 pp.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management* 19(1):81-97.

MacDonald, D.D. 1994. Sediment injury in the Southern California Bight: Review of the toxic effects of DDTs and PCBs in sediments. Report prepared by MacDonald Environmental Sciences, Ltd. for NOAA Damage Assessment Program - Southwest Region, Long Beach, CA. 96 pp.

Mayer, Gary E. (ed.) 1982. Ecological stress and the New York Bight: Science and management. Estuarine Research Federation, Columbia, SC. 715 pp.

Mueller, J.A., T.A. Gerrish and M.C. Casey. 1982. Contaminant inputs to the Hudson-Raritan Estuary. NOAA Tech. Memo. OMPA-21. 192 pp.

National Marine Fisheries Service. 1994. Bioassays to assess sublethal toxicity of sediments from the Hudson-Raritan Estuary, New York. Quarterly Report (April-May-June, 1994). Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, WA. 22 pp.

New York-New Jersey Harbor Estuary Program. 1995. Proposed comprehensive conservation and management plan. U.S. EPA, Region 2, New York, NY.

New York State Department of Environmental Conservation. 1993. Technical guidance for screening contaminated sediments. NYSDEC Division of Fish and Wildlife, Albany, NY.

NOAA. 1987. National Status and Trends Program for Marine Environmental Quality Progress Report. A summary of selected data on chemical contaminants in tissues collected during 1984, 1985, and 1986. NOAA Tech. Memo. NOS OMA 38. National Oceanic and Atmospheric Administration, Rockville, MD. 23 pp.

NOAA. 1988a. Hudson/Raritan Estuary: Issues, Resources, Status, and Management. NOAA Estuary-of-the-Month Seminar Series No. 9. National Oceanic and Atmospheric Administration, Washington, DC. 170 pp.

NOAA. 1988b. National Status and Trends Program for Marine Environmental Quality Progress Report. A summary of selected data on chemical contaminants in sediments collected during 1984, 1985, 1986, and 1987. NOAA Tech Memo. NOS OMA 44. Rockville, MD. 15 pp.

NOAA. 1989. National Status and Trends Program for Marine Environmental Quality Progress Report. A summary of data on tissue contamination from the first three years (1986-1988) of the mussel watch project. NOAA Tech. Memo. NOS OMA 49. Rockville, MD. 22 pp.

NOAA. 1991. National Status and Trends Program for Marine Environmental Quality Progress Report. Second summary of data on chemical contaminants in sediments from the National Status and Trends Program. NOAA Tech. Memo. NOS OMA 59. Rockville, MD. 29 pp.

O'Connor, T.P. and C.N. Ehler. 1991. Results from the NOAA National Status and Trends Program on distribution and effects of chemical contamination in the coastal and estuarine United States. *Environmental Monitoring and Assessment* 17:33-49.

Olsen, C.R., I.L. Larsen, R.H. Brewster, N.H. Cutshall, R.F. Bopp and H.J. Simpson. 1984. A geochemical assessment of sedimentation and contaminant distributions in the Hudson-Raritan Estuary. NOAA Tech. Report NOS OMS 2. Rockville, MD. 101 pp.

Pearce, J.B. 1988. Changing patterns of biological responses to pollution in the New York Bight. In: Hudson/Raritan Estuary: Issues, Resources, Status, and Management: 1-26. NOAA Estuary-of-the-Month Seminar Series No. 9. National Oceanic and Atmospheric Administration, Washington, D.C. 170 pp.

Peven, C.S. and A.D. Uhler. 1993. Analytical procedures followed by Battelle Ocean Sciences and Science Applications International Corporation to quantify organic contaminants. In: Sampling and

Analytical Methods of the National Status and Trends Program Benthic Surveillance and Mussel Watch Projects 1984-1992. Volume IV. Comprehensive descriptions of trace organic analytical methods. NOAA Tech. Memo. NOS ORCA 71. National Oceanic and Atmospheric Administration, Rockville, MD.

Pruell, R.J., N.I. Rubinstein, B.K. Taplin, J.A. LiVolsi, and C.B. Norwood. 1990. 2,3,7,8-TCDD, 2,3,7,8-TCDF and PCBs in marine sediments and biota: Laboratory and field studies. U.S. Environmental Protection Agency, Narragansett, R.I. Report No. EPA/600/8-90/068 prepared for U.S. Army Corps of Engineers, New York District. 75 pp.

Rice, C.A., P.D. Plesha, E. Casillas, D.A. Misitano, and J.P. Meador. In press. Growth and survival of three marine invertebrate species in sediments from the Hudson-Raritan Estuary, New York.

Robertson, A., B.W. Gottholm, D.D. Turgeon and D.A. Wolfe. 1991. A comparative study of contaminant levels in Long Island Sound. *Estuaries* 14(3):290-298.

Schimmel, S.C., B.D. Melzian, D.E. Campbell, C.J. Strobel, S.J. Benyi, J.S. Rosen, and H.W. Buffum. 1994. Statistical summary EMAP-Estuaries Virginian Province - 1991. Report No. EPA/620/R/94/005. U.S. Environmental Protection Agency, Narragansett, RI. 77 pp.

Scott, J., W. Berry, D. Cobb, D. Keith, G. Tracey, and N. Rubinstein. 1990. The application of the amphipod ten-day sediment toxicity test for dredged material evaluations. Submitted to U.S. EPA Region 2 by U.S. EPA Environmental Research Laboratory-Narragansett, RI.. ERL-Narragansett Contribution #1181. 25 pp.

Squibb, K.S., J.M. O'Connor and T.J. Kneip. 1991. New York/New Jersey Harbor Estuary Program. Module 3.1: Toxics Characterization Report. Prepared by Institute of Environmental Medicine, New York University Medical Center for U.S. EPA Region 2, New York City, N.Y. 188 pp.

Swartz, R.D., F.A. Cole, J.O. Lamberson, S.P. Ferraro, D.W. Schults, W.A. DeBen, H.Lee II and R.J.Ozretich. 1994. Sediment toxicity, contamination and amphipod abundance at a DDT- and dieldrin-contaminated site in San Francisco Bay. *Environmental Toxicology & Chemistry* 13(6):949-962.

Tatem, H.E., D.L. Brandon, C.R. Lee, A. S. Jarvis and R.G. Rhett. 1991. Effects of storage on sediment toxicity, bioaccumulation potential, and chemistry. Miscellaneous Paper EL-91-2. U.S. Army Waterways Experiment Station, Vicksburg, MS. 35 pp.

Tietjen, J.H. and J.J. Lee. 1984. The use of free-living nematodes as a bioassay for estuarine sediments. *Marine Environmental Research* 11:233-251.

Tillitt, D.E., J.P. Giesy and G.T. Ankley. 1991. Characterization of the H4IIE rat hepatoma cell bioassay as a tool for assessing toxic potency of planar halogenated hydrocarbons (PHHs) in environmental samples. *Environmental Science Technology* 25:87-92.

Tong, H.Y., S.J. Monson, M.L. Gross, R.F. Bopp, H.J. Simpson, B.L. Deck and F.C. Moser. 1990. Analysis of dated sediment samples from the Newark Bay area for selected PCDD/Fs. Chemosphere 20:1497-1502.

U.S. EPA. 1990. Recommended protocols for conducting laboratory bioassays on Puget Sound sediments. Revised April, 1990. Puget Sound Estuary Program, U.S. EPA Region 10, Seattle, WA. 79 pp.

U.S. EPA. 1993. Interim report on data and methods for assessment of 2,3,7,8-tetrachlorodibenzo-p-dioxin risks to aquatic life and associated wildlife. EPA/600/R-93/055. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

U.S. EPA. 1994. Notice of sediment quality criteria. Federal Register 59 (11):2652-2656. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA/ACOE. 1977. Ecological evaluation of proposed discharge of dredged material into ocean waters. Implementation Manual for Section 103 of Public Law 92-532. U.S. Environmental Protection Agency/U.S. Army Corps of Engineers, Washington, DC.

U.S. EPA/ACOE. 1991. Evaluation of dredged material proposed for ocean disposal. Testing Manual. U.S. Environmental Protection Agency/U.S. Army Corps of Engineers, Washington, DC. EPA-503/8-91/001.

Appendix

Appendix A. Phase 1 field notes.

Appendix B. Trace metals concentrations: Phase 1.

Appendix C. Acid-volatile sulfides and simultaneously extracted metals: Phase 1.

Appendix D. Polynuclear aromatic hydrocarbon concentrations : Phase 1.

Appendix E. PCB and pesticides concentrations: Phase 1.

Appendix F. Percent organic carbon, percent carbonate, and grain size: Phase 1.

Appendix G. Concentrations of all chemicals in Newark Bay samples: Phase 2.

Appendix H. Concentrations of dioxins and furans in Newark Bay samples: Phase 2.

Appendix I. Concentrations of tcdd-equivalents (pg/g) in H4IIE rat hepatoma bioassays of Newark Bay sediment extracts.

APPENDIX A. Field Notes				
Station Num.	Latitude (°N)	Longitude (°W)	Depth (m)	Sediment description
1a	40°54'52"	73°54'53"	14.3	Very fine watery brown mud; RPD 5 cm. deep; deep sediment with H2S odor.
1b	40°54'46"	73°54'58"	15.5	Brown watery mud with some small shell fragments; RPD 4 cm. deep.
1c	40°54'58"	73°54'52"	14.9	Soft brownish green mud with small shell fragments.
2a	40°52'42"	73°55'53"	14.3	Watery brown mud in top 1 cm.; RPD 3 cm. deep; few oil droplets.
2b	40°52'40"	73°55'52"	15.8	Soft brown silt in upper 3-4 cm.
2c	40°52'44"	73°55'55"	12.5	Fine watery brown silt in upper 4 cm.
3a	40°46'55"	73°59'25"	13.1	Watery mud; RPD <1 cm. deep; clay beneath; oil droplets.
3b	40°46'50"	73°59'28"	11.6	Soft brown silt; RPD <0.5 cm. deep; black clay beneath; oil droplets.
3c	40°46'44"	73°59'31"	11	Soft brown silt; RPD <0.5 cm. deep; black clay beneath; oil droplets.
4a	40°53'46"	73°42'21"	14.3	Brown flocculent surface layer; puddy-like green silt; RPD 1 cm. deep.
4b	40°53'45"	73°42'08"	14.6	Brown flocculent surface layer; puddy-like green silt; RPD 1 cm. deep.
4c	40°53'35"	73°42'19"	15.2	Puddy-like olive green silt; RPD 1 cm. deep.
5a	40°52'04"	73°44'54"	27.4	Brown-green silt w/shell fragments and amphipod tubes; RPD 1 cm. deep.
5b	40°51'53"	73°44'55"	25.9	Brown-green silt; flocculent on surface; RPD 0.5 cm. deep; few oil droplets.
5c	40°52'00"	73°45'04"	23.2	Brown-green silt; flocculent on surface; RPD 1 cm. deep; several oil droplets.
6a	40°50'04"	73°46'41"	18.6	Gooey brown-green surface mud; RPD 0.3 cm. deep; bottom mud oily black with anaerobic odor.
6b	40°49'56"	73°46'42"	18.6	Brown mud on top with flocculent and lots of shell fragments; RPD 0.5-1.0 cm.
6c	40°49'59"	73°46'34"	17.4	Light brown flocculent layer on top; RPD 0.25 to 0.50 cm. deep; dark anaerobic mud below.
7a	40°48'02"	73°47'14"	35.4	Loose fine sand and mud with floc. on surface; tube worms and shell fragments.
7b	40°48'01"	73°47'10"	35.4	Clean brown mud; light floc. on surface; RPD 1.0-2.5 cm. deep; high water content.
7c	40°47'56"	73°47'08"	32.9	Brown mud w/fine sand, shells, worm tubes, sea anemones crabs & clams; RPD 2-3 cm. deep.
8a	40°48'15"	73°50'17"	13.7	Brown muddy, silty sand with detritus & floc. on top; DPR 2-3 cm. deep.
8b	40°48'20"	73°50'25"	5.5	Gooey brwn mud w/ black depositional layer, oily smell, shell fragments; RPD 1 cm. deep.
8c	40°48'21"	73°50'19"	6.1	Brownish dense mud w/ scallop shells on surface; oily smell; RPD 0.5-1.0 cm. deep.
9a	40°47'46.2"	73°52'42"	9.7	Muddy, silty sand-dark green top w/black layer underneath; oily smell; RPD 1 cm.
9b	40°47'48"	73°52'51"	11.6	Brown sandy top w/thick mud; rust colored patches; light floc.; oily smell; RPD 1 cm. deep.
9c	40°47'44"	73°52'38"	11.6	Dark brown sandy top w/black oily mud below; RPD 1 cm. deep.
10a	40°47'58"	73°54'04"	10.7	Brown mud w/worm tubes and oily smell; RPD 2 cm. deep; dark black gooey mud below.
10b	40°47'56"	73°54'06"	7	Very thick, sticky mud with rust colored spots and shell fragments; RPD 2 cm. deep.

APPENDIX A (contd.)

Station Num.	Latitude (°N)	Longitude (°W)	Depth (m)	Sediment description
10c	40°47'54"	73°54'02"	5.5	Brown coarse top mud w/worm tubes; RPD 2 cm. deep w/darker, oily smelling mud below.
11a	40°44'38"	73°57'38"	4.1	Silty clay, amphipod tubes, mussels and sea grass; visible oil sheen on last grab of composite.
11b	40°44'39"	73°57'37"	6.2	Soft silty clay; amphipod tubes, polychaetes and gold flecks present; RPD <1 cm. deep.
11c	40°44'43"	73°57'35"	3.1	Silty sand with polychaetes and gold flecks; RPD 2 cm.
12a	40°42'33"	73°58'19"	16.5	Soft clay, amphipod tubes, snails, polychaetes, and oxidized material; RPD <1 cm.
12b	40°42'35"	73°58'13"	6.2	Soupy silt; RPD 2 cm. deep; worm tubes & hydroids in composite grab; benthic grab azoic.
12c	40°42'31"	73°58'14"	3.3	Soupy silt, almost clay; RPD 1 cm. deep; all grabs appeared azoic.
13a	40°42'11"	74°01'25"	15.5	Silty mud with black clay-like sediment below the RPD at <0.5 cm. depth.
13b	40°42'21"	74°01'34"	18	Soft silt with black clay-like sediment below the RPD at <0.5 cm. depth.
13c	40°42'11"	74°01'41"	19	Soft silt with black silt beneath the RPD at <1 cm. depth; shells, mussels and crabs.
14a	40°38'32"	74°03'12"	14.9	Fine sand w/slight RPD of 1 cm. deep; white specks, shells, polychaete worms; 1 razor clam shell.
14b	40°38'42"	74°03'14"	14.9	Fine sand, white specks, shells; RPD 1.5cm. deep; benthic grab- RPD 2.3 cm. deep.
14c	40°38'35"	74°03'24"	15.2	Fine sand, shells, white specks, worms; RPD 1.5 cm. deep; benthic grab- no visible RPD.
15a	40°36'42"	74°02'03"	6.4	Silty, sandy mud; shells, one crab, small tubes; rust colored spots; oil sheen; RPD 0.5 cm. deep.
15b	40°36'47"	74°02'30"	7.9	Dark brwn mud, light floc.. on top, small tubes; RPD 0.5 cm. deep; black mud below with oily sheen.
15c	40°36'59"	74°02'40"	6.1	Brown silty, sandy mud with mussel shells; RPD 0.5cm. deep.
16a	40°42'29"	74°07'02"	11	Sandy mud, shells, pebbles, worm tubes; RPD 1 cm. deep (RPD 3 cm. on one grab); oily sheen.
16b	40°42'27"	74°07'12"	11	Sandy mud, siltier below surface; RPD 0.5 to 1 cm. deep; oily sheen; benthic grab RPD 3 cm. deep.
16c	40°42'24"	74°07'06"	11.6	Silty sediment; RPD <0.5 cm. deep; oily sheen in composite.
17a	40°38'43"	74°10'20"	14.2	Fine silt with oil sheen on surface; small bivalves and polychaetes.
17b	40°38'43"	74°10'31"	11	Very fine silt with oil sheen on surface; small bivalves and polychaetes.
17c	40°38'41"	74°10'11"	9.5	Very fine silt with oil sheen on surface; small bivalves and polychaetes.
18a	40°34'11"	74°12'38"	12.8	Silty, petroleum odor; RPD 0.5 cm. deep; benthic grab- RPD 1.5 cm deep w/dark black silt beneath.
18b	40°34'09"	74°12'41"	11.6	Silty w/blk silt under RPD of 0.5 cm deep; oil sheen,organic matter, benthic grab- RPD 1cm deep.
18c	40°34'06"	74°12'42"	9.1	Soft black silt; RPD very close to surface; oil sheen; very small clams.
19a	40°29'01"	74°21'00"	1.9	Fine to coarse sand and fine silt on surface; bivalve shells, sticks, rocks; no distinct RPD.
19b	40°21'01"	74°20'54"	1.8	Medium brown soft silt and fine sand; RPD 0.5 cm. deep.
19c	40°29'02"	74°20'49"	1.8	Medium and dark brown silt with some fine sand; uneven surface; RPD 1 cm. deep.
20a	40°30'34"	74°18'13"	2.9	Medium brwn, fine, soupy silt with a few tar balls; worms, oysters, clam shells; RPD 2.5 cm deep.

APPENDIX A (contd.)					
Station Num.	Latitude (°N)	Longitude (°W)	Depth (m)	Sediment description	
20b	40°30'32"	74°18'19"	3.7	Fine brown silt with some mixed bivalve shells and worms; RPD 1 cm. deep.	
20c	40°30'35"	74°18'06"	3	Fine brown silt with mixed bivalve shells and small crabs; RPD 2 mm. deep.	
21a	40°29'55"	74°16'42"	3	Soupy light brown silt with bivalve shells and grass shrimp; RPD located at 4 cm.	
21b	40°29'52"	74°16'32.9"	2.8	Brown fine soupy silt; grass shrimp & bivalve shell bits; hydrogen sulfide smell; RPD 2.5 cm deep.	
21c	40°29'46"	74°16'41"	4.9	Very fine brown silt with amphipod tubes and occasional bivalve and shell bits; RPD 3 cm. deep.	
22a	40°30'43"	74°15'16"	3	Thin brown mud layer; RPD 2.5cm. deep; black mud layer below with anoxic, oily smell.	
22b	40°30'39"	74°15'18"	2.7	Brown mud w/ shell bits and worm tubes; RPD 1.5-2.5 cm.; black silt and sand below.	
22c	40°30'34"	74°15'21"	3	Drk brwn mud; top floc.; shell bits & organic matter; RPD 1.5 cm.; blck mud below w/anoxic smell.	
23a	40°29'15.0"	74°15'33.6"	6.4	Soft oozey mud with small dead bivalve spat; RPD 2.5 cm. with darker mud below.	
23b	40°29'14"	74°15'26"	6.4	Soft oozey mud with bivalve spat; RPD 2.5 cm.	
23c	40°29'08"	74°15'32"	4.9	Silty brwn mud w/shells,worm tubes,crabs, worms;deeper grab-blk tarry sand;RPD3 cm.	
24a	40°29'23"	74°13'35"	4.9	Dark brwn mud w/shell bits, worm tubes, snails, shrimp; RPD 0.5 cm. w/drk black mud below.	
24b	40°29'16"	74°13'31"	4.9	Green-brown silty mud with many worm tubes on top; RPD 0.5 cm. w/dark black mud underneath.	
24c	40°29'23"	74°13'25"	4.6	Green-brown silty mud with shell bits on top; RPD 0.5 cm. with black mud underneath.	
25a	40°29'24"	73°10'59"	6.1	Fine silt w/high density of amphipod tubes, shrimp, shell bits; high water content; RPD 4 cm.	
25b	40°29'31"	74°10'47"	6.1	Fine brwn silt w/worm tubes, gastropods, amphipods, ice-cream cone worms; high water content.	
25c	40°29'22"	74°10'45"	6.1	Fine brwn silt w/high density of amphipod tubes, gastropods; high water content; RPD 4 cm.	
26a	40°30'03"	74°09'02"	9.4	Soft brwn silt w/amphipods, amphipods tubes, gastropods; soupy & solid sediment mixed together.	
26b	40°30'09"	74°09'11"	7.9	Light brown silt and fine sand w/some bivalve shell bits, amphipod tubes; one large hard clam.	
26c	40°30'06"	74°09'00"	8.2	Brwn silt w/ worm tubes, amphipods, bivalve shells, two large hard clams; RPD 2.5 cm.	
27a	40°29'35"	74°06'56"	10.1	Med-brwn silt w/amphipod tubes, bivalve shells, amphipods, gastropods; RPD 3 cm. (varied)	
27b	40°29'34"	74°06'45"	9.7	Medium-brown sticky silt with numerous amphipod tubes and amphipods on surface; RPD 3 cm.	
27c	40°29'40"	74°06'58"	9.1	Medium-brown silt with amphipod tubes at surface; RPD 4 cm.	
28a	40°28'35"	74°04'22"	7.31	Green-brown soupy mud with worm tubes on the surface and some shell bits; RDP 1cm.	
28b	40°28'26"	74°04'29"	6.7	Green-brown silty mud with high density of worm tubes on surface.	
28c	40°28'27"	74°04'16"	6.7	Brown silty mud with worm tubes on the surface.	
29a	40°27'23"	74°02'00"	6.4	Dark brown silt w/amphipod tubes at surface, large hard clam; very sticky; RPD 3 cm.	
29b	40°27'21"	74°02'04"	6.1	Medium to dark brown silt with amphipods & gastropods; razor clam shells; RPD 3 cm.	
29c	40°27'27"	74°02'04"	6.1	Dark-med brwn silt & fine sand w/amphipod tubes, amphipods, gastropods, clico crab; RPD 3 cm.	

APPENDIX A (contd.)

Station Num.	Latitude (°N)	Longitude (°W)	Depth (m)	Sediment description
30a	40°25'34"	74°00'48"	5.5	Brown silt & fine sand w/amphipod tubes, gastropods & undecomposed organic matter.
30b	40°25'33"	74°00'38"	5.8	Med-dark brown silt; fine sand w/amphipod tubes, amphipods; cohesive (drops out of grab easily).
30c	40°25'27"	74°00'46"	5.8	Med-dark brown silt; fine sand w/amphipod tubes, gastropods, bivalves, undecomposed Ulva.
31a	40°28'03"	74°13'14"	3.3	Medium brown silt; fine sand with amphipod tubes, large bivalve fragments.
31b	40°28'08"	74°13'17"	3.3	Brown silt; fine sand with amphipod tubes, large & small shell bits; RPD 2 cm.
31c	40°28'06"	74°13'24"	3.3	Brown silt and fine sand with bivalve shell fragments.
32a	40°28'06"	74°09'33"	3.7	Brown silt; fine sand w/bivalve shell bits; patchy uneven surfaces; RPD 2 cm. (varied).
32b	40°28'03.7"	74°09'24.8"	3.7	Medium brown sand and silt w/large & small bivalve fragments; shallow and sharp; RPD 1 cm.
32c	40°27'57.8"	74°09'33.5"	3.7	Light brown, fine sand and silt with bivalve shell bits; RPD varied (2-4 cm).
33a	40°28'01"	74°05'52"	5.5	Medium brown silt w/fine sand, amphipod tubes, shrimp, amphipods; RPD 3 cm.
33b	40°28'03"	74°05'59"	7	Medium to dark brown silt and fine sand with bivalve shell bits & amphipod tubes; RPD 3cm.
33c	40°28'02"	74°05'47"	6.7	Med. to dark brwn silt & fine sand w/amphipod tubes, amphipods, shrimp & gastropods; RPD 3cm.
34a	40°30'41"	74°06'04"	6.4	Green-brwn silty mud w/ worm tubes; soft mud w/high water content; hard clams; no clear RPD.
34b	40°30'35"	74°06'05"	7.3	Green-brwn watery mud w/worm tubes, razor clams & hard clams; no visible RPD.
34c	40°30'37"	74°06'13"	6.7	Green-brwn silty mud w/worm tubes; no visible RPD.
35a	40°29'40"	74°02'40"	11.9	Brown silty, sandy mud w/shell bits, worm tubes; RPD 1-3 cm.; dark blk mud underneath.
35b	40°29'35"	74°02'42"	11.9	Brown sandy mud w/shell bits & worm tubes; RPD 1cm. with dark black mud underneath.
35c	40°29'26"	74°02'42"	9.7	Brown sandy mud with shell bits & worm tubes; RPD 1-2 cm.
36a	40°33'42"	74°03'08"	7.3	Fine silty mud; light at top, dark brown below; RPD 2-3 cm.
36b	40°33'41"	74°03'19"	7.6	Light brown silty mud on top with worm tubes; sharp RPD 1cm. dark black mud below.
36c	41°33'35"	74°03'08"	8.2	Brown, silty mud with shell bits; oily/anoxic smell; sharp RPD 1.0-1.5 cm.
37a	40°29'56"	73°58'35"	6.7	Medium-grained & fine sand with amphipods on top and shell bits.
37b	40°30'05"	73°58'29"	4.3	Medium-grained sand with small shell fragments.
37c	40°30'01"	73°58'41"	5.5	Medium-grained sand with small shell fragments.
38a	40°27'58"	73°55'56"	10.1	Fine sand w/bivalve shells, worms, red and calico crabs; no visible RPD.
38b	40°28'07"	73°55'59"	9.1	Fine sand with bivalve shells; no visible RPD.
38c	40°28'01"	73°56'10"	8.2	Fine and med-grained sand with shell bits; medium-sized (10 cm) surf clams.
39a	40°25'59"	73°53'32"	20.3	Silt & fine sand underlain by med-grained sand; shell bits, hard clam spat & worms; RPD 7cm.
39b	40°25'57"	73°53'43"	22.2	Silt and fine sand with small clams, one oyster drill; RPD 7 cm.
39c	40°25'59"	73°53'36"	20.4	Silt, fine sand and medium-grained sand with amphipod tubes at top, worms and amphipods.

Appendix B. Trace Metals Concentrations (ug/g); Phase 1.

MSL Code	Rep Sponsor ID	Ag	Al(%)	As	Cr	Cd	Cu	Fe(%)	Hg	Mn	Ni	Pb	Sb	Se	Sn	Zn
		GFAA	XRF	XRF	XRF	GFAA	XRF	XRF	CVAA	XRF	XRF	XRF	ICP/MS	GFAA	ICP/MS	XRF
574MW-1	NOAA 1-A	2.5	4.8	9.2	99	0.96	76	3.6	1.0	1000	31	96	1.2	0.59	11	190
574MW-2	NOAA 4-1	2.0	4.4	10	110	1.2	110	3.3	0.6	800	34	92	0.81	0.68	11	240
574MW-3	NOAA 6-C	2.6	3.9	14	110	2.1	150	3.5	1.0	1700	39	140	0.97	0.8	16	290
574MW-4	NOAA 9-B	2.5	5.4	26	130	1 .9	260	3.4	5.0	580	45	400	6.4	1.8	46	440
574MW-5	NOAA 7-B	1.5	4.5	7.2	73	1.2	66	2.5	5.0	700	27	95	1.2	0.32	12	170
574MW-6	NOAA 7-C	1.1	2.9	4.2	50	0.71	44	2.7	0.7	710	25	68	0.7	0.21	9.8	110
574MW-7	NOAA 10-B	1.1	4.6	41	96	0.51	140	4.2	4.7	600	43	300	1.2	0.64	30	210
574MW-8	NOAA 8-C	1.9	5.9	27	100	3.1	200	3.2	2.5	600	41	240	2.2	1.1	31	370
574MW-9	NOAA 10-A	2.3	5.5	11	81	0.8	96	3.1	1.0	810	34	110	0.85	0.43	9.8	170
574MW-10	NOAA 11 -B	2.4	5.4	19	180	1.6	210	4.1	2.1	760	56	250	2.2	0.69	23	290
574MW-11	NOAA 13-A	2.4	5.6	21	170	1.6	240	3.8	1.6	700	39	210	1.4	0.59	16	250
574MW-12	NOAA 14-A	0.2	2.1	4.2	1 9	0.18	11	0.7	0.1	270	8.5	30	0.16	0.43	3.2	43
574MW-13	NOAA 12-A	2.4	6.3	24	420	5.6	520	4.9	3.4	590	130	510	6.3	1.4	100	1400
574MW-14	NOAA 16-B	1.1	5.1	7.4	86	1.4	57	2.2	1.7	320	24	67	0.73	<.16	14	140
574MW-15	NOAA 17-C	2.2	6.8	21	160	3.1	190	3.8	3.9	590	54	240	2.7	1.4	34	400
574MW-16	NOAA 16-A	0.5	4.0	6.9	83	0.8	31	1.5	1.1	224	15	41	0.46	<.16	7.5	77
574MW- 17	NOAA 18-A	2.0	3.9	1 6	87	2.1	160	2.7	2.4	300	31	130	2.8	1.4	23	210
574MW-18	NOAA 18-C	2.1	6.1	38	190	6.4	520	3.4	15.0	340	53	300	7.8	4.3	55	460
574MW-19	NOAA 22-C	2.2	6.0	41	110	4.5	230	3.3	2.2	360	39	200	4.3	3	32	400
574MW-20	NOAA 23-A	2.3	7.9	36	130	1.6	180	4.7	2.5	660	48	190	3.6	1.9	27	370
574MW-21	NOAA 24-C	1.8	7.8	28	150	1.2	170	4.8	2.6	760	46	200	2.9	1.7	29	370
574MW-22	NOAA 25-A	1.8	7.9	27	150	1.1	150	4.9	2.6	740	44	210	2.3	1.3	28	370
574MW-23	NOAA 26-A	2.5	7.3	26	170	1.3	140	4.7	2.6	930	49	190	2.1	1.3	25	340
574MW-24	NOAA 28-C	2.6	7.8	17	160	0.96	120	4.4	2.5	1100	46	200	2.0	1.4	25	340
574MW-25	NOAA 29-A	3.4	7.5	26	140	1.6	98	4.3	1.7	660	38	130	1.7	1.1	17	300
574MW-26	NOAA 30-A	2.6	6.3	31	130	2.5	89	5.3	1.4	630	35	110	1.5	1.1	16	420
574MW-27	NOAA 30-B	2.2	5.3	28	110	2.1	79	5.0	1.3	560	29	100	1.4	0.50	13	350
574MW-28	NOAA 33-B	2.4	8.1	32	180	1.3	150	5.2	2.9	930	50	210	2.9	1.5	29	420
574MW-29	NOAA 37-A	0.01	1.2	<1.7	< 12	0.03	5.3	0.63	0.03	750	4.5	16	0.13	0.46	1.2	36
574MW-30	NOAA 17-B	2.7	5.0	24	167	3	200	4.0	3.9	580	48	210	2.6	1.2	32	360
574MW-31	NOAA 2-A	3.0	6.2	1 4	100	0.91	69	4.0	0.7	1300	37	83	1.3	0.79	6.6	200
574MW-32	NOAA 5-B	2.8	6.4	1 4	110	1.5	130	3.8	0.6	1300	38	110	0.86	0.96	12	260

Appendix B. Trace Metals Concentrations (ug/g); Phase 1 contd.

MSL CODE	Rep Sponsor ID	Ag	Al(%)	As	Cr	Cd	Cu	Fe(%)	Hg	Mn	Ni	Pb	Sb	Se	Sn	Zn
		GFAA	XRF	XRF	XRF	GFAA	XRF	XRF	CVAA	XRF	XRF	XRF	ICP/MS	GFAA	ICP/MS	XRF
574MW-33	NOAA 30-C	3	5.9	39	1 40	1.7	11 0	5.5	1.6	760	34	130	1.9	1.3	1 8	400
574MW-34	NOAA 34-B	1.6	3.3	1 1	59	0.39	39	2.2	0.76	720	1 7	62	0.68	0.79	9.8	190
574MW-35	NOAA 12-B	2.3	6.6	17	180	2.2	210	4.2	2.3	690	51	230	1.9	1	25	350
574MW-36	NOAA 36-C	2.1	5.6	21	120	1.3	98	3.5	1.4	660	35	120	1.4	1	1 7	220
574MW-37	NOAA 35-A	0.86	3.5	1 0	54	0.93	30	1.7	0.58	340	1 3	54	0.46	0.32	5.9	140
574MW-38	NOAA 38-B	0.04	2.4	6	33	0.04	3.3	1.3	0.06	210	6.2	1 7	0.13	0.47	2.2	38
Blank		0.02	NA	NA	NA	NA	NA	NA	0.007	NA	NA	NA	0.01	<0.16	0.41	NA
Blank		1.02	NA	NA	NA	NA	NA	NA	0.005	NA	NA	NA	1.01	<0.17	0.02	NA
Blank		2.02	NA	NA	NA	NA	NA	NA	0.006	NA	NA	NA	2.01	<0.18	< 0.01	NA
STANDARD REFERENCE MATERIAL																
1646 1		0.09	7.0	1 2	65	< 0.01	1 7	3.5	0.092	340	34	29	0.41	0.58	3.1	130
1646 2		0.10	6.5	12	65	< 0.2	18	3.3	0.084	340	33	26	0.44	0.38	3	130
1646 3		0.09	6.0	1 2	63	< 0.3	1 7	3.3	0.089	370	32	27	0.4	0.43	2.8	130
certified value		NC	6.25	11.6	76	0.36	1 8	3.35	0.063	375	32	28.2	NC	NC	NC	138
range		NC	±0.20	±1.3	±3	±0.07	±3	±0.10	±0.012	±20	±3	±1.8	NC	NC	NC	±6
MATRIX SPIKE RESULTS																
Amount Spiked		2	NS	NS	NS	2	NS	NS	2	NS	NS	NS	2.0	2.0	2.0	NS
574MW-12	NOAA 14-A	0.20	NS	NS	NS	0.18	NS	NS	0.14	NS	NS	NS	0.16	0.43	3.2	NS
574MW-12 + Spike		1.9	NS	NS	NS	2.4	NS	NS	2.1	NS	NS	NS	2.2	0.37	4.9	NS
Amount Recovered		1.7	NS	NS	NS	2.2	NS	NS	2.0	NS	NS	NS	2.1	0.00	1.7	NS
Percent Recovery		83%	NS	NS	NS	110%	NS	NS	100%	NS	NS	NS	103%	0%	85%	NS

Appendix B. Trace Metals Concentrations (ug/g); Phase 1 contd.																
MSL CODE	REP SPONSOR ID	Ag	Al(%)	As	Cr	Cd	Cu	Fe(%)	Hg	Mn	Ni	Pb	Sb	Se	Sn	Zn
		GFAA	XRF	XRF	XRF	GFAA	XRF	XRF	CVAA	XRF	XRF	XRF	ICP/MS	GFAA	ICP/MS	XRF
MATRIX SPIKE RESULTS																
Amount Spiked		2	NS	NS	NS	2	NS	NS	2	NS	NS	NS	2	2	2	NS
574MW-24	NOAA 26-C	2.6	NS	NS	NS	0.96	NS	NS	2.5	NS	NS	NS	2	1.4	2.5	NS
574MW-24 + Spike		2.6	NS	NS	NS	3.1	NS	NS	4.6	NS	NS	NS	3.8	1.6	2.7	NS
Amount Recovered		0.01	NS	NS	NS	2.1	NS	NS	2.1	NS	NS	NS	1.8	0.17	2	NS
Percent Recovery		1%	NS	NS	NS	105%	NS	NS	105%	NS	NS	NS	92%	9%	100%	NS
Amount Spiked		2	NS	NS	NS	2	NS	NS	2	NS	NS	NS	2	2	2	NS
574MW-36	NOAA 36-C	2.1	NS	NS	NS	1.3	NS	NS	1.4	NS	NS	NS	1.4	1	1.6	NS
574MW-36 + Spike		2.4	NS	NS	NS	3.3	NS	NS	3.9	NS	NS	NS	3.4	1.1	1.8	NS
Amount Recovered		0.29	NS	NS	NS	2.1	NS	NS	2.5	NS	NS	NS	2	0.06	1.7	NS
Percent Recovery		15%	NS	NS	NS	104%	NS	NS	125%	NS	NS	NS	100%	3%	85%	NS
Amount Spiked		2	NS	NS	NS	2	NS	NS	2	NS	NS	NS	2	2	2	NS
574MW-38	NOAA 38-B	0.04	NS	NS	NS	0.04	NS	NS	0.06	NS	NS	NS	0.13	0.47	2.2	NS
574MW-38 + Spike		1.6	NS	NS	NS	2.4	NS	NS	2.2	NS	NS	NS	2.2	0.59	4.4	NS
Amount Recovered		1.6	NS	NS	NS	2.3	NS	NS	2.1	NS	NS	NS	2.1	0.12	2.2	NS
Percent Recovery		80%	NS	NS	NS	116%	NS	NS	106%	NS	NS	NS	104%	6%	111%	NS
NA = Not applicable																
NC = Not certified																
NS = Not spiked																

Appendix C. Acid-Volatile Sulfides and Simultaneously-Extracted Metals: Phase 1.					
MSLCode			Sponsor ID	AVS	SEM
				µmole/g	Ratio*
574MW-1			NOAA 1-A	4.39	0.0067
574MW-1		DUP	NOAA 1-A	4.96	0.0074
574MW-2			NOAA 4-A	61.05	0.0028
574MW-3	**		NOAA 6-C	51.77	0.0029
574MW-4			NOAA 9-B	69.32	0.0042
574MW-5	**		NOAA 7-B	14.17	0.0212
574MW-5	**	DUP	NOAA 7-B	12.66	0.0092
574MW-6			NOAA 7-C	27.54	0.0087
574MW-7	**		NOAA 10-B	25.84	0.0068
574MW-8	**		NOAA 8-C	21.98	0.0099
574MW-9			NOAA 10-A	7.23	0.0128
574MW-10			NOAA 11-B	59.78	0.0041
574MW-11			NOAA 13-A	43.92	0.0051
574MW-12			NOAA 14-A	0.63	0.0291
574MW-13			NOAA 12-A	51.58	0.0049
574MW-14			NOAA 16-B	15.13	0.0125
574MW-15			NOAA 17-C	23.72	0.007
574MW-15		DUP	NOAA 17-C	18.58	0.0065
574MW-16			NOAA 16-A	10.16	0.0196
574MW-17			NOAA 18-A	56.73	0.0063
574MW-18	**		NOAA 18-C	63.45	0.0056
574MW-19			NOAA 22-C	54.71	0.0058
574MW-20			NOAA 23-A	35.37	0.004
574MW-21	**		NOAA 24-C	12.24	0.0073
574MW-22			NOAA 25-A	14.57	0.0066
574MW-23			NOAA 26-A	22.57	0.0068
574MW-23		DUP	NOAA 26-A	20.14	0.0045
574MW-24			NOAA 26-C	19.32	0.0067
574MW-25			NOAA 29-A	30.12	0.0058
574MW-26			NOAA 30-A	25.9	0.0035
574MW-27			NOAA 30-B	20.53	0.0072
574MW-28			NOAA 33-B	29.21	0.0051
574MW-29			NOAA 37-B	<0.036	0.0365
574MW-30	**		NOAA 17-B	20.78	0.005
574MW-31	**		NOAA 2-A	1.08	0.0055
574MW-32			NOAA 5-B	79.71	0.0012
574MW-33			NOAA 30-C	18.44	0.0087
574MW-34			NOAA 34-B	3.63	0.0148
574MW-35			NOAA 12-B	37.86	0.007
574MW-36	**		NOAA 36-C	28.08	0.0062
574MW-37			NOAA 35-A	18.76	0.0108
574MW-37		DUP	NOAA 35-A	20.42	0.009
574MW-38			NOAA 38-B	0.05	0.0495
574MW Blank-1				0	NA
574MW Blank-2				0	NA
*Sediment/acid volume					
** = Sample jar received broken.					

Appendix C. Acid-Volatile Sulfides and Simultaneously-Extracted Metals: Phase 1 contd.					
MSLCode	CADMIUM	CADMIUM	COPPER	COPPER	MERCURY
	µg/g	µmole/g	µg/g	µmole/g	µmole/g
574MW-1	0.602	0.0054	32.67	0.5141	0.0048
574MW-1	0.467	0.0042	28.53	0.4491	0.0066
574MW-2	1.07	0.0095	17.66	0.278	0.00048
574MW-3	1.09	0.0097	50.2	0.79	0.00052
574MW-4	0.939	0.0084	44.52	0.7006	<0.00024
574MW-5	0.781	0.0069	20.62	0.3245	0.00091
574MW-5	0.712	0.0063	23.4	0.3683	0.0024
574MW-6	0.404	0.0036	9.089	0.143	0.00005
574MW-7	0.218	0.0019	62.89	0.9897	0.003
574MW-8	1.67	0.015	82.13	1.293	0.00074
574MW-9	0.321	0.0029	31.59	0.4972	0.0021
574MW-10	0.771	0.0069	15.79	0.2485	0.0014
574MW-11	0.922	0.0082	47.89	0.7537	0.0034
574MW-12	0.171	0.0015	3.279	0.0516	0.0014
574MW-13	2.84	0.025	79.75	1.255	0.00084
574MW-14	0.817	0.0073	11.74	0.1847	0.0015
574MW-15	1.59	0.014	50.44	0.7938	0.004
574MW-15	1.78	0.016	54.02	0.8502	0.0036
574MW-16	0.515	0.0046	6.388	0.1005	0.00098
574MW-17	1.41	0.013	12.38	0.1948	0.0023
574MW-18	3.71	0.033	141.3	2.224	0.0172
574MW-19	1.89	0.017	28.13	0.4428	0.0022
574MW-20	0.933	0.0083	56.34	0.8866	0.0065
574MW-21	0.685	0.0061	70.68	1.112	0.014
574MW-22	0.571	0.0051	66.14	1.041	0.017
574MW-23	0.643	0.0057	56.9	0.8954	0.0093
574MW-23	0.646	0.0057	56.77	0.8934	0.015
574MW-24	0.507	0.0045	46.74	0.7356	0.0053
574MW-25	0.918	0.0082	32.92	0.5181	0.0088
574MW-26	1.89	0.017	33.84	0.5325	0.0048
574MW-27	1.39	0.012	37.33	0.5875	0.0099
574MW-28	0.757	0.0067	57	0.8971	0.012
574MW-29	<0.007	<0.00007	0.9984	0.0157	0.0049
574MW-30	1.67	0.015	66.34	1.044	0.0077
574MW-31	0.579	0.0052	38.82	0.6109	0.013
574MW-32	2.36	0.021	27.43	0.4317	0.0032
574MW-33	0.944	0.0084	45.95	0.7231	0.0065
574MW-34	0.207	0.0018	20.07	0.3158	0.0046
574MW-35	1.02	0.0091	24.85	0.3911	0.002
574MW-36	0.621	0.0055	38.53	0.6064	0.0029
574MW-37	0.635	0.0056	9.608	0.1512	0.0021
574MW-37	0.637	0.0057	9.514	0.1497	0.0021
574MW-38	0.023	0.0002	0.9516	0.015	0.0025
574MW Blank-	0.042	0.0004	0.0631	0.001	1.36
574MW Blank-	0.038	0.0003	0.2358	0.0037	2.27
*Sediment/acid volume					
** = Sample jar received broken.					

Appendix C. Acid-Volatile Sulfides and Simultaneously-Extracted Metals: Phase 1 contd.					
	Mercury	Nickel	Nickel	Lead	Lead
MSLCode	µg/g	µg/g	µmole/g	µg/g	µmole/g
574MW-1	0.000024	4.875	0.08304	63.89	0.3084
574MW-1	0.000033	3.953	0.06734	57.45	0.2773
574MW-2	2.40E-06	7.822	0.13323	58.76	0.2836
574MW-3	2.60E-06	3.886	0.06619	77.96	0.3763
574MW-4	<0.0000001	5.752	0.09797	272.1	1.313
574MW-5	4.50E-06	2.29	0.039	51.62	0.2492
574MW-5	0.000012	4.142	0.07054	51.28	0.2475
574MW-6	2.00E-07	2.188	0.03726	38.09	0.1839
574MW-7	0.000015	2.929	0.04988	201.3	0.9717
574MW-8	3.70E-06	3.185	0.05426	132.8	0.641
574MW-9	0.00001	2.499	0.04257	54.03	0.2608
574MW-10	7.10E-06	6.753	0.115	149.6	0.7219
574MW-11	0.000017	5.456	0.09293	111.O	0.5356
574MW-12	6.80E-06	0.5996	0.01021	16.31	0.07874
574MW-13	4.20E-06	9.769	0.1664	207.9	1.003
574MW-14	7.50E-06	1.928	0.03284	46.15	0.2228
574MW-15	0.00002	6.714	0.1144	147.1	0.7102
574MW-15	1.77E-05	6.911	0.1177	158.1	0.7629
574MW-16	4.90E-06	2.461	0.04192	30.36	0.1465
574MW-17	0.000012	3.996	0.06806	79.09	0.3817
574MW-18	0.000086	14.96	0.25478	189.7	0.9155
574MW-19	0.000011	6.472	0.1102	93.18	0.4497
574MW-20	0.000033	6.593	0.1123	130.7	0.6307
574MW-21	0.00007	6.178	0.1052	131.4	0.6344
574MW-22	0.000086	8.145	0.1387	162.3	0.7833
574MW-23	0.000047	5.592	0.09526	132.3	0.6388
574MW-23	0.000075	8.853	0.1508	133.4	0.6436
574MW-24	0.000027	5.742	0.0978	132.8	0.6411
574MW-25	0.000044	4.97	0.08464	81.8	0.3948
574MW-26	0.000024	5.117	0.08715	73.19	0.3533
574MW-27	0.000049	5.623	0.09578	74.38	0.359
574MW-28	0.000059	7.816	0.1331	145.9	0.7042
574MW-29	0.000025	2.158	0.03676	4.919	0.0237
574MW-30	0.000038	15.64	0.2664	132.6	0.6399
574MW-31	0.000064	15.15	0.2581	62.21	0.3003
574MW-32	0.000016	4.444	0.0757	79.54	0.3839
574MW-33	0.000033	6.65	0.1133	78.91	0.3808
574MW-34	0.000023	3.246	0.05528	50.92	0.2458
574MW-35	0.00001	4.929	0.08395	144	0.6952
574MW-36	0.000014	6.132	0.1044	89.66	0.4328
574MW-37	0.000011	2.446	0.04166	35.15	0.1696
574MW-37	0.00001	3.032	0.05164	39.03	0.1884
574MW-38	0.000013	0.712	0.01213	8.71	0.04204
574MW Blank-1	0.0068	0.1405	0.00239	0.0700 0.000	0.00034
574MW Blank-2	0.0013	0.3324	0.00566	0.0724 0.000	0.00035
	*Sediment/acid volume				
	** = Sample jar received broken.				

Appendix C. Acid-Volatile Sulfides and Simultaneously-Extracte				
Metals: Phase 1 contd.				
	Zinc	Zinc	Total SEM	SEM/AVS
MSLCode	µg/g	µmole/g	umole/g	ratio
574MW-1	95.74	1.465	2.38	0.54
574MW-1	87.67	1.341	2.14	0.43
574MW-2	122.7	1.877	2.58	0.04
574MW-3	120.9	1.85	3.09	0.06
574MW-4	190.7	2.917	5.04	0.07
574MW-5	80.72	1.235	1.85	0.13
574MW-5	83.41	1.276	1.97	0.16
574MW-6	52.71	0.8063	1.17	0.04
574MW-7	98	1.499	3.51	0.14
574MW-8	143.8	2.199	4.2	0.19
574MW-9	56.11	0.8583	1.66	0.23
574MW-10	131.5	2.011	3.1	0.05
574MW-11	127.6	1.951	3.34	0.08
574MW-12	23.74	0.3632	0.51	0.8
574MW-13	225.3	3.447	5.9	0.11
574MW-14	70.56	1.079	1.53	0.1
574MW-15	198.1	3.03	4.66	0.2
574MW-15	209.2	3.2	4.95	0.27
574MW-16	47.02	0.7194	1.01	0.1
574MW-17	126.9	1.942	2.6	0.05
574MW-18	233.4	3.571	7	0.11
574MW-19	240.4	3.677	4.7	0.09
574MW-20	206.8	3.163	4.8	0.14
574MW-21	209.4	3.203	5.06	0.41
574MW-22	211.9	3.241	5.21	0.36
574MW-23	174.4	2.668	4.3	0.19
574MW-23	180.3	2.759	4.45	0.22
574MW-24	180.5	2.761	4.24	0.22
574MW-25	155.1	2.373	3.38	0.11
574MW-26	291	4.452	5.44	0.21
574MW-27	232.7	3.56	4.61	0.22
574MW-28	247.8	3.791	5.53	0.19
574MW-29	16.93	0.2591	0.34	9.32
574MW-30	164.4	2.515	4.48	0.22
574MW-31	94.31	1.443	2.62	2.42
574MW-32	136.3	2.085	3	0.04
574MW-33	183.2	2.803	4.03	0.22
574MW-34	134.4	2.055	2.67	0.74
574MW-35	148.4	2.27	3.45	0.09
574MW-36	112.4	1.72	2.87	0.1
574MW-37	84.72	1.296	1.66	0.09
574MW-37	89.6	1.371	1.77	0.09
574MW-38	13.34	0.2041	0.27	5.47
574MW Blank-	1.225	0.0187		
574MW Blank-	1.417	0.0217		

Appendix C. Acid-Volatile Sulfides and Simultaneously-Extracted Metals: Phase 1 contd.			
MSL Code	Sponsor ID	AVS	Cadmium
STANDARD REFERENCE MATERIAL (µg/L)		µmole/g	µg/L
1643c-1		NA	9.72
1643c-2		NA	9.93
	certified value	NA	12.2
	range	NA	1
1641 b- 1		NA	NA
1641 b- 2		NA	NA
1641 b- 3		NA	NA
	certified value	NA	NA
	range	NA	NA
SPIKE RESULTS (µg/L)			
Amount Spiked		NA	250
574MW- 1	NOAA 1-A	NA	4.4
574MW-1 + Spike		NA	251.31
Amount Recovered		NA	246.91
Percent Recovery x100		NA	99.00%
Amount Spiked		NA	250
574MW-7	NOAA 10-B	NA	1.85
574MW-7 + Spike		NA	234.74
Amount Recovered		NA	232.89
Percent Recovery x100		NA	93%
Amount Spiked		NA	250
574MW-16	NOAA 16-A	NA	10.49
574MW-16 + Spike		NA	251.18
Amount Recovered		NA	240.69
Percent Recovery		NA	96%
Amount Spiked		NA	250
574MW-24	NOAA 26-C	NA	3.76
574MW-24 + Spike 1		NA	237.46
Amount Recovered		NA	233.7
Percent Recovery		NA	93%
Amount Spiked		NA	500
574MW-24	NOAA 26-C	NA	3.76
574MW-24 + Spike 2		NA	521.31
Amount Recovered		NA	517.55
Percent Recovery		NA	104%

Appendix C. Acid-Volatile Sulfides and Simultaneously-Extracted Metals: Phase 1 contd.				
MSL Code		Copper	Mercury	Nickel
STANDARD REFERENCE MATERIAL (µg/L)		µg/L	µg/L	µg/L
1643c-1		18.92	NA	57.23
1643c-2		19.33	NA	57.21
		22.3	NA	60.6
		2.8	NA	7.3
1641 b- 1		NA	1550	NA
1641 b- 2		NA	1600	NA
1641 b- 3		NA	1580	NA
		NA	1520	NA
		NA	40	NA
SPIKE RESULTS (µg/L)				
Amount Spiked	250	0.136	250	250
574MW- 1	219.2	0.049	34.76	426.63
574MW-1 + Spike	489.37	0.1798	284.57	699.25
Amount Recovered	270.17	0.1308	249.81	272.62
Percent Recovery x100	108.00%	96.00%	100.00%	109.00%
Amount Spiked	250	0.136	250	250
574MW-7	425.91	0.0375	22.03	1359.65
574MW-7 + Spike	620.79	0.1742	255.7	1464.32
Amount Recovered	194.88	0.1367	233.67	104.67
Percent Recovery x100	78%	101%	93%	.42#
Amount Spiked	250	0.136	250	250
574MW-16	126.79	0.0366	50.55	596.44
574MW-16 + Spike	362.81	0.1745	287.21	825.7
Amount Recovered	236.02	0.1379	236.66	229.26
Percent Recovery	94%	1.01	95%	92%
Amount Spiked	250	0.136	250	250
574MW-24	313.02	0.053	40.54	886.16
574MW-24 + Spike 1	538.44	0.2214	275.95	1110.32
Amount Recovered	225.42	0.1684	235.41	224.16
Percent Recovery	90%	124%	94%	90%
Amount Spiked	500	NS	500	500
574MW-24	313.02	NS	40.53	886.16
574MW-24 + Spike 2	858.68	NS	563.42	1505.04
Amount Recovered	545.66	NS	522.89	618.88
Percent Recovery	1.09	NS	105%	124%

Appendix C. Acid-Volatile Sulfides and Simultaneously-Extracted Metals: Phase 1 contd.					
	Lead	Zinc			
STD. REF. MAT.	µg/L	µg/L			
1643c-1	25.09	60.41			
1643c-2	24.47	67.52			
	35.3	73.9			
	0.9	0.9			
1641 b- 1	NA	NA			
1641 b- 2	NA	NA			
1641 b- 3	NA	NA			
	NA	NA			
	NA	NA			
SPIKE RESULTS (µg/L)					
Amount Spiked	250				
574MW- 1	650.91				
574MW-1 + Spike	959.53				
Amount Recovered	308.62				
Percent Recovery x100	123.00%				
Amount Spiked	250				
574MW-7	674.11				
574MW-7 + Spike	850.64				
Amount Recovered	176.53				
Percent Recovery x100	71%				
Amount Spiked	250				
574MW-16	935.46				
574MW-16 + Spike	1162.29				
Amount Recovered	226.83				
Percent Recovery	91%				
Amount Spiked	250				
574MW-24	1216.04				
574MW-24 + Spike 1	1473.25				
Amount Recovered	257.21				
Percent Recovery	103%				
Amount Spiked	500				
574MW-24	1216.04				
574MW-24 + Spike 2	1893.06				
Amount Recovered	677.02				
Percent Recovery	135%				

Appendix C. Acid-Volatile Sulfides and Simultaneously-Extracted					
Metals: Phase 1 contd.					
REPLICATE ANALYSES (mg/g)					
MSLCode					
574MW-1			NOAA 1-A	4.39	0.602
574MW-1		DUP	NOAA 1-A	4.96	0.467
			RPD%	12%	25%
574MW-5			NOAA 7-B	14.17	0.781
574MW-5		DUP	NOAA 7-B	12.66	0.712
			RPD %	11%	9%
574MW-15			NOAA 17-C	23.72	1.59
574MW-15		DUP	NOM 17-C	18.58	1.78
				24%	11%
574MW-23			NOAA 26-A	22.57	0.643
574MW-23		DUP	NOAA 26-A	20.14	0.646
			RPD%	11%	0%
574MW-37			NOAA 35-A	18.76	0.635
574MW-37		DUP	NOAA 35-A	20.42	0.637
			RPD%	8%	0%

Appendix C. Acid-Volatile Sulfides and Simultaneously-Extracted					
Metals: Phase 1 contd.					
REPLICATE ANALYSES (mg/g)					
MSLCode					
32.67	0.00476	4.88	63.89	95.7	
28.53	0.00664	3.95	57.45	87.7	
14%	33%	21%	11%	9%	
20.62	0.00091	2.29	51.62	80.7	
23.4	0.00236	4.14	51.28	83.4	
13%	89%	58%	1%	3%	
50.44	0.00398	6.71	147.14	198.06	
54.02	0.00356	6.91	158.07	209.19	
7%	0.11	3%	7%	5%	
56.9	0.00934	5.59	132.34	174.39	
56.77	0.01509	8.85	133.36	180.34	
0%	47%	45%	1%	3%	
9.61	0.00214	2.45	35.15	84.72	
9.51	0.00208	3.03	39.03	89.6	
1%	0.03	21%	10%	6%	

Appendix D. Polynuclear aromatic hydrocarbon concentrations (ng/g).						
Sample ID		MJ32PB		NOAA 12 B	IOAA 13 A	NOAA 14 A
Dry Weight (g)		1.000		11.725	14.345	22.762
naphthalene		7.54		431.29	278.53	15.24
2-methylnaphthalene		0.44	ND	340.55	200.17	10.55
1-methylnaphthalene		0.43	ND	161.41	84.58	4.28
biphenyl		0.58	ND	109.97	62.83	3.02
2,6-dimethylnaphthalene		0.60	ND	140.07	71.08	3.99
acenaphthylene		0.68	ND	298.17	138.08	5.44
acenaphthene		0.52	ND	159.85	65.58	6.23
1,6,7-trimethylnaphthalene		0.67	ND	89.14	30.55	3.67
fluorene		0.42	ND	192.59	102.36	15.03
phenanthrene		0.70	ND	923.19	510.89	145.05
anthracene		0.66	ND	601.30	327.38	74.56
1-methylphenanthrene		0.87	ND	346.23	125.38	21.34
fluoranthene		1.27		2095.38	1043.36	241.05
pyrene		1.61		2506.57	1240.71	207.12
benz[a]anthracene		0.74	ND	1247.92	650.12	110.95
chrysene		1.15		1075.53	538.75	94.37
benzo[b]fluoranthene		0.70	ND	1660.51	833.27	112.53
benzo[k]fluoranthene		0.83	ND	596.99	315.75	13824.00
benzo[e]pyrene		4.15		964.49	504.84	61.41
benzo[a]pyrene		4.99		1519.02	815.13	110.17
perylene		24.20		545.31	292.34	31.62
indeno[1,2,3-c,d]pyrene		1.18	ND	777.33	435.73	50.32
dibenz[a,h]anthracene		0.69	ND	200.35	105.65	12.31
benzo[g,h,i]perylene		1.28	ND	822.59	448.09	45.29
GROUP A (Petroleum Related)		10.97		1701.28	892.65	74.09
GROUP B (Cumbustion Related)		18.58		13466.68	6931.39	1099.51
GROUP C (Total PAHs)		56.90		17805.73	9221.13	1439.52
Surrogate Recoveries,%						
naphthalene-d8		81.63		53.57	56.28	55.54
acenaphthene-d10		78.76		60.40	62.31	63.81
benzo[a]pyrene-d12		67.09		66.95	72.01	74.01
Procedural Blank Reported in Total ng.						
ND - Non Detected						
NA - Not Applicable						
& - Surrogate Recovery outside criteria (50-150%)						

Appendix D. Polynuclear aromatic hydrocarbon conc. (ng/g) contd.					
Sample ID	NOAA 16 A	NOAA 16 B	NOAA 18 A	NOAA 22 C	NOAA 23 A
Dry Weight (g)	22.651	21.094	17.219	15.591	11.373
naphthalene	379.98	163.29	109.57	168.12	185.2
2-methylnaphthalene	100.9	76.05	77.88	106.44	125.28
1-methylnaphthalene	58.49	36.68	35.4	48.21	51.08
biphenyl	39.29	31.11	24.8	34.31	45.28
2,6-dimethylnaphthalene	33.14	30.09	38.83	43.37	50.76
acenaphthylene	236.52	107.24	49.57	87.12	89.44
acenaphthene	159.74	79.52	31.5	50.8	41.37
1,6,7-trimethylnaphthalene	21.47	21.45	23.83	27.19	19.7
fluorene	215.09	78.73	65.52	85.05	75.07
phenanthrene	1056	373.9	405.87	668.27	367.32
anthracene	952.5	217.34	151.75	300.28	186.44
1-methylphenanthrene	134.64	93.42	86.13	96.8	82.16
fluoranthene	2938.9	1384	998.9	1378.29	12547
pyrene	2620.7	1230.5	913.2	1668.63	850.3
benz[a]anthracene	1439.8	562.5	343.26	779.99	401.26
chrysene	1281.9	438.02	312.08	634.44	-32767
benzo[b]fluoranthene	1804.9	797	529.7	1056.52	691.8
benzo[k]fluoranthene	737.8	272.65	214.54	352.22	274.37
benzo[e]pyrene	927.1	430.98	312.41	761.98	410.94
benzo[a]pyrene	1613.4	670.5	356.04	957.04	503.26
perylene	419.15	199.25	137.41	273.49	242.61
indeno[1,2,3-c,d]pyrene	783.4	22785	241.31	493.87	367.8
dibenz[a,h]anthracene	192.86	85.96	61.51	141.85	81.41
benzo[g,h,i]perylene	731.7	343.26	257.19	607.54	388.45
GROUP A (Petroleum Related)	943.7	499.7	437.16	575.19	589.2
GROUP B (Combustion Related)	15072	6560.4	4540.2	8832.4	5170.6
GROUP C (Total PAHs)	18879	8068.4	5778.2	10821.8	6732.2
Surrogate Recoveries,%					
naphthalene-d8	62.15	59.02	54.65	56.06	63.55
acenaphthene-d10	70.82	70.36	65.08	64.8	73.53
benzo[a]pyrene-d12	85.95	79.48	72.6	73.23	83.25
Procedural Blank Reported in Total ng.					
ND - Non Detected					
NA - Not Applicable					
& - Surrogate Recovery outside criteria (50-150%)					

Appendix D. Polynuclear aromatic hydrocarbon conc. (ng/g) contd.						
Sample ID	NOAA 25 A	NOAA 26 A	NOAA 26 C	NOAA 29 A	NOAA 30 B	NOAA 30 C
Dry Weight (g)	10.816	11.761	12.237	13.598	12.769	10.622
naphthalene	176.9	190.67	210.35	129.62	80.98	115.37
2-methylnaphthalene	122.57	135.98	140.32	84.88	59.3	86.06
1-methylnaphthalene	47.61	51.52	58.47	34.59	23.54	40.62
biphenyl	42.16	47.05	50.2	27.72	21.54	28.35
2,6-dimethylnaphthalene	46.1	46.71	58.11	30.87	25.31	31.91
acenaphthylene	77.96	76.46	109.96	67.94	54.62	52.41
acenaphthene	27.39	32.62	51.25	32.51	16.61	24.64
1,6,7-trimethylnaphthalene	14.85	15.54	17.65	12.26	7.85	13.6
fluorene	53.86	61.62	89.21	52.98	83.72	52.43
phenanthrene	240.44	289.25	500.26	286.43	261.44	311.87
anthracene	131.51	153.95	224.1	146.86	270.09	112.9
1-methylphenanthrene	50.59	74.84	79.83	60.35	41.94	63.34
fluoranthene	503.65	591	816.9	569.6	475.22	620.7
pyrene	563.3	673.2	874.56	572.6	497.2	665.8
benz[a]anthracene	289.43	305.24	494.17	311.52	248.44	249.85
chrysene	288.37	305.06	462.31	268.52	254.72	293.7
benzo[b]fluoranthene	525.8	509.65	741.54	433.88	427.52	488.63
benzo[k]fluoranthene	196.84	202.13	262.66	177.1	139.56	185.23
benzo[e]pyrene	314.29	311.59	426.25	251.23	231.97	273.66
benzo[a]pyrene	453.74	455.33	641.96	395.33	324.8	365.19
perylene	176.95	203.9	-2048	133.01	122.78	135.83
indeno[1,2,3-c,d]pyrene	285.27	284.99	389.94	220.79	211.23	248.81
dibenz[a,h]anthracene	65.03	65.81	92.87	52.26	45.19	55.34
benzo[g,h,i]perylene	301.62	299.11	31745	224.84	199.59	245.53
GROUP A (Petroleum Related)	512.5	576.9	653.94	405.54	322.65	403.33
GROUP B (Cumbustion Related)	3787.3	4003.2	5583.17	3477.6	3055.4	3692.5
GROUP C (Total PAHs)	4996.2	5383.3	7420.87	4577.6	4125.1	4761.8
Surrogate Recoveries,%						
naphthalene-d8	60.24	54.52	61.37	64.65	60.95	67.25
acenaphthene-d10	70.13	62.39	66.43	69.7	68.09	70.87
benzo[a]pyrene-d12	76.22	74.57	72.39	82.52	75.8	82.69
Procedural Blank Reported in Total ng.						
ND - Non Detected						
NA - Not Applicable						
& - Surrogate Recovery outside criteria (50-150%)						

Appendix D. Polynuclear aromatic hydrocarbon conc. (ng/g) contd.							
Sample ID	NOAA 33 B	NOAA 34 B	NOAA 35 A	NOAA 37 B		NOAA 38 B	
Dry Weight (g)	12.687	17.520	20.614	23.377		22.906	
naphthalene	217.03	60.53	45.63	0.68		1.35	
2-methylnaphthalene	158.1	44.77	32.23	0.35		0.68	
1-methylnaphthalene	60.43	17.99	13.41	0.23		0.34	
biphenyl	52.50	14.97	10.23	0.17		0.28	
2,6-dimethylnaphthalene	57.62	17.46	12.36	0.60	ND	0.15	
acenaphthylene	87.69	22.44	21.48	0.68	ND	0.39	
acenaphthene	35.84	11.41	13.56	0.10		0.16	
1,6,7-trimethylnaphthalene	16.93	5.22	4.41	0.67	ND	0.67	ND
fluorene	70.81	21.02	19.9	0.11		0.21	
phenanthrene	321.21	91.44	109.12	0.39		1.18	
anthracene	174.52	48.64	50.91	0.15		0.7	
1-methylphenanthrene	65.83	21.89	28.36	0.08		0.43	
fluoranthene	638.56	166.74	208.74	0.31		4.36	
pyrene	789.83	203.95	228.65	0.37		4.61	
benz[a]anthracene	319.59	86.14	114.29	0.29		3.18	
chrysene	312.51	82.31	100.22	0.22		2.43	
benzo[b]fluoranthene	605.17	160.36	169.54	0.23		3.69	
benzo[k]fluoranthene	220.27	59.8	64.83	0.11		1.5	
benzo[e]pyrene	356.71	98.35	114.1	0.3		1.97	
benzo[a]pyrene	492.8	126.25	163.55	0.2		3.48	
perylene	225.48	72.86	60.4	0.34		1.15	
indeno[1,2,3-c,d]pyrene	356.63	86.98	87.02	0.15		1.57	
dibenz[a,h]anthracene	78.75	19.48	21.75	0.69	ND	0.37	
benzo[g,h,i]perylene	354.65	88.31	95.43	0.45		2.23	
GROUP A (Petroleum Related)	646.74	188.89	156.3	2.73		3.83	
GROUP B (Cumbustion Related)	4525.45	1178.67	1274	3.32		29.39	
GROUP C (Total PAHs)	6069.42	1629.31	1696	7.89		37.08	
Surrogate Recoveries,%							
naphthalene-d8	59.53	68.12	54.42	74.75		72.82	
acenaphthene-d10	64.37	110.01	63.67	74.11		71.91	
benzo[a]pyrene-d12	75.06	126.19	68.75	69.94		74.82	
Procedural Blank Reported in Total ng.							
ND - Non Detected							
NA - Not Applicable							
& - Surrogate Recovery outside criteria (50-150%)							

Appendix D. Polynuclear aromatic hydrocarbon conc. (ng/g) contd.						
Sample ID		MJ38PB		NOAA10A		NOAA10B
Dry Weight (g)		1.000		19.252		17.473
naphthalene	NA	5.32		423.11		2905.29
2-methylnaphthalene	2MN	2.63		290.93		915.93
1-methylnaphthalene	1MN	1.96		133.67		626.88
biphenyl	B	0.58	ND	84.53		624.16
2,6-dimethylnaphthalene	DMN	0.60	ND	92.65		155.71
acenaphthylene	AC	2.96		151.72		636.88
acenaphthene	ACN	0.52	ND	71.45		1133.37
1,6,7-trimethylnaphthalene	TMN	0.67	ND	33.79		65.39
fluorene	F	0.42	ND	101.29		652.70
phenanthrene	PH	5.02		510.36		3217.40
anthracene	AN	1.53		300.87		2212.95
1-methylphenanthrene	1MP	0.87	ND	128.61		474.94
fluoranthene	FL	17.40		961.03		5769.79
pyrene	PY	29.04		1259.06		6921.67
benz[a]anthracene	BAN	20.11		634.32		2707.69
chrysene	CY	19.04		526.07		2396.60
benzo[b]fluoranthene	BBF	33.21		754.40		3092.41
benzo[k]fluoranthene	BKF	14.37		270.43		1038.76
benzo[e]pyrene	BEP	16.86		451.74		2371.45
benzo[a]pyrene	BAP	8.85		723.53		-7153.00
perylene	PER	6.94		221.23		774.12
indeno[1,2,3-c,d]pyrene	IN	15.44		359.30		1946.91
dibenz[a,h]anthracene	DBA	3.12		92.50		340.75
benzo[g,h,i]perylene	BP	20.18		358.88		2537.97
GROUP A (Petroleum Related)		12.47		1204.05		5796.82
GROUP B (Cumbustion Related)		197.62		6391.25		33191.99
GROUP C (Total PAHs)		227.64		8935.44		47587.69
Surrogate Recoveries,%						
naphthalene-d8		73.45		42.73	&	59.75
acenaphthene-d10		70.49		47.12	&	66.30
benzo[a]pyrene-d12		79.47		56.40		73.24

Appendix D. Polynuclear aromatic hydrocarbon conc. (ng/g) contd.					
Sample ID	NOAA11B	NOAA12A		NOAA17B	NOAA17C
Dry Weight (g)	12.663	15.081		15.232	13.334
naphthalene	656.84	663.30		307.71	490.92
2-methylnaphthalene	639.73	600.15		192.68	383.34
1-methylnaphthalene	377.41	280.49		84.08	215.80
biphenyl	112.25	166.59		66.13	90.28
2,6-dimethylnaphthalene	211.17	271.45		98.50	134.22
acenaphthylene	548.87	249.30		154.63	792.14
acenaphthene	347.93	266.19		114.73	221.22
1,6,7-trimethylnaphthalene	113.54	172.92		64.33	96.35
fluorene	394.93	299.36		178.10	296.95
phenanthrene	2745.66	1248.98		835.23	1933.53
anthracene	1183.29	619.61		485.21	1370.22
1-methylphenanthrene	1045.45	354.83		187.26	837.29
fluoranthene	4591.76	2013.27		2076.62	4356.75
pyrene	5527.88	2274.18		1972.39	6415.16
benz[a]anthracene	2876.35	1196.34		907.27	3748.46
chrysene	2781.68	1017.97		840.20	3418.87
benzo[b]fluoranthene	2989.70	1437.13		1298.59	3590.44
benzo[k]fluoranthene	1079.38	529.40		486.02	1359.53
benzo[e]pyrene	1803.85	22019.00		744.39	2283.47
benzo[a]pyrene	3265.49	1303.08		1067.83	4770.75
perylene	627.59	387.68		370.55	798.20
indeno[1,2,3-c,d]pyrene	1433.34	711.49		616.57	1814.68
dibenz[a,h]anthracene	360.74	191.58		146.72	468.83
benzo[g,h,i]perylene	1416.88	717.40		605.13	-3322.00
GROUP A (Petroleum Related)	3439.07	2642.49		1112.67	2454.87
GROUP B (Cumbustion Related)	28127.04	12245.83		10761.72	34005.93
GROUP C (Total PAHs)	37131.69	17826.66		13900.86	41666.38
Surrogate Recoveries,%					
naphthalene-d8	58.64	45.56	&	56.92	58.42
acenaphthene-d10	65.72	45.56	&	61.27	62.59
benzo[a]pyrene-d12	81.90	47.51	&	74.42	81.02

Appendix D. Polynuclear aromatic hydrocarbon conc. (ng/g) contd.						
Sample ID	NOAA18C	NOAA1A		NOAA24C	NOAA2A	NOAA30A
Dry Weight (g)	17.395	15.406		14.519	9.722	14.631
naphthalene	185.67	173.36		53.03	76.14	79.86
2-methylnaphthalene	133.01	49.54		31.11	46.52	57.56
1-methylnaphthalene	70.89	21.84		13.12	21.38	35.86
biphenyl	48.18	17.61		11.04	18.53	25.76
2,6-dimethylnaphthalene	84.38	15.77		11.14	18.49	30.15
acenaphthylene	77.92	57.67		40.64	69.15	65.83
acenaphthene	104.03	26.34		10.54	19.29	32.59
1,6,7-trimethylnaphthalene	114.40	9.12		4.58	9.41	10.86
fluorene	125.53	39.82		18.33	37.31	58.37
phenanthrene	349.75	271.11		105.98	252.69	334.09
anthracene	340.12	86.07		54.30	93.93	134.47
1-methylphenanthrene	126.10	53.54		30.53	85.01	82.79
fluoranthene	1379.56	511.38		273.09	663.85	612.20
pyrene	1443.84	519.95		300.08	631.73	658.95
benz[a]anthracene	596.52	220.65		139.91	275.63	256.65
chrysene	621.07	230.49		141.11	350.23	246.33
benzo[b]fluoranthene	957.55	330.56		230.41	397.17	414.46
benzo[k]fluoranthene	288.03	117.76		86.89	159.79	163.12
benzo[e]pyrene	542.66	187.49		141.99	215.64	234.43
benzo[a]pyrene	704.14	301.73		219.82	343.22	336.17
perylene	220.61	137.12		67.35	163.01	113.77
indeno[1,2,3-c,d]pyrene	452.89	176.67		131.75	196.66	206.96
dibenz[a,h]anthracene	116.66	40.85		30.41	47.83	47.93
benzo[g,h,i]perylene	545.74	168.82		136.33	181.34	250.90
GROUP A (Petroleum Related)	839.97	362.99		161.85	294.26	355.44
GROUP B (Cumbustion Related)	7648.65	2806.33		1831.79	3463.09	3428.10
GROUP C (Total PAHs)	9629.22	3765.23		2283.48	4373.94	4490.04
Surrogate Recoveries,%						
naphthalene-d8	63.56	43.53	&	57.62	56.86	51.01
acenaphthene-d10	64.60	47.39	&	64.02	63.60	57.72
benzo[a]pyrene-d12	87.14	67.14		86.99	88.65	81.27

Appendix D continued.				
Sample ID	NOAA36C	NOAA4A	NOAA5B	NOAA6C
Dry Weight (g)	15.505	16.532	7.570	10.234
naphthalene	171.49	31.01	103.26	145.58
2-methylnaphthalene	115.15	20.53	77.18	106.90
1-methylnaphthalene	48.12	9.58	34.44	62.21
biphenyl	40.71	5.72	23.84	29.74
2,6-dimethylnaphthalene	44.24	7.81	31.30	49.29
acenaphthylene	97.69	33.72	86.96	302.68
acenaphthene	43.10	7.58	26.11	73.28
1,6,7-trimethylnaphthalene	19.83	3.25	9.78	25.73
fluorene	70.38	11.66	39.55	79.67
phenanthrene	418.74	83.79	269.51	477.72
anthracene	214.12	32.27	104.50	363.16
1-methylphenanthrene	103.57	19.45	72.49	187.22
fluoranthene	886.95	200.53	610.59	1144.11
pyrene	960.91	219.48	662.45	1566.87
benz[a]anthracene	486.38	89.86	248.29	895.81
chrysene	421.62	98.49	249.57	808.56
benzo[b]fluoranthene	655.24	167.48	465.98	1004.68
benzo[k]fluoranthene	240.39	61.16	171.32	346.90
benzo[e]pyrene	381.99	100.55	281.88	623.30
benzo[a]pyrene	593.97	140.92	408.94	1218.39
perylene	208.93	29.59	87.07	216.62
indeno[1,2,3-c,d]pyrene	334.74	98.72	262.75	544.34
dibenz[a,h]anthracene	78.21	22.49	59.08	138.11
benzo[g,h,i]perylene	332.02	102.37	268.23	513.66
GROUP A (Petroleum Related)	572.78	103.29	28673.00	656.59
GROUP B (Cumbustion Related)	5372.43	1302.03	3689.08	8804.73
GROUP C (Total PAHs)	6968.50	15878.00	4655.07	10924.51
Surrogate Recoveries,%				
naphthalene-d8	52.77	52.70	55.18	56.63
acenaphthene-d10	58.94	61.05	63.69	64.03
benzo[a]pyrene-d12	75.96	83.33	86.16	84.78

Appendix D continued.						
Sample ID	NOAA7B		NOAA7C	NOAA8C		NOAA9B
Dry Weight (g)	20.641		21.164	17.383		14.912
naphthalene	1350.21		186.74	1047.53		17414.18
2-methylnaphthalene	995.26		117.62	1003.15		15556.60
1-methylnaphthalene	613.09		49.85	468.48		48783.50
biphenyl	250.57		38.07	207.46		9095.85
2,6-dimethylnaphthalene	370.06		60.18	319.73		27888.59
acenaphthylene	2984.66		70.11	777.71		12915.13
acenaphthene	609.08		56.51	439.36		56337.88
1,6,7-trimethylnaphthalene	260.17		41.64	188.90		6806.37
fluorene	1043.15		96.74	499.93		54208.65
phenanthrene	6430.44		478.57	2395.37		194342.88
anthracene	4338.97		298.71	1551.70		89365.95
1-methylphenanthrene	2088.39		111.47	1201.39		39129.60
fluoranthene	13079.92		1097.29	5457.95		108236.19
pyrene	16052.43		1105.77	6452.17		143131.57
benz[a]anthracene	8452.82		472.66	3647.63		59298.22
chrysene	6577.55		535.97	3519.73		60330.78
benzo[b]fluoranthene	7997.26		767.93	3758.01		39168.09
benzo[k]fluoranthene	3087.22		297.47	1481.92		15749.82
benzo[e]pyrene	4898.81		449.45	2282.92		22676.21
benzo[a]pyrene	9368.31		623.09	4336.47		54861.52
perylene	1894.46		233.39	799.80		8606.85
indeno[1,2,3-c,d]pyrene	4064.36		391.29	1838.73		18024.98
dibenz[a,h]anthracene	955.37		94.64	466.93		4533.87
benzo[g,h,i]perylene	3904.74		396.18	1783.38		16891.42
GROUP A (Petroleum Related)	6720.32		664.23	4729.12		209787.50
GROUP B (Cumbustion Related)	78438.78		6231.73	35025.84		542902.67
GROUP C (Total PAHs)	101667.28		8071.32	45926.35		1123354.70
Surrogate Recoveries,%						
naphthalene-d8	40.26	&	53.49	46.89	&	32.69
acenaphthene-d10	48.29	&	57.25	52.49		33.31
benzo[a]pyrene-d12	78.86		72.57	64.35		30.57

Appendix E. PCB and Pesticides Concentrations (ng/g).

Sample ID	MJ32PB		NOAA 12 B		NOAA 13 A		NOAA 14 A		NOAA 16 A		NOAA 16 B		NOAA 18 A
Dry Weight (g)	1.0000		11.725		14.345		22.762		22.651		21.094		17.219
CL2(08)	0.000	ND	14.824		8.759		0.435	ND	1.849		3.275		3.662
HEXACHLOROBENZENE	0.000	ND	19.413		11.240		0.177		3.301		3.387		10.843
LINDANE	0.000	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099
CL3(18)	0.000	ND	20.342		12.135		0.238	ND	4.646		7.060		8.063
CL3(28)	0.000	ND	90.035		62.870		1.362		11.572		18.490		26.888
HEPTACHLOR	0.000	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271
CL4(52)	0.000	ND	34.562		20.878		0.545		17.209		13.033		20.134
ALDRIN	0.000	ND	0.208	ND	0.208	ND	0.208	ND	0.208	ND	0.208	ND	0.208
CL4(44)	0.000	ND	25.397		14.784		0.430		6.876		9.799		14.530
HEPTACHLOREPOXIDE	0.000	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230
CL4(66)	0.000	ND	44.186		29.456		0.946		7.811		12.345		19.189
2,4-DDE	0.000	ND	2.859		1.903		0.161	ND	2.123		3.298		21.229
CL5(101)	0.000	ND	41.391		21.351		0.717		24.438		13.215		30.642
CIS-CHLORDANE	0.000	ND	7.190		3.483		0.170		3.072		4.634		10.391
TRANS-NONACHLOR	0.000	ND	4.577		2.144		0.138		1.975		2.938		6.004
DIELDRIN	0.000	ND	13.597		3.112		0.432		1.632		2.309		3.900
4,4-DDE	0.000	ND	20.683		14.241		0.519		8.650		13.394		71.551
CL4(77)	0.000	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299
2,4-DDD	0.000	ND	12.649		6.602		0.349		31.662		6.964		82.401
ENDRIN	0.000	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569
CL5(118)	0.000	ND	27.620		15.269		0.539		10.645		7.524		19.532
4,4-DDD	0.000	ND	29.410		15.907		0.847		10.132		12.859		193.732
2,4-DDT	0.000	ND	2.226		1.275		0.089		1.393		0.906		19.801
CL6(153)	0.000	ND	46.776		23.822		0.898		71.742		11.524		28.800
CL5(105)	0.000	ND	12.240		7.208		0.326		3.906		3.714		8.983
4,4-DDT	0.000	ND	24.640		1.015		0.094		14.628		39.438		532.201
CL6(138)	0.000	ND	33.861		18.528		0.805		17.667		8.550		24.499
CL5(126)	0.000	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301
CL7(187)	0.000	ND	9.849		5.674		0.358		38.666		3.024		5.519
CL6(128)	0.000	ND	11.803		5.817		0.343		5.035		3.234		4.137
CL7(180)	0.000	ND	20.625		9.800		0.314		17.939		5.259		11.292
Procedural Blank Reported in Total ng.													
ND - Non Detected													
NA - Not Applicible													
& - Surrogate Recovery outside criteria (50 - 150%)													

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.																
Sample ID		NOAA 22 C		NOAA 23 A		NOAA 25 A		NOAA 26 A		NOAA 26 C		NOAA 29 A		NOAA 30 B
Dry Weight (g)		15.591		11.373		10.816		11.761		12.237		13.598		12.769
CL2(08)		5.777		7.616		9.377		9.924		9.590		6.469		4.969
HEXACHLOROBENZENE		20.221		16.334		7.020		9.288		7.672		8.717		6.414
LINDANE	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099
CL3(18)		14.130		9.286		8.186		10.151		8.445		5.464		4.936
CL3(28)		41.283		42.474		38.133		47.539		61.186		22.664		17.862
HEPTACHLOR	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271
CL4(52)		41.076		20.780		13.587		15.432		17.346		7.849		7.049
ALDRIN	ND	0.208	ND	0.208	ND	0.208	ND	0.208	ND	0.208	ND	0.208	ND	0.208
CL4(44)		27.613		14.471		10.206		11.689		11.131		5.712		6.845
HEPTACHLOREPOXIDE	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230
CL4(66)		35.618		29.318		23.450		25.826		32.266		13.967		14.088
2,4-DDE		26.064		7.692		3.014		2.066		2.345		1.335		1.409
CL5(101)		56.944		25.097		17.395		18.464		19.810		10.931		10.395
CIS-CHLORDANE		5.236		7.030		4.421		3.532		4.280		2.102		2.813
TRANS-NONACHLOR		2.698		5.395		3.266		2.633		3.058		1.654		1.865
DIELDRIN		4.687		8.771		6.658		4.458		6.400		3.215		3.719
4,4-DDE		94.695		33.995		12.889		12.025		14.441		7.393		8.077
CL4(77)	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299
2,4-DDD		31.798		27.178		7.813		6.869		8.180		5.172		5.201
ENDRIN	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569
CL5(118)		36.829		18.020		12.720		13.355		15.677		8.550		9.159
4,4-DDD		127.740		83.663		18.953		14.935		19.751		14.509		12.304
2,4-DDT		2.275		2.846		1.270		1.187		1.806		1.919		0.822
CL6(153)		45.153		27.465		15.796		17.142		19.685		10.492		10.057
CL5(105)		13.315		6.842		6.278		6.891		8.114		4.179		4.314
4,4-DDT		75.579		14.555		1.499		1.385		1.054		82.231		0.706
CL6(138)		39.706		18.603		11.860		13.795		16.075		7.811		7.845
CL5(126)	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301
CL7(187)		6.370		5.978		4.326		4.694		5.019		3.011		3.513
CL6(128)		7.443		4.436		3.756		4.077		4.447		3.216		3.270
CL7(180)		12.578		10.857		5.146		6.241		7.310		3.506		3.452
Procedural Blank Reported in Total ng.														
ND - Non Detected														
NA - Not Applicible														
& - Surrogate Recovery outside criteria (50 - 150%)														

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.

Sample ID		NOAA 30 C		NOAA 33 B		NOAA 34 B		NOAA 35 A		NOAA 37 B		NOAA 38 B		MJ36SSRM	
Dry Weight (g)		10.622		12.687		17.520		20.614		23.377		22.906		7.026	
CL2(08)		6.493		7.346		4.600		2.178		0.435	ND	0.435	ND	0.435	ND
HEXACHLOROBENZENE		4.531		8.384		0.748		3.163		0.140	ND	0.140	ND	29.878	
LINDANE	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.648	
CL3(18)		4.485		7.959		3.281		1.988		0.238	ND	0.238	ND	7.626	
CL3(28)		18.331		43.174		18.487		8.127		0.117	ND	0.117	ND	15.539	
HEPTACHLOR	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND
CL4(52)		8.206		13.776		5.253		3.736		0.129	ND	0.129	ND	17.032	
ALDRIN	ND	0.208	ND	0.208	ND	0.208	ND	0.208	ND	0.208	ND	0.208	ND	0.208	ND
CL4(44)		7.069		9.864		3.533		2.715		0.336	ND	0.336	ND	12.496	
HEPTACHLOREPOXIDE	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	3.370	
CL4(66)		15.683		28.170		9.974		6.784		0.217	ND	0.217	ND	15.782	
2,4-DDE		1.041		3.700		0.398		0.742		0.161	ND	0.161	ND	2.167	
CL5(101)		13.019		19.452		5.938		4.771		0.244	ND	0.244	ND	32.844	
CIS-CHLORDANE		3.140		4.074		1.205		0.913		0.195	ND	0.195	ND	2.612	
TRANS-NONACHLOR		2.152		2.754		0.918		0.643		0.209	ND	0.209	ND	1.108	
DIELDRIN		6.335		5.628		4.264		0.468		0.200	ND	0.200	ND	3.432	
4,4-DDE		10.068		17.151		5.278		3.473		0.127	ND	0.127	ND	9.779	
CL4(77)	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND
2,4-DDD		6.312		10.770		3.230		2.161		0.247	ND	0.247	ND	5.474	
ENDRIN	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND
CL5(118)		12.216		20.310		5.988		4.044		0.223	ND	0.223	ND	15.131	
4,4-DDD		15.959		25.719		7.778		4.025		0.292	ND	0.292	ND	7.481	
2,4-DDT		1.216		1.557		0.692		5.737		0.183	ND	0.183	ND	1.833	
CL6(153)		13.348		24.559		7.175		4.841		0.409	ND	0.409	ND	31.798	
CL5(105)		5.632		10.018		3.177		2.065		0.298	ND	0.298	ND	10.075	
4,4-DDT		1.543		4.659		1.436		0.321		0.312	ND	0.312	ND	3.200	
CL6(138)		10.731		18.825		6.318		4.024		0.227	ND	0.227	ND	23.227	
CL5(126)	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND
CL7(187)		3.473		6.261		1.924		1.382		0.292	ND	0.292	ND	14.187	
CL6(128)		3.506		5.323		1.800		1.490		0.172	ND	0.172	ND	6.628	
CL7(180)		4.508		6.311		2.387		1.289		0.243	ND	0.243	ND	18.072	

Procedural Blank Reported in Total ng.

ND - Non Detected

NA - Not Applicible

& - Surrogate Recovery outside criteria (50 - 150%)

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.													
Sample ID	MJ32PB		NOAA 12 B		NOAA 13 A		NOAA 14 A		NOAA 16 A		NOAA 16 B		NOAA 18 A
Dry Weight (g)	1.0000		11.725		14.345		22.762		22.651		21.094		17.219
MIREX	0.000	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247
CL7(170)	0.000	ND	9.966		5.463		0.334	ND	7.434		3.214		6.976
CL8(195)	0.000	ND	2.974		1.819		0.303	ND	2.994		0.645		1.528
CL9(206)	0.000	ND	5.083		2.855		0.480	ND	2.422		1.001		1.465
CL10(209)	0.000	ND	4.703		3.281		0.314	ND	0.727		1.685		1.363
GROUP D (INDENO PEST)	0.000		12.268		6.128		0.809		5.548		8.073		16.896
SUM OF DDT	0.000		92.467		40.943		2.059		68.588		76.859		920.915
TOTAL PCB	0.000		456.237		269.769		9.687		253.578		126.591		237.202
GROUP D (NO MDL)	0.000		11.767		5.627		0.308		5.047		7.572		16.395
SUM OF DDT (NO MDL)	0.000		92.467		40.943		1.898		68.588		76.859		920.915
TOTAL PCB (NO MDL)	0.000		456.237		269.769		7.583		253.578		126.591		237.202
Total non-DDT pest.			46.4010		21.6030		2.5410		11.6040		14.8920		32.7620
Surrogate Recoveries,%													
DBOFB	84.363		54.120		43.148	&	67.428		62.471		56.110		46.974
CL5(112)	76.520		63.244		64.620		69.398		79.277		77.846		75.258
Procedural Blank Reported In Total ng.													
ND - Non Detected													
NA - Not Applicible													
& - Surrogate Recovery outside criteria (50 - 150%)													

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.														
Sample ID		NOAA 22 C		NOAA 23 A		NOAA 25 A		NOAA 26 A		NOAA 26 C		NOAA 29 A		NOAA 30 B
Dry Weight (g)		15.591		11.373		10.816		11.761		12.237		13.598		12.769
MIREX	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247
CL7(170)		7.376		7.378		3.929		4.200		4.878		2.668		2.586
CL8(195)		4.693		2.647		1.448		1.457		1.791		0.303	ND	0.947
CL9(206)		2.035		2.580		1.900		1.865		2.462		0.480	ND	0.957
CL10(209)		3.504		2.788		2.069		1.914		2.136		0.314	ND	1.118
GROUP D (INDENO PEST)		8.435		12.926		8.188		6.666		7.839		4.257		5.179
SUM OF DDT		358.151		169.929		45.438		38.467		47.577		112.559		28.519
TOTAL PCB		401.443		256.636		189.562		214.656		247.368		117.586		113.162
GROUP D (NO MDL)		7.934		12.425		7.687		6.165		7.338		3.756		4.678
SUM OF DDT (NO MDL)		358.151		169.929		45.438		38.467		47.577		112.559		28.519
TOTAL PCB (NO MDL)		401.443		256.636		189.562		214.656		247.368		116.489		113.162
Total non-DDT pest.		34.4660		39.1540		22.9890		21.5350		23.0340		17.3120		16.4350
Surrogate Recoveries,%														
DBOFB	&	35.912	&	58.401		46.883	&	45.618	&	42.210	&	47.847	&	56.746
CL5(112)		64.559		79.545		71.688		69.148		71.698		70.176		67.630
Procedural Blank Reported in Total ng.														
ND - Non Detected														
NA - Not Applicible														
& - Surrogate Recovery outside criteria (50 - 150%)														

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.																		
Sample ID		NOAA 30 C		NOAA 33 B		NOAA 34 B		NOAA 35 A		NOAA 37 B		NOAA 38 B		MJ36SSRM				
Dry Weight (g)		10.622		12.687		17.520		20.614		23.377		22.906		7.026				
MIREX	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND			
CL7(170)		3.798		5.960		1.831		1.463		0.334	ND	0.334	ND	8.681				
CL8(195)		1.256		2.793		0.455		0.457		0.303	ND	0.303	ND	3.229				
CL9(206)		1.296		3.220		0.837		0.543		0.480	ND	0.480	ND	9.315				
CL10(209)		1.571		5.223		1.018		1.528		0.314	ND	0.314	ND	9.770				
GROUP D (INDENO PEST)		5.793		7.329		2.624		2.057		0.905		0.905		7.361				
SUM OF DDT		36.139		63.556		18.812		16.459		1.322		1.322		29.934				
TOTAL PCB		134.621		238.544		83.976		53.425		5.011		5.011		251.867				
GROUP D (NO MDL)		5.292		6.828		2.123		1.556		0.000		0.000		7.090				
SUM OF DDT (NO MDL)		36.139		63.556		18.812		16.459		0.000		0.000		29.934				
TOTAL PCB (NO MDL)		134.621		238.544		83.976		53.425		0.000		0.000		251.432				
Total non-DDT pest.		17.7820		22.4640		8.7590		6.8110		2.3680		2.3680		42.3430				
Surrogate Recoveries,%																		
DBOFB		68.185		48.625	&	34.919	&	58.866		79.929		85.344		56.893				
CL5(112)		76.368		73.478		71.631		61.166		72.013		73.250		60.520				
Procedural Blank Reported in Total ng.																		
ND - Non Detected																		
NA - Not Applicible																		
& - Surrogate Recovery outside criteria (50 - 150%)																		

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.

Sample ID	MP31PB		NOAA1A-R		NOAA2A		NOAA4A-R		NOAA5B-R		NOAA6C-R		NOAA7B-R
Dry Weight (g)	1.0000		5.227		9.722		5.183		2.450		3.951		7.932
CL2(08)	0.000	ND	32.188		14.635		38.479		0.435	ND	28.348		0.435
HEXACHLOROBENZENE	0.000	ND	1.450		0.457		3.079		0.140	ND	0.140	ND	0.140
LINDANE	0.000	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099
CL3(18)	0.000	ND	41.633		17.895		8.220		12.743		6.849		7.537
CL3(28)	0.000	ND	179.938		54.088		7.649		11.632		17.791		16.642
HEPTACHLOR	0.000	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271
CL4(52)	0.000	ND	55.416		25.615		4.872		5.363		11.394		11.129
ALDRIN	0.000	ND	0.208	ND	5.886		0.208	ND	0.208	ND	0.208	ND	0.208
CL4(44)	0.000	ND	34.104		16.152		1.726		0.336	ND	7.008		4.620
HEPTACHLOREPOXIDE	0.000	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230
CL4(66)	0.000	ND	65.696		25.602		7.581		9.950		24.605		13.047
2,4-DDE	0.000	ND	14.219		6.961		4.642		3.378		6.814		5.065
CL5(101)	0.000	ND	33.072		16.579		8.292		10.423		21.771		14.001
CIS-CHLORDANE	0.000	ND	2.318		1.619		1.997		4.879		5.307		5.126
TRANS-NONACHLOR	0.000	ND	2.642		0.945		2.424		3.520		3.893		4.369
DIELDRIN	0.000	ND	1.922		0.966		0.837		0.200	ND	0.200	ND	0.200
4,4-DDE	0.000	ND	8.873		4.358		3.476		8.069		10.148		6.811
CL4(77)	0.000	ND	8.873		0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299
2,4-DDD	0.000	ND	3.126		2.101		1.631		0.247	ND	0.247	ND	0.247
ENDRIN	0.000	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569
CL5(118)	0.000	ND	22.239		9.902		5.160		10.443		16.684		13.032
4,4-DDD	0.000	ND	12.933		5.516		4.713		10.510		15.420		20.754
2,4-DDT	0.000	ND	1.858		0.614		0.183	ND	0.183	ND	0.183	ND	0.183
CL6(153)	0.000	ND	17.186		8.686		5.563		11.232		19.080		9.737
CL5(105)	0.000	ND	19.908		9.432		4.903		9.974		18.168		8.294
4,4-DDT	0.000	ND	3.468		4.275		1.320		0.312	ND	3.793		5.304
CL6(138)	0.000	ND	20.087		10.628		6.672		15.129		23.566		10.289
CL5(126)	0.000	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301
CL7(187)	0.000	ND	7.673		3.549		2.669		5.842		9.757		7.145
CL6(128)	0.000	ND	3.960		1.868		1.225		0.172	ND	3.511		0.172
Procedural Blank Reported in Total ng.													
ND - Non Detected													
NA - Not Applicible													
& - Surrogate Recovery outside criteria (50 - 150%)													
Surrogate Recoveries,%													

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.																
Sample ID		NOAA7C-R		NOAA8C-R		NOAA9B-R		NOAA10A		NOAA10B-R		NOAA11B-R		NOAA12A-R		
Dry Weight (g)		7.321		6.358		5.021		19.252		6.048		4.302		6.078		
CL2(08)	ND	5.503		11.152		0.435	ND	7.371		0.435	ND	34.521		63.050		
HEXACHLOROBENZENE	ND	0.140	ND	0.140	ND	0.140	ND	0.931		0.140	ND	1.464		6.668		
LINDANE	ND	0.099	ND	1.234		0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099		
CL3(18)		2.993		5.039		20.207		8.182		0.238	ND	30.345		161.625		
CL3(28)		6.704		10.007		56.246		25.459		7.543		84.207		424.806		
HEPTACHLOR	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271		
CL4(52)		4.063		8.472		0.129	ND	12.878		1.715		38.060		248.261		
ALDRIN	ND	0.208	ND	0.208	ND	0.208	ND	6.863		0.208	ND	0.208	ND	0.208		
CL4(44)		2.678		3.485		0.336	ND	8.530		1.447		25.317		184.699		
HEPTACHLOREPOXIDE	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	5.676		
CL4(66)		5.016		6.926		8.712		14.501		2.466		48.703		47.040		
2,4-DDE		1.975		3.791		0.161	ND	4.173		2.433		13.280		68.428		
CL5(101)		5.200		12.723		0.244	ND	12.553		1.654		37.020		207.478		
CIS-CHLORDANE		1.398		1.048		0.195	ND	3.838		1.654		9.122		13.501		
TRANS-NONACHLOR		1.362		1.800		0.209	ND	2.713		1.731		7.976		13.022		
DIELDRIN	ND	0.784		0.200	ND	0.200	ND	0.912		0.200	ND	0.200	ND	10.628		
4,4-DDE		4.942		2.244		30.730		6.613		1.088		23.211		86.299		
CL4(77)	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299		
2,4-DDD	ND	0.247	ND	0.247	ND	0.247	ND	3.447		0.247	ND	0.247	ND	26.527		
ENDRIN	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569		
CL5(118)		12.875		8.762		0.223	ND	9.155		2.913		42.830		123.937		
4,4-DDD		7.318		4.697		0.292	ND	10.342		1.787		32.990		120.159		
2,4-DDT	ND	0.183	ND	0.183	ND	0.183	ND	0.851		0.183	ND	0.183	ND	0.183		
CL6(153)		7.861		12.400		13.417		9.438		2.127		30.157		94.135		
CL5(105)		6.411		11.141		0.298	ND	8.970		1.532		28.910		114.207		
4,4-DDT		3.037		3.808		43.322		1.970		0.312	ND	11.017		13.111		
CL6(138)		8.666		12.628		16.189		10.921		1.022		37.341		125.443		
CL5(126)	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301		
CL7(187)		4.258		10.305		15.236		3.947		3.586		17.028		28.585		
CL6(128)	ND	1.229		3.037		0.172	ND	1.954		0.172	ND	5.808		15.921		
Procedural Blank Reported In Total ng.																
ND - Non Detected																
NA - Not Applicible																
& - Surrogate Recovery outside criteria (50 - 150%)																
Surrogate Recoveries,%																

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.

Sample ID		NOAA17B-R		NOAA17C-R		NOAA18C-R		NOAA24C-R		NOAA30A-R		NOAA36C-R		MP35SSRM	
Dry Weight (g)		4.987		4.915		6.005		5.988		5.363		6.911		7.050	
CL2(08)		24.674		25.476		26.633		15.867		0.435	ND	16.653		0.435	ND
HEXACHLOROBENZENE		5.863		5.553		8.430		0.636		6.723		0.711		38.621	
LINDANE	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	0.099	ND	10.346	
CL3(18)		32.240		30.629		61.411		11.360		21.924		10.127		6.465	
CL3(28)		87.922		90.871		136.844		42.445		33.266		43.261		15.789	
HEPTACHLOR	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND	0.271	ND
CL4(52)		52.380		52.877		132.403		21.760		14.155		15.600		14.882	
ALDRIN	ND	0.208	ND	0.208	ND	13.164		7.030		0.208	ND	6.194		0.208	ND
CL4(44)		38.477		38.420		84.733		14.322		7.225		10.601		7.897	
HEPTACHLOREPOXIDE		0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND	0.230	ND
CL4(66)		58.795		54.374		96.418		29.026		26.281		21.366		14.082	
2,4-DDE		58.819		51.288		61.652		12.919		8.959		6.755		6.535	
CL5(101)		49.968		50.428		92.097		22.862		14.975		15.527		19.092	
CIS-CHLORDANE		15.186		15.829		18.965		6.235		3.598		2.828		0.195	ND
TRANS-NONACHLOR		12.356		12.886		14.792		5.078		3.171		2.441		0.209	ND
DIELDRIN		0.200	ND	6.884		6.480		3.099		1.617		1.879		2.260	
4,4-DDE		181.917		142.493		115.370		27.337		8.327		14.857		8.730	
CL4(77)	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND	0.299	ND
2,4-DDD		128.953		145.881		64.651		17.814		4.807		8.015		0.247	ND
ENDRIN	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND	0.569	ND
CL5(118)		40.129		26.102		35.831		21.864		10.777		18.343		21.036	
4,4-DDD		380.209		461.650		199.220		40.667		13.197		17.432		10.274	
2,4-DDT	ND	131.344		33.314		57.902		10.141		4.779		2.446		0.183	ND
CL6(153)		40.440		39.406		39.293		23.568		10.692		19.588		23.962	
CL5(105)		37.800		37.887		35.145		22.691		10.855		14.836		21.470	
4,4-DDT		1614.974		357.773		128.417		2.410		3.892		14.540		0.312	ND
CL6(138)		47.968		47.942		38.112		23.872		10.829		18.131		24.049	
CL5(126)	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND	0.301	ND
CL7(187)		19.136		19.033		13.024		14.303		5.349		7.240		14.117	
CL6(128)		6.727		6.735		5.146		3.362		1.795		2.547		3.814	
Procedural Blank Reported in Total ng.															
ND - Non Detected															
NA - Not Applicible															
& - Surrogate Recovery outside criteria (50 - 150%)															
Surrogate Recoveries,%															

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.

Sample ID	MP31PB		NOAA1A-R		NOAA2A		NOAA4A-R		NOAA5B-R		NOAA6C-R		NOAA7B-R
Dry Weight (g)	1.0000		5.227		9.722		5.183		2.450		3.951		7.932
CL7(180)	0.000	ND	10.018		4.983		2.845		5.954		8.580		4.340
MIREX	0.000	ND	0.247	ND	0.247	ND	4.240		0.247	ND	0.247	ND	0.247
CL7(170)	0.000	ND	10.489		6.590		4.672		11.565		18.792		15.836
CL8(195)	0.000	ND	3.729		0.754		0.408		0.303	ND	3.417		0.303
CL9(206)	0.000	ND	7.430		0.480	ND	0.653		0.480	ND	7.682		0.480
CL10(209)	0.000	ND	5.124		0.314	ND	1.120		0.314	ND	4.577		0.314
GROUP D (INDENO PEST)	0.000		5.461		3.065		4.922		8.900		9.701		9.996
SUM OF DDT	0.000		44.477		23.825		15.965		22.699		36.605		38.364
TOTAL PCB	0.000		569.890		227.752		112.709		122.290		251.580		137.353
GROUP D (NO MDL)	0.000		4.960		2.564		4.421		8.399		9.200		9.495
SUM OF DDT (NO MDL)	0.000		44.477		23.825		15.782		21.957		36.175		37.934
TOTAL PCB (NO MDL)	0.000		569.890		226.958		112.709		120.250		251.580		135.649
Total non-DDT pest.			9.9560		11.2890		13.9540		10.3630		11.1640		11.4590
Procedural Blank Reported in Total ng.													
ND - Non Detected													
NA - Not Applicible													
& - Surrogate Recovery outside criteria (50 - 150%)													
Surrogate Recoveries,%													
DBOFB	69.977		54.506		61.470		53.086		59.247		71.496		64.485
CL5(112)	69.448		74.121		75.990		71.328		77.478		68.352		68.532

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.															
Sample ID		NOAA7C-R		NOAA8C-R		NOAA9B-R		NOAA10A		NOAA10B-R		NOAA11B-R		NOAA12A-R
Dry Weight (g)		7.321		6.358		5.021		19.252		6.048		4.302		6.078
CL7(180)		4.893		6.969		0.243	ND	6.436		0.243	ND	20.381		56.182
MIREX	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247
CL7(170)		8.584		21.264		50.170		7.270		13.695		26.507		33.249
CL8(195)	ND	0.469		17.765		0.303	ND	0.975		0.303	ND	0.303	ND	8.358
CL9(206)	ND	0.480	ND	0.480	ND	0.480	ND	0.480	ND	0.480	ND	0.480	ND	15.518
CL10(209)	ND	0.314	ND	0.314	ND	0.314	ND	0.314	ND	0.314	ND	0.314	ND	20.352
GROUP D (INDENO PEST)		3.261		3.349		0.905		7.052		3.886		17.599		32.470
SUM OF DDT		17.702		14.970		74.935		27.396		6.050		80.928		314.707
TOTAL PCB		88.197		162.869		183.354		149.334		41.885		508.232		1972.846
GROUP D (NO MDL)		2.760		2.848		0.000		6.551		3.385		17.098		32.199
SUM OF DDT (NO MDL)		17.272		14.540		74.052		27.396		5.308		80.498		314.524
TOTAL PCB (NO MDL)		87.403		162.075		180.177		148.540		39.700		507.135		1972.846
Total non-DDT pest.		5.3080		5.9470		2.3680		16.6730		5.3490		20.3860		50.8890
Procedural Blank Reported in Total ng.														
ND - Non Detected														
NA - Not Applicible														
& - Surrogate Recovery outside criteria (50 - 150%)														
Surrogate Recoveries,%														
DBOFB		69.906		77.715		107.814		49.014	&	71.492		63.739		54.434
CL5(112)		80.877		74.028		80.541		56.275		75.097		75.506		72.950

Appendix E. PCB and Pesticides Concentrations (ng/g) contd.

Sample ID		NOAA17B-R		NOAA17C-R		NOAA18C-R		NOAA24C-R		NOAA30A-R		NOAA36C-R		MP35SSRM	
Dry Weight (g)		4.987		4.915		6.005		5.988		5.363		6.911		7.050	
CL7(180)		30.725		32.150		23.764		12.460		5.018		8.821		16.703	
MIREX	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND	0.247	ND
CL7(170)		27.701		26.622		15.782		11.654		6.344		9.235		25.543	
CL8(195)		4.099		4.155		0.303	ND	3.612		1.303		0.303	ND	2.997	
CL9(206)		7.755		0.480	ND	0.480	ND	3.929		2.044		0.480	ND	0.480	ND
CL10(209)		9.444		0.314	ND	0.314	ND	4.099		2.114		0.314	ND	0.314	ND
GROUP D (INDENO PEST)		28.043		29.216		34.258		11.814		7.270		5.770		0.905	
SUM OF DDT		897.392		842.668		501.682		111.288		43.961		64.045		26.281	
TOTAL PCB		616.380		583.901		837.733		303.056		185.381		232.973		233.127	
GROUP D (NO MDL)		27.542		28.715		33.757		11.313		6.769		5.269		0.000	
SUM OF DDT (NO MDL)		897.392		842.668		501.682		111.288		43.961		64.045		25.539	
TOTAL PCB (NO MDL)		616.380		583.107		836.636		303.056		184.946		231.876		231.898	
Total non-DDT pest.		35.2290		42.7760		63.2470		23.4940		16.7330		15.4690		53.1560	
Procedural Blank Reported in Total ng.															
ND - Non Detected															
NA - Not Applicible															
& - Surrogate Recovery outside criteria (50 - 150%)															
Surrogate Recoveries,%															
DBOFB		67.487		76.293		63.348		66.825		62.421		69.137		58.531	
CL5(112)		71.871		77.526		98.320		76.483		72.001		77.027		59.708	

Appendix F. Percent organic carbon, percent carbonate, and grain size.									
SAMPLE	% TOC	TOC Dup	% TIC	TIC Dup	% Fines	% GRAVEL	% SAND	% SILT	% CLAY
NOAA 1-A	2.49	2.48	0.07	0.07	65.1	1.0	34.0	46.4	18.7
NOAA 2-A	2.67		0.22		72.7	0.0	27.4	53.2	19.5
NOAA 4-A	2.86		0.50		56.0	0.2	43.8	30.8	25.2
NOAA 5-B	3.09		0.03		67.5	0.0	32.4	38.3	29.2
NOAA 6-C	3.86		0.19		73.5	0.6	25.9	40.6	32.9
NOAA 7-B	4.44		2.38		10.4	2.6	87.1	5.6	4.8
NOAA 7-C	1.88		1.00		12.5	8.5	79.1	7.5	5.0
NOAA 8-C	3.47		1.02		42.5	3.0	54.5	23.8	18.7
NOAA 9-B	5.02		1.35		46.1	0.4	53.5	27.7	18.4
NOAA 10-A	4.44		2.55		24.7	9.1	66.1	14.2	10.5
NOAA 10-B	2.61		0.22		55.8	2.1	42.0	31.4	24.4
NOAA 11-B	3.99	4.23	0.62	0.65	45.1	0.0	54.8	29.8	15.3
NOAA 12-A	4.78		1.52		48.3	1.3	50.3	32.9	15.4
NOAA 12-B	3.63		0.10		64.1	0.0	35.8	40.9	23.2
NOAA 13-A	2.55		0.26		48.1	15.0	36.9	29.5	18.6
NOAA 14-A	0.25		0.00		1.5	0.0	98.5	1.2	0.3
NOAA 16-A	0.77		0.39		15.2	3.2	81.6	10.6	4.6
NOAA 16-B	0.95		0.07		32.3	6.7	61.1	22.6	9.7
NOAA 17-B	3.19	3.17	0.07	0.07	76.7	0.2	23.2	53.5	23.2
NOAA 17-C	2.98		0.15		65.4	0.3	34.4	47.1	18.3
NOAA 18-A	1.47		0.09		32.1	1.2	66.7	17.5	14.6
NOAA 18-C	1.98		0.07		35.8	12.8	51.3	22.7	13.1
NOAA 22-C	3.47		0.66		37.9	3.1	59.0	22.1	15.8
NOAA 23-A	2.98	2.93	0.51	0.50	51.3	32.5	16.2	31.8	19.5
NOAA 24-C	2.98		0.18		46.8	0.9	52.3	29.9	16.9
NOAA 25-A	3.21		0.09		51.0	0.1	48.9	33.8	17.2
NOAA 26-A	3.15		1.42		9.4	0.0	90.5	5.9	3.5
NOAA 26-C	3.02		0.09		43.7	0.7	55.6	29.4	14.3
NOAA 29-A	2.80		0.13		40.3	0.1	59.5	25.5	14.8
NOAA 30-A	2.20		0.25		28.5	0.5	70.9	16.8	11.7
NOAA 30-B	1.94		0.07		26.7	0.7	72.5	16.2	10.5
NOAA 30-C	3.05		0.06		30.4	2.0	67.6	18.6	11.8
NOAA 33-B	3.18		0.14		47.9	3.7	48.4	31.4	16.5
NOAA 34-B	1.00		0.00		17.2	0.0	82.8	7.4	9.8
NOAA 35-A	0.69		1.07		13.6	11.2	75.3	7.9	5.7
NOAA 36-C	2.50		0.03		55.8	0.0	44.2	37.5	18.3
NOAA 37-B	0.07		0.00		0.0	0.0	100.0	0.0	0.0
NOAA 38-B	0.07		0.00		0.0	0.0	100.0	0.0	0.0

Appendix G. Newark Bay all chem/toxicity				
station no.	Submitter Number, Sample Location:	Rep.	NFCR Lab no.	DF07, Inj. No.
	(Site No.)			
			NBS	
1	Site 1 Upper Passaic R		9561	49
3	Site 3 Passaic River		9562	47
5	Site 5 Lower Passaic R, Upstream of Pt Source		9563	46
7a	Site 7A Lower Passaic R Pt Source		9593	40
7b	Site 7B Lower Passaic R Pt Source	Ave(n=3)	9594	
7c	Site 7C Lower Passaic R Pt Source		9595	45
8a	Site 8A Lower Passaic R Pt Source		9596	37
8b	Site 8B Lower Passaic R Pt Source		9597	39
10	Site 10 Lower Passaic R Below Pt Sour	Ave(n=3)	9564	
11	Site 11 Lower Passaic R Below Pt Source		9565	32
12	Site 12 Hackensack R, N of Berry's Creek		9566	27
14	Site 14 Hackensack R, N of Berry's Creek		9567	26
17	Site 17 Hackensack R,S of Berry's Ck, N of		9598	25
20	Site 20 Mouth of Hackensack River, Upper Newark Bay		9568	24
21	Site 21 Mouth of Passaic River, Upper Newark Bay		9569	31
26	Site 26 Upper Newark Bay		9570	22
31	Site 31 Upper-Mid Newark Bay		9526	17
36	Site 36 Lower-Mid- Newark Bay		9529	21
56	Site 56 Lower Newark Bay, Port Richmond		9528	20
57	Site 57 Upper New York Harbor		9527	19
57 gc/qms	Site 57 Upper New York Harbor		9527	GC/QMS
7a gc/qms	Site 7A Lower Passaic R Pt Source		9593	GC/QMS
7b rep 1	Site 7B Lower Passaic R Pt Source	Replicate 1	9594-1	41
7b rep 2	Site 7B Lower Passaic R Pt Source	Replicate 2	9594-2	42
7b rep 3	Site 7B Lower Passaic R Pt Source	Replicate 3	9594-3	44
7b	Site 7B Lower Passaic R Pt Source		9594-ave(n=3)	
10 rep 1	Site 10 Lower Passaic R Below Pt Sour	Replicate 1	9564-1	34
10 rep 2	Site 10 Lower Passaic R Below Pt Sour	Replicate 2	9564-2	35
10 rep 3	Site 10 Lower Passaic R Below Pt Sour	Replicate 3	9564-3	36
10 Ave	Site 10 Lower Passaic R Below Pt Sour	Ave(n=3)		

Appendix G. Newark Bay all chem/toxicity contd.							
station no.	(Site No.)	% AmphSurv Rel. to Ctls.	Stat. signif. Hit/Nohit	UAN, ug/l	2,3,7,8-tcdd, pg/g	kutz 90 TEF	TEQ 1
1	Site 1	76	H	330	99	1	99
3	Site 3	31.3	H	235	270	1	270
5	Site 5	29.1	H	460	450	1	450
7a	Site 7A	34.8	H	nd	390	1	390
7b	Site 7B	32.6	H	nd	376.67	1	376.67
7c	Site 7C	9	H	nd	620	1	620
8a	Site 8A	19.1	H	nd	440	1	440
8b	Site 8B	14.6	H	nd	300	1	300
10	Site 10	20.2	H	nd	363.33	1	363.33
11	Site 11	51.9	H	0.35	280	1	280
12	Site 12	96.2	N	0.35	7.4	1	7.4
14	Site 14	77.2	N	0.35	62	1	62
17	Site 17	72.2	H	0.35	29	1	29
20	Site 20	79.4	H	0.35	38	1	38
21	Site 21	17.5	H	0.35	140	1	140
26	Site 26	0	H	0.35	470	1	470
31	Site 31	52.6	H	0.35	62	1	62
36	Site 36	68.4	H	0.35	55	1	55
56	Site 56	83.3	N	0.35	30	1	30
57	Site 57	111.1	N	620	3.6	1	3.6
57 gc/qms	Site 57				2	1	2
7a gc/qms	Site 7A				480	1	480
7b rep 1	Site 7B				430	1	430
7b rep 2	Site 7B				340	1	340
7b rep 3	Site 7B				360	1	360
7b	Site 7B				376.667	1	376.67
10 rep 1	Site 10				310	1	310
10 rep 2	Site 10				350	1	350
10 rep 3	Site 10				430	1	430
10 Ave	Site 10				363.33	1	363.33

Appendix G. Newark Bay all chem/toxicity contd.						
station no.		1,2,3,7,8-pcdd,	Kutz 90 TEF	TEQ 2	1,2,4,7,8-pcdd,	MDL
	(Site No.)	pg/g			pg/g	
1	Site 1	2.2	0.5	1.1	1.3	
3	Site 3	4.4	0.5	2.2	1.1	NQ
5	Site 5	7.8	0.5	3.9	0.5	ND
7a	Site 7A	8.1	0.5	4.1	13	
7b	Site 7B	8.833	0.5	4.4	9.93	
7c	Site 7C	12	0.5	6	23	
8a	Site 8A	10	0.5	5	13	
8b	Site 8B	7	0.5	3.5	8.5	
10	Site 10	7.97	0.5	4	10.33	
11	Site 11	9.1	0.5	4.6	12	
12	Site 12	0.5	0.5	0.3	0.8	
14	Site 14	3.3	0.5	1.7	3.4	
17	Site 17	1	0.5	0.5	1.4	NQ
20	Site 20	1.2	0.5	0.6	1.6	NQ
21	Site 21	1.9	0.5	1	1.9	
26	Site 26	6.5	0.5	3.3	8.6	
31	Site 31	3	0.5	1.5	4.1	
36	Site 36	4	0.5	2	5.4	
56	Site 56	3	0.5	1.5	4	
57	Site 57	0.7	0.5	0.4	0.8	NQ
57 gc/qms	Site 57	1	0.5	0.5	3	
7a gc/qms	Site 7A	8	0.5	4	15	
7b rep 1	Site 7B	8.3	0.5	4.15	9	
7b rep 2	Site 7B	10	0.5	5	8.8	
7b rep 3	Site 7B	8.2	0.5	4.1	12	
7b	Site 7B	8.833	0.5	4.4165	9.93	
10 rep 1	Site 10	7.3	0.5	3.65	9.4	
10 rep 2	Site 10	9.1	0.5	4.55	13	
10 rep 3	Site 10	7.5	0.5	3.75	8.6	
10 Ave	Site 10	7.97	0.5	3.985	10.33	

Appendix G. Newark Bay all chem/toxicity contd.						
station no.		TEQ 3	1,2,3,6,7,	Kutz 90 TEF	TEQ 4	1,2,3,7,8,
	(Site No.)		8-hcdd, pg/g			9-hcdd, ng/g
1	Site 1	0.16	7.5	0.1	0.75	4.3
3	Site 3	0.41	33	0.1	3.3	4.5
5	Site 5	0.8	44	0.1	4.4	26
7a	Site 7A	0.77	29	0.1	2.9	20
7b	Site 7B	0.97	32.33	0.1	3.23	29.67
7c	Site 7C	0.97	39	0.1	3.9	29
8a	Site 8A	0.97	38	0.1	3.8	29
8b	Site 8B	0.82	32	0.1	3.2	22
10	Site 10	0.74	33.67	0.1	3.37	23.33
11	Site 11	0.83	31	0.1	3.1	24
12	Site 12	0.07	2.9	0.1	0.29	2
14	Site 14	0.35	17	0.1	1.7	12
17	Site 17	0.12	4.1	0.1	0.41	2.8
20	Site 20	0.12	6.2	0.1	0.62	4
21	Site 21	0.23	8	0.1	0.8	5.9
26	Site 26	0.55	32	0.1	3.2	21
31	Site 31	0.32	15	0.1	1.5	11
36	Site 36	0.41	17	0.1	1.7	13
56	Site 56	0.32	16	0.1	1.6	12
57	Site 57	0.07	2.4	0.1	0.24	1.4
57 gc/qms	Site 57	0.1	3	0.1	0.3	0.9
7a gc/qms	Site 7A	0.8	57	0.1	5.7	28
7b rep 1	Site 7B	0.96	29	0.1	2.9	25
7b rep 2	Site 7B	1.1	37	0.1	3.7	39
7b rep 3	Site 7B	0.84	31	0.1	3.1	25
7b	Site 7B	0.97	32.333	0.1	3.23	29.667
10 rep 1	Site 10	0.71	34	0.1	3.4	22
10 rep 2	Site 10	0.78	34	0.1	3.4	24
10 rep 3	Site 10	0.73	33	0.1	3.3	24
10 Ave	Site 10	0.74	33.67	0.1	3.37	23.33

Appendix G. Newark Bay all chem/toxicity contd.						
station no.	(Site No.)	Kutz 90 TEF	TEQ 5	1,2,3,4,6,7, 8-hcdd, ng/g	Kutz 90 TEF	TEQ 6
1	Site 1	0.1	0.43	180	0.01	1.8
3	Site 3	0.1	0.45	450	0.01	4.5
5	Site 5	0.1	2.6	720	0.01	7.2
7a	Site 7A	0.1	2	590	0.01	5.9
7b	Site 7B	0.1	2.97	753.3	0.01	7.53
7c	Site 7C	0.1	2.9	790	0.01	7.9
8a	Site 8A	0.1	2.9	870	0.01	8.7
8b	Site 8B	0.1	2.2	780	0.01	7.8
10	Site 10	0.1	2.33	633.3	0.01	6.33
11	Site 11	0.1	2.4	660	0.01	6.6
12	Site 12	0.1	0.2	63	0.01	0.63
14	Site 14	0.1	1.2	400	0.01	4
17	Site 17	0.1	0.28	71	0.01	0.71
20	Site 20	0.1	0.4	110	0.01	1.1
21	Site 21	0.1	0.59	140	0.01	1.4
26	Site 26	0.1	2.1	620	0.01	6.2
31	Site 31	0.1	1.1	310	0.01	3.1
36	Site 36	0.1	1.3	350	0.01	3.5
56	Site 56	0.1	1.2	410	0.01	4.1
57	Site 57	0.1	0.14	42	0.01	0.42
57 gc/qms	Site 57	0.1	0.09	55	0.01	0.55
7a gc/qms	Site 7A	0.1	2.8	700	0.01	7
7b rep 1	Site 7B	0.1	2.5	740	0.01	7.4
7b rep 2	Site 7B	0.1	3.9	860	0.01	8.6
7b rep 3	Site 7B	0.1	2.5	660	0.01	6.6
7b	Site 7B	0.1	2.97	753.333	0.01	7.53
10 rep 1	Site 10	0.1	2.2	630	0.01	6.3
10 rep 2	Site 10	0.1	2.4	660	0.01	6.6
10 rep 3	Site 10	0.1	2.4	610	0.01	6.1
10 Ave	Site 10	0.1	2.33	633.33	0.01	6.33

Appendix G. Newark Bay all chem/toxicity contd.					
station no.		Octa chloro-dd,	Kutz 90 TEF	TEQ 7	2,3,7,8-tcdf,
	(Site No.)	pg/g			pg/g
1	Site 1	1,900	0.001	1.9	71
3	Site 3	4,800	0.001	4.8	160
5	Site 5	7,100	0.001	7.1	190
7a	Site 7A	6,400	0.001	6.4	170
7b	Site 7B	7800	0.001	7.8	220
7c	Site 7C	8,100	0.001	8.1	230
8a	Site 8A	8,700	0.001	8.7	230
8b	Site 8B	7,700	0.001	7.7	170
10	Site 10	6300	0.001	6.3	233.33
11	Site 11	7,400	0.001	7.4	220
12	Site 12	1,200	0.001	1.2	10
14	Site 14	5,000	0.001	5	89
17	Site 17	1,100	0.001	1.1	29
20	Site 20	1,400	0.001	1.4	41
21	Site 21	1,800	0.001	1.8	140
26	Site 26	5,900	0.001	5.9	370
31	Site 31	3,100	0.001	3.1	92
36	Site 36	3,600	0.001	3.6	66
56	Site 56	4,800	0.001	4.8	56
57	Site 57	510	0.001	0.51	9.5
57 gc/qms	Site 57	580	0.001	0.58	7
7a gc/qms	Site 7A	5,960	0.001	5.96	190
7b rep 1	Site 7B	7,000	0.001	7	220
7b rep 2	Site 7B	9,700	0.001	9.7	270
7b rep 3	Site 7B	6,700	0.001	6.7	170
7b	Site 7B	7800	0.001	7.8	220
10 rep 1	Site 10	6,700	0.001	6.7	250
10 rep 2	Site 10	6,300	0.001	6.3	230
10 rep 3	Site 10	5,900	0.001	5.9	220
10 Ave	Site 10	6300	0.001	6.3	233.33

Appendix G. Newark Bay all chem/toxicity contd.						
station no.	(Site No.)	Kutz 90 TEF	TEQ 8	1,2,3,7,8-pcdf, pg/g	Kutz 90 TEF	TEQ 9
1	Site 1	0.1	7.1	2.8	0.05	0.14
3	Site 3	0.1	16	8.7	0.05	0.435
5	Site 5	0.1	19	14	0.05	0.7
7a	Site 7A	0.1	17	12	0.05	0.6
7b	Site 7B	0.1	22	13.333	0.05	0.66665
7c	Site 7C	0.1	23	19	0.05	0.95
8a	Site 8A	0.1	23	16	0.05	0.8
8b	Site 8B	0.1	17	11	0.05	0.55
10	Site 10	0.1	23.33	22.33	0.05	1.1165
11	Site 11	0.1	22	18	0.05	0.9
12	Site 12	0.1	1	1.3	0.05	0.065
14	Site 14	0.1	8.9	9	0.05	0.45
17	Site 17	0.1	2.9	2.7	0.05	0.135
20	Site 20	0.1	4.1	5.4	0.05	0.27
21	Site 21	0.1	14	5.2	0.05	0.26
26	Site 26	0.1	37	15	0.05	0.75
31	Site 31	0.1	9.2	10	0.05	0.5
36	Site 36	0.1	6.6	7.5	0.05	0.375
56	Site 56	0.1	5.6	6.4	0.05	0.32
57	Site 57	0.1	0.95	1.1	0.05	0.055
57 gc/qms	Site 57	0.1	0.7	0.8	0.05	0.04
7a gc/qms	Site 7A	0.1	19	13	0.05	0.65
7b rep 1	Site 7B	0.1	22	13	0.05	0.65
7b rep 2	Site 7B	0.1	27	14	0.05	0.7
7b rep 3	Site 7B	0.1	17	13	0.05	0.65
7b	Site 7B	0.1	22	13.333	0.05	0.66665
10 rep 1	Site 10	0.1	25	23	0.05	1.15
10 rep 2	Site 10	0.1	23	22	0.05	1.1
10 rep 3	Site 10	0.1	22	22	0.05	1.1
10 Ave	Site 10	0.1	23.33	22.33	0.05	1.1165

Appendix G. Newark Bay all chem/toxicity contd.						
station no.		2,3,4,7,8-pcdf,	Kutz 90 TEF	TEQ 10	1,2,3,4,7,	Kutz 90 TEF
	(Site No.)	pg/g			8-hcdf, pg/g	
1	Site 1	6.2	0.5	3.1	19	0.1
3	Site 3	36	0.5	18	120	0.1
5	Site 5	33	0.5	16.5	220	0.1
7a	Site 7A	27	0.5	13.5	170	0.1
7b	Site 7B	29.333	0.5	14.67	220	0.1
7c	Site 7C	41	0.5	20.5	370	0.1
8a	Site 8A	43	0.5	21.5	350	0.1
8b	Site 8B	25	0.5	12.5	170	0.1
10	Site 10	47.33	0.5	23.67	386.67	0.1
11	Site 11	40	0.5	20	380	0.1
12	Site 12	2	0.5	1	16	0.1
14	Site 14	22	0.5	11	230	0.1
17	Site 17	5.5	0.5	2.75	45	0.1
20	Site 20	8.4	0.5	4.2	75	0.1
21	Site 21	8.4	0.5	4.2	69	0.1
26	Site 26	36	0.5	18	200	0.1
31	Site 31	15	0.5	7.5	95	0.1
36	Site 36	14	0.5	7	90	0.1
56	Site 56	9.4	0.5	4.7	32	0.1
57	Site 57	1.4	0.5	0.7	4.3	0.1
57 gc/qms	Site 57	0.3	0.5	0.15	3	0.1
7a gc/qms	Site 7A	29	0.5	14.5	200	0.1
7b rep 1	Site 7B	29	0.5	14.5	230	0.1
7b rep 2	Site 7B	28	0.5	14	220	0.1
7b rep 3	Site 7B	31	0.5	15.5	210	0.1
7b	Site 7B	29.333	0.5	14.67	220	0.1
10 rep 1	Site 10	47	0.5	23.5	340	0.1
10 rep 2	Site 10	52	0.5	26	460	0.1
10 rep 3	Site 10	43	0.5	21.5	360	0.1
10 Ave	Site 10	47.33	0.5	23.67	386.67	0.1

Appendix G. Newark Bay all chem/toxicity contd.						
station no.		TEQ 11	1,2,3,6,7,	88-TEF	TEQ 12	1,2,3,7,8,
	(Site No.)		8-hcdf, pg/g			9-hcdf, ng/g
1	Site 1	1.9	5.5	0.1	0.55	0.4
3	Site 3	12	29	0.1	2.9	0.4
5	Site 5	22	47	0.1	4.7	0.9
7a	Site 7A	17	40	0.1	4	1.5
7b	Site 7B	22	47	0.1	4.7	1.167
7c	Site 7C	37	74	0.1	7.4	1.2
8a	Site 8A	35	68	0.1	6.8	1.4
8b	Site 8B	17	38	0.1	3.8	1.2
10	Site 10	38.67	75	0.1	7.5	1.47
11	Site 11	38	72	0.1	7.2	1.5
12	Site 12	1.6	3.1	0.1	0.31	0.4
14	Site 14	23	36	0.1	3.6	0.8
17	Site 17	4.5	7.6	0.1	0.76	0.4
20	Site 20	7.5	14	0.1	1.4	0.4
21	Site 21	6.9	12	0.1	1.2	0.7
26	Site 26	20	35	0.1	3.5	1.2
31	Site 31	9.5	21	0.1	2.1	1.5
36	Site 36	9	17	0.1	1.7	0.7
56	Site 56	3.2	8.9	0.1	0.89	0.4
57	Site 57	0.43	1.2	0.1	0.12	0.4
57 gc/qms	Site 57	0.3	0.9	0.1	0.09	5
7a gc/qms	Site 7A	20	28	0.1	2.8	8
7b rep 1	Site 7B	23	49	0.1	4.9	1.2
7b rep 2	Site 7B	22	47	0.1	4.7	1.2
7b rep 3	Site 7B	21	45	0.1	4.5	1.1
7b	Site 7B	22	47	0.1	4.7	1.167
10 rep 1	Site 10	34	70	0.1	7	1.5
10 rep 2	Site 10	46	84	0.1	8.4	1.5
10 rep 3	Site 10	36	71	0.1	7.1	1.4
10 Ave	Site 10	38.67	75	0.1	7.5	1.47

Appendix G. Newark Bay all chem/toxicity contd.							
station no.	(Site No.)	Kutz 90 TEF	TEQ 13	2,3,4,6,7, 8-hcdf, pg/g	Kutz 90 TE	TEQ 14	1,2,3,4,6,7, 8-hcdf, pg/g
1	Site 1	0.1	0.04	4.2	0.1	0.42	82
3	Site 3	0.1	0.04	2.2	0.1	0.22	460
5	Site 5	0.1	0.09	9.4	0.1	0.94	940
7a	Site 7A	0.1	0.15	19	0.1	1.9	830
7b	Site 7B	0.1	0.12	14.1	0.1	1.41	1003.33
7c	Site 7C	0.1	0.12	34	0.1	3.4	1,600
8a	Site 8A	0.1	0.14	12	0.1	1.2	1,500
8b	Site 8B	0.1	0.12	9.2	0.1	0.92	800
10	Site 10	0.1	0.15	30.33	0.1	3.03	1633.33
11	Site 11	0.1	0.15	30	0.1	3	1,600
12	Site 12	0.1	0.04	1.8	0.1	0.18	95
14	Site 14	0.1	0.08	14	0.1	1.4	950
17	Site 17	0.1	0.04	3.1	0.1	0.31	190
20	Site 20	0.1	0.04	5.6	0.1	0.56	320
21	Site 21	0.1	0.07	5.8	0.1	0.58	280
26	Site 26	0.1	0.12	18	0.1	1.8	750
31	Site 31	0.1	0.15	9.5	0.1	0.95	510
36	Site 36	0.1	0.07	9.7	0.1	0.97	380
56	Site 56	0.1	0.04	6.4	0.1	0.64	190
57	Site 57	0.1	0.04	1.2	0.1	0.12	23
57 gc/qms	Site 57	0.1	0.5	0.5	0.1	0.05	14
7a gc/qms	Site 7A	0.1	0.8	5	0.1	0.5	600
7b rep 1	Site 7B	0.1	0.12	9.8	0.1	0.98	1,100
7b rep 2	Site 7B	0.1	0.12	23	0.1	2.3	1,000
7b rep 3	Site 7B	0.1	0.11	9.5	0.1	0.95	910
7b	Site 7B	0.1	0.12	14.1	0.1	1.41	1003.333
10 rep 1	Site 10	0.1	0.15	28	0.1	2.8	1,500
10 rep 2	Site 10	0.1	0.15	34	0.1	3.4	1,800
10 rep 3	Site 10	0.1	0.14	29	0.1	2.9	1,600
10 Ave	Site 10	0.1	0.15	30.33	0.1	3.03	1633.33

Appendix G. Newark Bay all chem/toxicity contd.						
station no.		Kutz 90 TEF	TEQ 15	1,2,3,4,7,8,	Kutz 90 TEF	TEQ 16
	(Site No.)			9-hcdf, pg/g		
1	Site 1	0.01	0.82	5.3	0.01	0.05
3	Site 3	0.01	4.8	19	0.01	0.19
5	Site 5	0.01	9.4	26	0.01	0.26
7a	Site 7A	0.01	8.3	21	0.01	0.21
7b	Site 7B	0.01	10.03	26.333	0.01	0.26
7c	Site 7C	0.01	16	41	0.01	0.41
8a	Site 8A	0.01	15	36	0.01	0.36
8b	Site 8B	0.01	8	24	0.01	0.24
10	Site 10	0.01	16.33	37	0.01	0.37
11	Site 11	0.01	16	37	0.01	0.37
12	Site 12	0.01	0.95	2.4	0.01	0.02
14	Site 14	0.01	9.5	24	0.01	0.24
17	Site 17	0.01	1.9	4.8	0.01	0.05
20	Site 20	0.01	3.2	8.7	0.01	0.09
21	Site 21	0.01	2.8	6.6	0.01	0.07
26	Site 26	0.01	7.5	21	0.01	0.21
31	Site 31	0.01	5.1	18	0.01	0.18
36	Site 36	0.01	3.8	12	0.01	0.12
56	Site 56	0.01	1.9	6.7	0.01	0.07
57	Site 57	0.01	0.23	1	0.01	0.01
57 gc/qms	Site 57	0.01	0.14	2	0.01	0.02
7a gc/qms	Site 7A	0.01	6	28	0.01	0.28
7b rep 1	Site 7B	0.01	11	26	0.01	0.26
7b rep 2	Site 7B	0.01	10	27	0.01	0.27
7b rep 3	Site 7B	0.01	9.1	26	0.01	0.26
7b	Site 7B	0.01	10.03	26.333	0.01	0.26
10 rep 1	Site 10	0.01	15	34	0.01	0.34
10 rep 2	Site 10	0.01	18	42	0.01	0.42
10 rep 3	Site 10	0.01	16	35	0.01	0.35
10 Ave	Site 10	0.01	16.33	37	0.01	0.37

Appendix G. Newark Bay all chem/toxicity contd.							
station no.		Octa chloro df,	Kutz 90 T	TEQ 17	Cum dioxin TEQ	PCB 81	PCB 77
	(Site No.)	pg/g			pg/g	pg/g	pg/g
1	Site 1	210	0.001	0.21	119.47	59	2200
3	Site 3	770	0.001	0.77	341.02	94	5200
5	Site 5	1,300	0.001	1.3	550.89	130	6100
7a	Site 7A	1,200	0.001	1.2	475.88	110	4900
7b	Site 7B	1333	0.001	1.33	480.77	120	5300
7c	Site 7C	2,000	0.001	2	760.55	140	9500
8a	Site 8A	1,800	0.001	1.8	575.67	150	7000
8b	Site 8B	1,200	0.001	1.2	386.55	120	4900
10	Site 10	2000	0.001	2	502.55	173.33	6233.3
11	Site 11	2,100	0.001	2.1	414.6	160	5400
12	Site 12	180	0.001	0.18	15.389	28	480
14	Site 14	1,500	0.001	1.5	135.57	90	3500
17	Site 17	310	0.001	0.31	45.773	27	910
20	Site 20	490	0.001	0.49	64.087	23	1100
21	Site 21	430	0.001	0.43	176.28	78	2700
26	Site 26	1,200	0.001	1.2	581.28	320	12000
31	Site 31	970	0.001	0.97	108.77	76	2500
36	Site 36	640	0.001	0.64	97.785	76	3000
56	Site 56	330	0.001	0.33	61.207	67	2600
57	Site 57	44	0.001	0.04	8.029	13	370
57 gc/qms	Site 57	33	0.001	0.03	6.143	20	260
7a gc/qms	Site 7A	1,580	0.001	1.58	572.37	87	5400
7b rep 1	Site 7B	1,400	0.001	1.4	533.72	130	5500
7b rep 2	Site 7B	1,300	0.001	1.3	454.39	120	5300
7b rep 3	Site 7B	1,300	0.001	1.3	454.21	110	5100
7b	Site 7B	1333.333	0.001	1.33	480.773	120	5300
10 rep 1	Site 10	2,000	0.001	2	443.9	170	6200
10 rep 2	Site 10	2,100	0.001	2.1	502.6	180	6300
10 rep 3	Site 10	1,900	0.001	1.9	561.17	170	6200
10 Ave	Site 10	2000	0.001	2	502.553	173.33	6233.3

Appendix G. Newark Bay all chem/toxicity contd.						
station no.		Barnes 91 TEF	TEQ 19	PCB 126	Barnes 91 TEF	TEQ 20
	(Site No.)			pg/g		
1	Site 1	0.01	22	35	0.1	3.5
3	Site 3	0.01	52	110	0.1	11
5	Site 5	0.01	61	170	0.1	17
7a	Site 7A	0.01	49	130	0.1	13
7b	Site 7B	0.01	53	176.67	0.1	17.67
7c	Site 7C	0.01	95	170	0.1	17
8a	Site 8A	0.01	70	190	0.1	19
8b	Site 8B	0.01	49	150	0.1	15
10	Site 10	0.01	62.33	170	0.1	17
11	Site 11	0.01	54	140	0.1	14
12	Site 12	0.01	4.8	23	0.1	2.3
14	Site 14	0.01	35	90	0.1	9
17	Site 17	0.01	9.1	23	0.1	2.3
20	Site 20	0.01	11	19	0.1	1.9
21	Site 21	0.01	27	56	0.1	5.6
26	Site 26	0.01	120	210	0.1	21
31	Site 31	0.01	25	74	0.1	7.4
36	Site 36	0.01	30	74	0.1	7.4
56	Site 56	0.01	26	57	0.1	5.7
57	Site 57	0.01	3.7	9	0.1	0.9
57 gc/qms	Site 57	0.01	2.6	19	0.1	1.9
7a gc/qms	Site 7A	0.01	54	120	0.1	12
7b rep 1	Site 7B	0.01	55	240	0.1	24
7b rep 2	Site 7B	0.01	53	150	0.1	15
7b rep 3	Site 7B	0.01	51	140	0.1	14
7b	Site 7B	0.01	53	176.667	0.1	17.67
10 rep 1	Site 10	0.01	62	180	0.1	18
10 rep 2	Site 10	0.01	63	180	0.1	18
10 rep 3	Site 10	0.01	62	150	0.1	15
10 Ave	Site 10	0.01	62.33	170	0.1	17

Appendix G. Newark Bay all chem/toxicity contd.						
station no.		PCB 169	Barnes 91 TEF	TEQ 21	Cum PCB TEQ	Total Cum TEQ
	(Site No.)	pg/g				
1	Site 1	5	0.05	0.25	25.75	145.22
3	Site 3	28	0.05	1.4	64.4	405.42
5	Site 5	11	0.05	0.55	78.55	629.44
7a	Site 7A	22	0.05	1.1	63.1	538.98
7b	Site 7B	19.667	0.05	0.98	71.65	552.42
7c	Site 7C	28	0.05	1.4	113.4	873.95
8a	Site 8A	32	0.05	1.6	90.6	666.27
8b	Site 8B	18	0.05	0.9	64.9	451.45
10	Site 10	9.67	0.05	0.48	79.82	582.37
11	Site 11	5	0.05	0.25	68.25	482.85
12	Site 12	7	0.05	0.35	7.45	22.84
14	Site 14	5	0.05	0.25	44.25	179.82
17	Site 17	5	0.05	0.25	11.65	57.42
20	Site 20	5	0.05	0.25	13.15	77.24
21	Site 21	40	0.05	2	34.6	210.88
26	Site 26	14	0.05	0.7	141.7	722.98
31	Site 31	5	0.05	0.25	32.65	141.42
36	Site 36	5	0.05	0.25	37.65	135.44
56	Site 56	5	0.05	0.25	31.95	93.16
57	Site 57	5	0.05	0.25	4.85	12.88
57 gc/qms	Site 57	10	0.05	0.5	5	11.14
7a gc/qms	Site 7A	16	0.05	0.8	66.8	639.17
7b rep 1	Site 7B	31	0.05	1.55	80.55	614.27
7b rep 2	Site 7B	13	0.05	0.65	68.65	523.04
7b rep 3	Site 7B	15	0.05	0.75	65.75	519.96
7b	Site 7B	19.667	0.05	0.98	71.65	552.42
10 rep 1	Site 10	11	0.05	0.55	80.55	524.45
10 rep 2	Site 10	9	0.05	0.45	81.45	584.05
10 rep 3	Site 10	9	0.05	0.45	77.45	638.62
10 Ave	Site 10	9.67	0.05	0.48	79.82	582.37

Appendix G. Newark Bay all chem/toxicity contd.					
NFCRC No.	Field station ID	Hexachloro-benzene, ng/g	Pentachloro-anisole, ng/g	Alpha-BHC, ng/g	Lindane, ng/g
9561	STATION #1	0.9	0.4	1.3	0.1
9562	STATION #3	3	0.7	1	0.7
9563	STATION #5	5.6	0.8	2.4	0.1
9593	STATION #7A	6.6	0.7	0.8	0.1
9594	STATION #7B	5.3	0.8	1.2	0.1
9595	STATION #7C	6.3	0.6	0.7	0.1
9596	STATION #8A	7.6	0.7	0.9	0.1
9597	STATION #8B	3.9	0.8	0.9	0.1
9564*	STATION #10	7	0.7	1.7	0.1
9565	STATION #11	10.1	0.6	2	0.1
9566	STATION #12	0.1	0.1	0.1	0.1
9567	STATION #14	2.6	0.4	1.5	0.1
9598	STATION #17	1.6	0.3	0.6	0.1
9568	STATION #20	2	0.1	0.5	0.1
9569	STATION #21	2	0.4	0.4	0.9
9570	STATION #26	5.2	0.3	0.7	0.9
9526	STATION #31	5.6	0.5	1.5	0.9
9529	STATION #36	4	0.4	0.9	0.1
9528	STATION #56	1	0.4	0.6	0.6
9527	STATION #57	0.1	0.1	0.5	0.1

*Values are average of GC Replicate injections.

MDL = 0.11 ng/g; MQL = 0.26 ng/g.

DUP = Duplicate sample

Appendix G. Newark Bay all chem/toxicity contd.						
NFCRC No.	Field station ID	Beta-BHC, ng/g	Heptachlor, ng/g	Delta-BHC, ng/g	Dacthal, ng/g	Oxychlordane, ng/g
9561	STATION #1	0.1	0.1	1.2	2.3	0.3
9562	STATION #3	0.4	0.1	1	2	0.4
9563	STATION #5	0.5	0.1	3	2.3	0.8
9593	STATION #7A	0.1	0.1	3.8	2.4	0.6
9594	STATION #7B	0.1	0.1	3.5	1.6	0.5
9595	STATION #7C	0.1	0.1	3.1	2	0.5
9596	STATION #8A	0.7	0.1	3.2	1.5	0.5
9597	STATION #8B	0.3	0.5	3.5	2.1	1.3
9564*	STATION #10	0.1	0.1	3.2	2.1	0.3
9565	STATION #11	0.1	0.1	3.8	3.3	0.5
9566	STATION #12	0.1	0.1	0.1	1.2	0.1
9567	STATION #14	0.1	0.1	1.5	2.5	0.4
9598	STATION #17	0.8	1.3	0.6	2.7	0.1
9568	STATION #20	0.9	0.1	0.9	2.7	0.4
9569	STATION #21	0.3	0.1	1.6	2.8	0.6
9570	STATION #26	0.1	0.1	1.6	4.4	0.3
9526	STATION #31	0.1	0.1	2.7	1.4	0.1
9529	STATION #36	0.1	0.1	1.7	1.6	0.1
9528	STATION #56	0.7	0.1	1.9	1.8	0.1
9527	STATION #57	0.5	0.1	1.6	1.4	0.1

*Values are average of GC Replicate injections.

MDL = 0.11 ng/g; MQL = 0.26 ng/g.

DUP = Duplicate sample

Appendix G. Newark Bay all chem/toxicity contd.				
NFCRC No.	Field station ID	Heptachlor epoxide, ng/g	trans-chlordane, ng/g	trans-nonachlor, ng/g
9561	STATION #1	2.8	11.5	7.2
9562	STATION #3	8.5	31.7	15.8
9563	STATION #5	13	42.5	30.5
9593	STATION #7A	9.9	36.3	19.2
9594	STATION #7B	10.9	40.4	17.7
9595	STATION #7C	10.6	42.1	18.2
9596	STATION #8A	10.6	42.7	17.1
9597	STATION #8B	12.9	41.8	28.3
9564*	STATION #10	7	25.1	17.9
9565	STATION #11	8	26.5	16.9
9566	STATION #12	0.4	1.1	0.6
9567	STATION #14	2.9	7.7	5.6
9598	STATION #17	1.1	2.2	1.2
9568	STATION #20	0.9	2.4	1.7
9569	STATION #21	1	3.6	2.9
9570	STATION #26	4.7	13.8	12.4
9526	STATION #31	1.7	5.7	4.8
9529	STATION #36	1.7	6.3	4.1
9528	STATION #56	1.7	5.8	4
9527	STATION #57	0.4	0.6	0.9

*Values are average of GC Replicate injections.

MDL = 0.11 ng/g; MQL = 0.26 ng/g.

DUP = Duplicate sample

Appendix G. Newark Bay all chem/toxicity contd.						
NFCRC No.	Field station ID	cis-chlordane, ng/g	o,p'-DDE, ng/g	Dieldrin, ng/g	p,p'-DDE, ng/g	o,p'-DDD, ng/g
9561	STATION #1	12.3	1.9	4.9	13.8	8.8
9562	STATION #3	34.3	4	12.9	51.6	37.4
9563	STATION #5	59.7	16.7	21.2	60.7	40.4
9593	STATION #7A	42.3	5.9	12.7	49	31.2
9594	STATION #7B	48.7	6.4	13.3	53	27.2
9595	STATION #7C	53.2	16	15.6	57.7	35.5
9596	STATION #8A	49.2	7.1	13.9	55.6	31.3
9597	STATION #8B	56.6	8.7	19.1	50	31.1
9564*	STATION #10	28.8	11.2	10	71.8	26
9565	STATION #11	29	9.2	12.4	53.3	25.2
9566	STATION #12	1.4	0.8	0.9	3.9	0.8
9567	STATION #14	10	3.8	5.4	22.7	8.5
9598	STATION #17	2.6	1.5	1.7	9.5	2.2
9568	STATION #20	3.1	6.7	1.8	19.4	4.2
9569	STATION #21	3	8.4	5.5	24.4	4.4
9570	STATION #26	12.2	14.3	15.2	72.1	11.9
9526	STATION #31	7.2	8.3	3	37.1	14
9529	STATION #36	8.9	7	6.2	31.5	13.6
9528	STATION #56	6.3	8.6	3.6	37.1	16.7
9527	STATION #57	1	0.3	1	3.3	1.1

*Values are average of GC Replicate injections.

MDL = 0.11 ng/g; MQL = 0.26 ng/g.

DUP = Duplicate sample

Appendix G. Newark Bay all chem/toxicity contd.						
NFCRC No.	Field station ID	Endrin, ng/g	cis-nonachlor, ng/g	o,p'-DDT, ng/g	p,p'-DDD, ng/g	p,p'-DDT, ng/g
9561	STATION #1	3.3	2.7	1.4	25.8	8.2
9562	STATION #3	0.7	9.4	1.3	72.6	50.6
9563	STATION #5	1	9.4	8.6	74.4	38.9
9593	STATION #7A	0.8	10.2	7.1	63.3	38.6
9594	STATION #7B	1	10.8	14.1	61.8	125
9595	STATION #7C	1.2	12	2.7	72.6	25.2
9596	STATION #8A	1.3	11	4.9	67.2	64.1
9597	STATION #8B	0.9	11	4	60.5	27.7
9564*	STATION #10	1.2	6.8	2.8	51.5	29.4
9565	STATION #11	0.7	6.7	5.3	53.7	63.5
9566	STATION #12	0.1	0.4	0.3	2.8	0.9
9567	STATION #14	0.5	2.5	1	20.2	99.8
9598	STATION #17	0.1	0.7	1.7	8.2	2.6
9568	STATION #20	0.1	0.9	4.2	18.2	4.4
9569	STATION #21	0.3	0.7	7.5	16.1	4.7
9570	STATION #26	0.4	3.1	9.3	26.9	7.7
9526	STATION #31	0.4	2.3	7.6	30.9	54.2
9529	STATION #36	0.8	1.9	2.4	30.3	107.1
9528	STATION #56	0.6	1.7	0.8	36.9	23.9
9527	STATION #57	0.4	0.6	2.5	3.1	1.2

*Values are average of GC Replicate injections.

MDL = 0.11 ng/g; MQL = 0.26 ng/g.

DUP = Duplicate sample

Appendix G. Newark Bay all chem/toxicity contd.						
NFCRC No.	Field station ID	mirex, ng/g	total PCBs, ng/g	total DDTs, ng/g	Total cPCB, ng/g	Total mPCB, ng/g
9561	STATION #1	8.4	320	59.8	208.91	23.39
9562	STATION #3	25.2	2850.2	217.5	2046.09	69.84
9563	STATION #5	23.1	1799.6	239.8	967.94	67.93
9593	STATION #7A	14.3	1206.3	195.1	622.49	52.14
9594	STATION #7B	12.8	1362.7	287.4	1038.48	85.31
9595	STATION #7C	14	1454.3	209.6	863.19	60.01
9596	STATION #8A	13.5	1609	230.2	891.56	68.16
9597	STATION #8B	19.6	1340.7	182	808.12	61.38
9564*	STATION #10	11.5	1324.3	192.6	1129.52	72.5
9565	STATION #11	11.4	1087.4	210.2	567.34	46.55
9566	STATION #12	0.7	109.7	9.5	43.68	5.77
9567	STATION #14	3.9	671	155.9	286.53	38.98
9598	STATION #17	2.4	206.7	25.8	76.46	10.12
9568	STATION #20	3.4	400	57.2	152.1	2.53
9569	STATION #21	3	539.4	65.3	238.24	19.29
9570	STATION #26	3.3	2318	142.2	1289.81	15.78
9526	STATION #31	3.2	564.9	152.2	243.53	23.35
9529	STATION #36	3.6	576.5	191.9	278.7	23.27
9528	STATION #56	3.2	484.9	124	181.79	16.97
9527	STATION #57	1.6	105.5	11.4	15.76	3
	7b				942.78	77.22
	7b				963.64	76.77
	7b				1209.01	101.93
	7b ave.				1038.48	85.31
	10				1100.97	70.98
	10				1219.92	75.96
	10				1067.67	70.57
	10 ave.				1129.52	72.5
*Values are average of GC Replicate injections.						
MDL = 0.11 ng/g; MQL = 0.26 ng/g.						
DUP = Duplicate sample						

Appendix G. Newark Bay all chem/toxicity contd.						
NFCRC No.	Field station ID	Total PCBs, ng/g	% TOC	%TOC/100	Dieldrin, ng/goc	Endrin, ng/goc
9561	STATION #1	232.3	2	0.02	245	165
9562	STATION #3	2115.93	5	0.05	258	, 14
9563	STATION #5	1035.87	6.1	0.061	347.54	16.39
9593	STATION #7A	674.63	5.8	0.058	218.97	13.79
9594	STATION #7B	1123.79	2.4	0.024	554.17	41.67
9595	STATION #7C	923.2	2.3	0.023	678.26	52.17
9596	STATION #8A	959.71	2.4	0.024	579.17	54.17
9597	STATION #8B	869.51	2.4	0.024	795.83	37.5
9564*	STATION #10	1202.02	4.2	0.042	238.1	28.57
9565	STATION #11	613.89	5.1	0.051	243.14	13.73
9566	STATION #12	49.45	1.7	0.017	52.94	5.88
9567	STATION #14	325.51	4.3	0.043	125.58	11.63
9598	STATION #17	86.59	2.4	0.024	70.83	4.17
9568	STATION #20	154.63	1.7	0.017	105.88	5.88
9569	STATION #21	257.52	1.5	0.015	366.67	20
9570	STATION #26	1305.58	2.2	0.022	690.91	18.18
9526	STATION #31	266.89	2.1	0.021	142.86	19.05
9529	STATION #36	301.97	2.4	0.024	258.33	33.33
9528	STATION #56	198.76	2.5	0.025	144	24
9527	STATION #57	18.76	0.47	0.0047	212.77	85.11
	7b	1020				
	7b	1040.41				
	7b	1310.95				
	7b ave.	1123.79				
	10	1171.95				
	10	1295.88				
	10	1138.24				
	10 ave.	1202.02				
*Values are average of GC Replicate injections.						
MDL = 0.11 ng/g; MQL = 0.26 ng/g.						
DUP = Duplicate sample						

Appendix G. Newark Bay all chem/toxicity contd.						
NFCRC No.	Field station ID	Dieldrin, ug/goc	Endrin, ug/goc	p,p-DDE, ng/goc	p,p-DDE, ug/goc	tDDTs, ng/goc
9561	Station 1, 3/93	0.245	0.165	690	0.69	2990
9562	Station 3, 3/93	0.258	0.014	1032	1.03	4350
9563	Station 5, 3/93	0.348	0.016	995.08	1	3931.15
9593	Sta. 7A, 3/93, h	0.219	0.014	844.83	0.84	3363.79
9594	Station 7B, 3/9	0.554	0.042	2208.33	2.21	11975
9595	Station 7C, 3/9	0.678	0.052	2508.7	2.51	9113.04
9596	Station 8A, 3/9	0.579	0.054	2316.67	2.32	9591.67
9597	Station 8B, 3/9	0.796	0.038	2083.33	2.08	7583.33
9564*	Station 10, 3/9	0.238	0.029	1709.52	1.71	4585.71
9565	Station 11, 3/9	0.243	0.014	1045.1	1.05	4121.57
9566	Station 12, 3/9	0.053	0.006	229.41	0.23	558.82
9567	Station 14, 3/9	0.126	0.012	527.91	0.53	3625.58
9598	Station 17, 3/9	0.071	0.004	395.83	0.4	1075
9568	Station 20, 3/9	0.106	0.006	1141.18	1.14	3364.71
9569	Station 21, 3/9	0.367	0.02	1626.67	1.63	4353.33
9570	Station 26, 3/9	0.691	0.018	3277.27	3.28	6463.64
9526	Sta. 31, 1/93, H	0.143	0.019	1766.67	1.77	7247.62
9529	Sta. 36, 1/93	0.258	0.033	1312.5	1.31	7995.83
9528	Sta. 56, 1/93, H	0.144	0.024	1484	1.48	4960
9527	Sta. 57, 1/93	0.213	0.085	702.13	0.7	2425.53

Appendix G. Newark Bay all chem/toxicity contd.						
Lab no.	Station No.	tDDTs, ug/goc	tPCB, ng/goc	tPCB, ug/goc	TOC(%)	total AVS, umol/g
9581	STATION #1	2.99	11615	11.62	2	0.98
9582	STATION #3	4.35	42319	42.32	5	13.9
9583	STATION #5	3.93	16981	16.98	6.1	29.6
9605	STATION #7A	3.36	11632	11.63	5.8	20.8
9607	STATION #7B	11.98	46825	46.82	2.4	33
9608	STATION #7C	9.11	40139	40.14	2.3	54.9
9609	STATION #8A	9.59	39988	39.99	2.4	62.9
9610	STATION #8B	7.58	36230	36.23	2.4	9.6
9584	STATION #10	4.59	28620	28.62	4.2	20.4
9585	STATION #11	4.12	12037	12.04	5.1	20.1
9586	STATION #12	0.56	2908.8	2.91	1.7	7.7
9587	STATION #14	3.63	7570	7.57	4.3	35
9611	STATION #17	1.08	3607.9	3.61	2.4	6.6
9588	STATION #20	3.36	9095.9	9.1	1.7	11.1
9589	STATION #21	4.35	17168	17.17	1.5	9
9590	STATION #26	6.46	59345	59.34	2.2	32.2
9535	STATION #31	7.25	12709	12.71	2.1	4.1
9539	STATION #36	8	12582	12.58	2.4	14.6
9538	STATION #56	4.96	7950.4	7.95	2.5	4
9536	STATION #57	2.43	3991.5	3.99	0.47	5.2
9606	STATION #7A				2.5	13.6
9534	STATION #31				2.8	6.7
9537	STATION #56				3.2	6.5
9163	STATION #57				2.2	32.6

Appendix G. Newark Bay all chem/toxicity contd.					
Lab no.	Station No.	SE Cd, ug/g dw	SE Cr, ug/g dw	SE Cu, ug/g dw	SE Fe, ug/g dw
9581	Station 1, 3/93	1.02	11	17.3	2720
9582	Station 3, 3/93	2.54	44.6	28.1	5870
9583	Station 5, 3/93	3.76	64.6	38.5	9810
9605	Sta. 7A, 3/93, homogenized	3.97	63.5	54.8	10300
9607	Station 7B, 3/93	3.62	61.4	42.2	9530
9608	Station 7C, 3/93	4.49	77.3	27.1	10900
9609	Station 8A, 3/93	4.86	81.7	23	11500
9610	Station 8B, 3/93	3.75	53.3	75.8	9550
9584	Station 10, 3/93	3.6	115	53.3	8510
9585	Station 11, 3/93	3.16	87.9	77.4	11100
9586	Station 12, 3/93	0.383	13.6	10.8	5970
9587	Station 14, 3/93	2.02	79	15.1	8280
9611	Station 17, 3/93	0.55	52.4	14	2950
9588	Station 20, 3/93	0.839	41.2	16.8	3660
9589	Station 21, 3/93	0.98	70.2	17.4	2590
9590	Station 26, 3/93	3.19	173	13.9	5220
9535	Sta. 31, 1/93, Homogenized	0.965	39.9	42.3	4230
9539	Sta. 36, 1/93	1.06	40.7	47.8	6610
9538	Sta. 56, 1/93, Homogenized	0.978	33.3	68.4	7260
9536	Sta. 57, 1/93	0.245	7.62	11.7	3060
9606	STATION #7A	2.92	45.7	53.8	9100
9534	STATION #31	1.24	53.1	61.2	6280
9537	STATION #56	1.25	40.3	80.8	7920
9163	STATION #57	0.934	29.1	35.5	6840

Appendix G. Newark Bay all chem/toxicity contd.				
Lab no.	Station No.	SE Ag, ug/g dw	SE As, ug/g dw	SE Al, ug/g dw
9581	Station 1, 3/93	0.113	0.61	577
9582	Station 3, 3/93	0.153	0.79	1509
9583	Station 5, 3/93	0.384	1.14	2528
9605	Sta. 7A, 3/93, homogenized	0.335	2.01	2613
9607	Station 7B, 3/93	0.42	1.56	2571
9608	Station 7C, 3/93	0.643	1.35	3226
9609	Station 8A, 3/93	0.678	1.16	3218
9610	Station 8B, 3/93	0.437	1.75	2399
9584	Station 10, 3/93	0.752	2.13	2933
9585	Station 11, 3/93	0.686	2.44	2869
9586	Station 12, 3/93	0.097	0.99	1168
9587	Station 14, 3/93	0.501	1.16	2028
9611	Station 17, 3/93	0.099	1.36	757
9588	Station 20, 3/93	0.218	1	1052
9589	Station 21, 3/93	0.113	1.44	882
9590	Station 26, 3/93	0.378	1.89	1787
9535	Sta. 31, 1/93, Homogenized	0.368	2.34	1295
9539	Sta. 36, 1/93	0.356	2.38	1743
9538	Sta. 56, 1/93, Homogenized	0.761	4.05	1921
9536	Sta. 57, 1/93	0.204	1.59	465
9606	STATION #7A	0.284	1.64	2009
9534	STATION #31	0.372	3.09	1757
9537	STATION #56	0.736	4.51	1976
9163	STATION #57	0.431	1.45	1573

Appendix G. Newark Bay all chem/toxicity contd.					
lab. no.	station no.	SE Hg, ug/g dw	SE Hg (1/2 mdl)	SE Ni, ug/g dw	SE Pb, ug/g dw
9581	Station 1, 3/93	<0.125	0.0625	3.87	81.8
9582	Station 3, 3/93	<0.125	0.0625	7.88	196
9583	Station 5, 3/93	<0.125	0.0625	11.2	250
9605	Sta. 7A, 3/93, homogenized	<0.125	0.0625	12.1	245
9607	Station 7B, 3/93	<0.125	0.0625	11.7	231
9608	Station 7C, 3/93	<0.125	0.0625	12.2	248
9609	Station 8A, 3/93	<0.125	0.0625	12.9	261
9610	Station 8B, 3/93	<0.125	0.0625	11.8	258
9584	Station 10, 3/93	<0.125	0.0625	11.4	201
9585	Station 11, 3/93	<0.125	0.0625	12.3	200
9586	Station 12, 3/93	<0.125	0.0625	3.62	34.3
9587	Station 14, 3/93	<0.125	0.0625	8.55	81.2
9611	Station 17, 3/93	<0.125	0.0625	3.06	33.4
9588	Station 20, 3/93	<0.125	0.0625	4.26	59.5
9589	Station 21, 3/93	<0.125	0.0625	2.99	57.8
9590	Station 26, 3/93	<0.125	0.0625	6.49	140
9535	Sta. 31, 1/93, Homogenized	<0.125	0.0625	6.15	78.2
9539	Sta. 36, 1/93	<0.125	0.0625	7.06	94.1
9538	Sta. 56, 1/93, Homogenized	<0.125	0.0625	10.1	131
9536	Sta. 57, 1/93	<0.125	0.0625	2.8	29.4
9606	Sta. 7A, 3/93, direct	<0.125	0.0625	10.2	244
9534	Sta. 31, 1/93, Direct	<0.125	0.0625	7.71	108
9537	Sta. 56, 1/93, Direct	<0.125	0.0625	9.41	136
9163	Sta. 57, 10/27/92	<0.125	0.0625	18.6	91.7

Appendix G. Newark Bay all chem/toxicity contd.						
lab. no.	station no.	SE Sb, ug/g dw	SE Sb (1/2mdl)	SE Sn, ug/g dw	SE Se, ug/g dw	SE Se (1/2 mdl)
9581	Station 1, 3/93	<2.0	1	9.55	<0.381	0.19
9582	Station 3, 3/93	<2.0	1	19.4	<0.381	0.19
9583	Station 5, 3/93	2.88	2.88	25.7	<0.381	0.19
9605	Sta. 7A, 3/93, homogenized	2.1	2.1	26.1	<0.381	0.19
9607	Station 7B, 3/93	2.01	2.01	25.6	<0.381	0.19
9608	Station 7C, 3/93	2.06	2.06	27.8	<0.381	0.19
9609	Station 8A, 3/93	2.16	2.16	33.4	<0.381	0.19
9610	Station 8B, 3/93	2.23	2.23	28.9	<0.381	0.19
9584	Station 10, 3/93	<2.0	1	24.8	<0.381	0.19
9585	Station 11, 3/93	3.28	3.28	23.7	<0.381	0.19
9586	Station 12, 3/93	<2.0	1	2.46	<0.381	0.19
9587	Station 14, 3/93	<2.0	1	8.93	<0.381	0.19
9611	Station 17, 3/93	<2.0	1	3.68	<0.381	0.19
9588	Station 20, 3/93	<2.0	1	8.34	<0.381	0.19
9589	Station 21, 3/93	<2.0	1	9.41	<0.381	0.19
9590	Station 26, 3/93	<2.0	1	9.81	<0.381	0.19
9535	Sta. 31, 1/93, Homogenized	<2.0	1	19.6	<0.381	0.19
9539	Sta. 36, 1/93	<2.0	1	11	<0.381	0.19
9538	Sta. 56, 1/93, Homogenized	<2.0	1	10.8	<0.381	0.19
9536	Sta. 57, 1/93	<2.0	1	2.48	<0.381	0.19
9606	Sta. 7A, 3/93, direct	<2.0	1	23.5	<0.381	0.19
9534	Sta. 31, 1/93, Direct	2.26	2.26	11.9	<0.381	0.19
9537	Sta. 56, 1/93, Direct	2.05	2.05	13.5	<0.381	0.19
9163	Sta. 57, 10/27/92	2.41	2.41	7.76	<0.381	0.19

Appendix G. Newark Bay all chem/toxicity contd.					
lab. no.	station no.	SE Zn, ug/g dw	SEM/AVS ratio	Cd as % SEM	Cu as % SEM
9581	Station 1, 3/93	134	2.85	108	57
9582	Station 3, 3/93	341	0.49	76	22
9583	Station 5, 3/93	444	0.3	78	17
9605	Sta. 7A, 3/93, homogenized	446	0.44	86	31
9607	Station 7B, 3/93	435	0.26	76	23
9608	Station 7C, 3/93	495	0.17	84	12
9609	Station 8A, 3/93	526	0.16	85	10
9610	Station 8B, 3/93	465	1.02	82	41
9584	Station 10, 3/93	353	0.36	78	26
9585	Station 11, 3/93	339	0.38	80	41
9586	Station 12, 3/93	56	0.16	80	35
9587	Station 14, 3/93	185	0.1	77	13
9611	Station 17, 3/93	74.3	0.24	87	45
9588	Station 20, 3/93	91.4	0.18	92	28
9589	Station 21, 3/93	99.8	0.069	70	21
9590	Station 26, 3/93	212	0.133	75	10
9535	Sta. 31, 1/93, Homogenized	115	0.71	80	51
9539	Sta. 36, 1/93	127	0.22	73	42
9538	Sta. 56, 1/93, Homogenized	149	1.04	19	59
9536	Sta. 57, 1/93	199	0.66	132	80
9606	Sta. 7A, 3/93, direct	401	0.61	89	38
9534	Sta. 31, 1/93, Direct	144	0.57	---b	---
9537	Sta. 56, 1/93, Direct	163	0.71	---	---
9163	Sta. 57, 10/27/92	122	0.098	76	39

Appendix G. Newark Bay all chem/toxicity contd.					
lab. no.	station no.	Pb as % SEM	Ni as % SEM	Zn as % SEM	total Ag, ug/g
9581	Station 1, 3/93	82	22	100	1.54
9582	Station 3, 3/93	80	22	83	1.99
9583	Station 5, 3/93	73	24	79	4.16
9605	Sta. 7A, 3/93, homogenized	85	25	99	4.98
9607	Station 7B, 3/93	81	24	81	4.39
9608	Station 7C, 3/93	80	26	83	5.5
9609	Station 8A, 3/93	84	26	82	5.74
9610	Station 8B, 3/93	73	27	83	5.64
9584	Station 10, 3/93	78	21	75	5.02
9585	Station 11, 3/93	83	24	79	3.11
9586	Station 12, 3/93	54	13	58	<0.73
9587	Station 14, 3/93	65	23	65	3.19
9611	Station 17, 3/93	81	11	74	<0.73
9588	Station 20, 3/93	68	19	13	1.39
9589	Station 21, 3/93	69	14	62	1.19
9590	Station 26, 3/93	88	24	69	3.43
9535	Sta. 31, 1/93, Homogenized	82	14	66	2.22
9539	Sta. 36, 1/93	76	14	59	2.89
9538	Sta. 56, 1/93, Homogenized	97	14	65	3.24
9536	Sta. 57, 1/93	93	7	356	0.843
9606	Sta. 7A, 3/93, direct	91	27	85	4.32
9534	Sta. 31, 1/93, Direct	---	---	---	---b
9537	Sta. 56, 1/93, Direct	---	---	---	---
9163	Sta. 57, 10/27/92	88	10	65	3.26

Appendix G. Newark Bay all chem/toxicity contd.					
lab. no.	station no.	total As, ug/g	total Al, ug/g	total Cd, ug/g	total Cr, ug/g
9581	Station 1, 3/93	1.94	32400	0.941	29.8
9582	Station 3, 3/93	4.68	39800	3.35	75.5
9583	Station 5, 3/93	9.17	54800	4.81	137
9605	Sta. 7A, 3/93, homogenized	10.2	54300	4.6	134
9607	Station 7B, 3/93	9.97	61900	4.73	137
9608	Station 7C, 3/93	11.4	61400	5.31	188
9609	Station 8A, 3/93	11.8	56000	5.69	174
9610	Station 8B, 3/93	8.03	50000	4.56	134
9584	Station 10, 3/93	15.1	64100	4.64	217
9585	Station 11, 3/93	15.8	62700	3.96	184
9586	Station 12, 3/93	8.19	45800	0.476	59
9587	Station 14, 3/93	14.2	62600	2.61	213
9611	Station 17, 3/93	7.06	38800	0.633	111
9588	Station 20, 3/93	8.02	51500	0.91	96.3
9589	Station 21, 3/93	12.8	39300	1.39	135
9590	Station 26, 3/93	16.7	47700	4.23	277
9535	Sta. 31, 1/93, Homogenized	9.83	55600	1.2	106
9539	Sta. 36, 1/93	13.4	65200	1.46	122
9538	Sta. 56, 1/93, Homogenized	13.6	64100	1.29	104
9536	Sta. 57, 1/93	6.64	32100	0.186	35.7
9606	Sta. 7A, 3/93, direct	7.71	46100	3.29	102
9534	Sta. 31, 1/93, Direct	14.1	---	---	---
9537	Sta. 56, 1/93, Direct	15.4	---	---	---
9163	Sta. 57, 10/27/92	12.4	53500	1.23	110

Appendix G. Newark Bay all chem/toxicity contd.					
lab. no.	station no.	total Cu, ug/g	total Fe, ug/g	total Hg, ug/g	total Pb, ug/g
9581	Station 1, 3/93		14700	0.359	100
9582	Station 3, 3/93	125	25100	3.16	246
9583	Station 5, 3/93	224	35000	2.4	344
9605	Sta. 7A, 3/93, homogenized	178	38800	2.28	289
9607	Station 7B, 3/93	184	38100	2.46	284
9608	Station 7C, 3/93	217	39500	2.91	310
9609	Station 8A, 3/93	232	41300	3.26	310
9610	Station 8B, 3/93	185	35600	2.09	353
9584	Station 10, 3/93	206	40900	3.58	259
9585	Station 11, 3/93	191	44400	3.18	241
9586	Station 12, 3/93	30.8	30400	0.665	63.5
9587	Station 14, 3/93	114	42700	4.29	125
9611	Station 17, 3/93	31	27300	1.07	41
9588	Station 20, 3/93	58.8	27500	1.92	87.2
9589	Station 21, 3/93	82.5	21900	1.9	84.2
9590	Station 26, 3/93	141	28500	3.89	159
9535	Sta. 31, 1/93, Homogenized	82.4	29300	1.51	95.9
9539	Sta. 36, 1/93	113	37200	1.89	124
9538	Sta. 56, 1/93, Homogenized	116	38600	1.46	135
9536	Sta. 57, 1/93	14.7	13800	0.14	31.7
9606	Sta. 7A, 3/93, direct	143	34700	2.23	268
9534	Sta. 31, 1/93, Direct	---	---	2.34	---
9537	Sta. 56, 1/93, Direct	---	---	1.79	---
9163	Sta. 57, 10/27/92	91.8	27600	1.18	104

Appendix G. Newark Bay all chem/toxicity contd.						
lab. no.	station no.	total Sb, ug/g	total Sb (1/2 mdl)	total Sn, ug/g	total Se, ug/g	total Zn, ug/g
9581	Station 1, 3/93	<5.24	2.62	14	0.289	133
9582	Station 3, 3/93	<5.24	2.62	42.6	0.661	411
9583	Station 5, 3/93	<5.24	2.62	82.9	0.984	560
9605	Sta. 7A, 3/93, homogenized	<5.24	2.62	64.5	1.11	450
9607	Station 7B, 3/93	<5.24	2.62	63.2	1.27	539
9608	Station 7C, 3/93	<5.24	2.62	68.6	1.21	593
9609	Station 8A, 3/93	<5.24	2.62	80.3	1.34	639
9610	Station 8B, 3/93	<5.24	2.62	68.5	0.976	562
9584	Station 10, 3/93	<5.24	2.62	71.1	1.07	471
9585	Station 11, 3/93	<5.24	2.62	52.1	1.18	429
9586	Station 12, 3/93	<5.24	2.62	9.6	0.328	97
9587	Station 14, 3/93	<5.24	2.62	28.9	1.01	284
9611	Station 17, 3/93	<5.24	2.62	15.5	0.306	101
9588	Station 20, 3/93	<5.24	2.62	20	0.421	720
9589	Station 21, 3/93	<5.24	2.62	25	1.08	160
9590	Station 26, 3/93	8.17	8.17	25.9	0.936	308
9535	Sta. 31, 1/93, Homogenized	<5.24	2.62	21.8	0.552	173
9539	Sta. 36, 1/93	<5.24	2.62	25.6	0.713	214
9538	Sta. 56, 1/93, Homogenized	<5.24	2.62	22.5	0.684	228
9536	Sta. 57, 1/93	<5.24	2.62	4.9	0.104	55.9
9606	Sta. 7A, 3/93, direct	<5.24	2.62	51.8	0.972	471
9534	Sta. 31, 1/93, Direct	---		---	0.801	---
9537	Sta. 56, 1/93, Direct	---		---	0.952	---
9163	Sta. 57, 10/27/92	<5.24	2.62	19.4	0.62	188

Appendix G. Newark Bay all chem/toxicity contd.						
lab no.	station no.	Cd SEM/AVS	Cu SEM/AVS	Pb SEM/AVS	Ni SEM/AVS	Zn SEM/AVS
9581	Station 1, 3/93	0.00925993	0.27782596	0.40286398	0.0672625	2.0917041
9582	Station 3, 3/93	0.00162575	0.03181591	0.06805695	0.0096561	0.3752849
9583	Station 5, 3/93	0.00113013	0.02047019	0.04076425	0.0064449	0.2294631
9605	Sta. 7A, 3/93, ho	0.00169809	0.04146389	0.05685046	0.0099086	0.3280145
9607	Station 7B, 3/93	0.00097595	0.02012571	0.03378541	0.0060389	0.2016494
9608	Station 7C, 3/93	0.00072763	0.00776872	0.02180271	0.0037851	0.1379286
9609	Station 8A, 3/93	0.00068742	0.0057548	0.02002724	0.0034932	0.1279254
9610	Station 8B, 3/93	0.00347531	0.12426555	0.12971186	0.0209362	0.7409745
9584	Station 10, 3/93	0.00157002	0.04111969	0.0475551	0.0095184	0.2647074
9585	Station 11, 3/93	0.0013987	0.0606035	0.04802475	0.0104231	0.2580032
9586	Station 12, 3/93	0.00044263	0.02207424	0.02149981	0.0080077	0.1112548
9587	Station 14, 3/93	0.00051347	0.00678987	0.01119745	0.0041609	0.0808584
9611	Station 17, 3/93	0.0007414	0.03338389	0.02442495	0.0078971	0.1722132
9588	Station 20, 3/93	0.00067247	0.02381985	0.02587171	0.0065369	0.1259635
9589	Station 21, 3/93	0.00096876	0.03042703	0.03099678	0.0056587	0.0006476
9590	Station 26, 3/93	0.00088139	0.00679378	0.02098473	0.003433	0.1007167
9535	Sta. 31, 1/93, Ho	0.002094	0.16237131	0.09205643	0.0255493	0.4290773
9539	Sta. 36, 1/93	0.00064593	0.05152617	0.03110771	0.0082364	0.1330676
9538	Sta. 56, 1/93, Ho	0.00217527	0.26912181	0.15806747	0.043008	0.5698333
9536	Sta. 57, 1/93	0.00041918	0.03541076	0.02728822	0.0091716	0.585425
						0883PH
9606	Sta. 7A, 3/93, di	0.00191019	0.06225814	0.08659287	0.0127747	0.4510524
9534	Sta. 31, 1/93, Di	0.00164657	0.14375714	0.0778001	0.0196005	0.3287829
9537	Sta. 56, 1/93, Di	0.00171092	0.19563691	0.10098497	0.0246584	0.3836152
9163	Sta. 57, 10/27/9	0.0002549	0.01713813	0.01357635	0.0097181	0.0572485

Appendix G. Newark Bay all chem/toxicity contd.						
Lab Number:	GC/MS Number:	Analysis date	Submitter no.	% toc	%toc/100	Naphthalene ng/g
9561	0902PH	1/26/94	Site 1	2	0.02	420
9562	0976PH	6/2/94	Site 3	5	0.05	430
9563	0977PH	6/2/94	Site 5	6.1	0.061	320
9593	0990PH	6/8/94	Site 7A	5.8	0.058	370
9594	0887PH	1/20/94	Site 7B	2.4	0.024	250
9595	0898PH	1/26/94	Site 7C	2.3	0.023	250
9596	0899PH	1/26/94	Site 8A	2.4	0.024	310
9597	0900PH	1/26/94	Site 8B	2.4	0.024	250
			Ave. 10	4.2	0.04	266.67
			Site 11	5.1	0.051	370
			Site 12	1.7	0.017	120
9565	0980PH	6/2/94	Site 14	4.3	0.043	630
9566	0989PH	6/8/94	Site 17	2.4	0.024	350
9567	0979PH	6/2/94	Site 20	1.7	0.017	570
9598	0901PH	2/2/94	Site 21	1.5	0.015	600
9568	0988PH	6/8/94	Site 26	2.2	0.022	200
9569	0978PH	6/2/94	Site 31	2.1	0.021	190
9570	0991PH	6/8/94	Site 36	2.4	0.024	160
9526	0881PH	1/10/94	Site 56	2.5	0.025	120
9529b	0884PH	1/10/94	Site 57	0.47	0.0047	39
9528	0883PH	1/10/94				
9527	0882PH	1/10/94				
			1941A			400
			1941A			380
SRM Rep 1	0992PH	6/8/94	1941A			400
SRM Rep 2	0993PH	6/8/94	PC1			47.4646
SRM Rep 3	0994PH	6/8/94	PC2			61.3302
PC1	0975PH	6/2/94	MS1			390
PC2	0987PH	6/8/94	MS2			270
MS1	0974PH	6/2/94	MB1			11.7572
MS2	0986PH	6/8/94	MB2			8.3604
MB1	0973PH	6/2/94	PB1			0
MB2	0985PH	6/8/94	PB2			29.303
PB1	0972PH	6/2/94	PC1			15
PB2	0984PH	6/8/94				

Appendix G. Newark Bay all chem/toxicity contd.			
Lab Number:	Submitter no.	Benzo(b)thiophene	2-Methyl naphthalene
		(1/2mdl), 1/2mdl, ng/g	1/2mdl, ng/g
9561	Site 1	8	1400
9562	Site 3	50	360
9563	Site 5	50	220
9593	Site 7A	50	290
9594	Site 7B	10	300
9595	Site 7C	10	180
9596	Site 8A	11	200
9597	Site 8B	12	230
	Ave. 10	65.44	213.9
	Site 11	50	200
	Site 12	20	62.1
9565	Site 14	50	260
9566	Site 17	7	32
9567	Site 20	20	150
9598	Site 21	50	200
9568	Site 26	20	78.416
9569	Site 31	7	110
9570	Site 36	7	140
9526	Site 56	6	100
9529b	Site 57	0.5	14
9528			
9527			
	1941A	29.2756	220
	1941A	23.8318	210
SRM Rep 1	1941A	20.6338	200
SRM Rep 2	PC1	2	59.321
SRM Rep 3	PC2	2	70.2892
PC1	MS1	380	540
PC2	MS2	260	300
MS1	MB1	2	5.425
MS2	MB2	2	5.4882
MB1	PB1	0	0
MB2	PB2	10	10
PB1	PC1	1	44
PB2			

Appendix G. Newark Bay all chem/toxicity contd.				
Lab Number:	Submitter no.	1-Methyl-naphthalene 1/2mdl, ng/g	Biphenyl 1/2mdl, ng/g	2,6-/ 2,7-Dimethyl-naphthalene, 1/2mdk, ng/g
9561	Site 1	2200	130	850
9562	Site 3	260	120	230
9563	Site 5	150	50	220
9593	Site 7A	110	50	50
9594	Site 7B	180	66	140
9595	Site 7C	77	46	15
9596	Site 8A	78	50	39
9597	Site 8B	130	51	52
	Ave. 10	111.53	20	62
	Site 11	130	50	170
	Site 12	20	20	180
9565	Site 14	140	110	170
9566	Site 17	49	48	26
9567	Site 20	94.578	57.11	66
9598	Site 21	130	50	150
9568	Site 26	20	20	20
9569	Site 31	44	23	37
9570	Site 36	72	30	32
9526	Site 56	32	19	13
9529b	Site 57	6	9	5
9528				
9527				
	1941A	90.3906	67.5532	140
	1941A	97.7296	61.3412	140
SRM Rep 1	1941A	83.1484	65.3144	150
SRM Rep 2	PC1	37.2004	25.8582	34
SRM Rep 3	PC2	38.1146	43.9196	61
PC1	MS1	550	380.398	790
PC2	MS2	300	360	740
MS1	MB1	2	2	2
MS2	MB2	2	2	2
MB1	PB1	0	28.179	10
MB2	PB2	10	10	71.888
PB1	PC1	22	11	0.5
PB2				

Appendix G. Newark Bay all chem/toxicity contd.					
Lab Number:	Submitter no.	Acenaphthylene	Acenaphthene	Fluorene	Dibenzothiophene
		1/2mdl, ng/g	1/2mdl, ng/g	1/2mdl, ng/g	1/2mdl, ng/g
9561	Site 1	280	1800	4000	1900
9562	Site 3	50	900	880	430
9563	Site 5	50	240	240	179.9
9593	Site 7A	50	200	260	170
9594	Site 7B	28	210	260	160
9595	Site 7C	51	160	230	110
9596	Site 8A	45	170	200	110
9597	Site 8B	56	250	320	210
	Ave. 10	20	43.99	61.34	27.63
	Site 11	50	120	190	50
	Site 12	20	11.004	49.864	20
9565	Site 14	50	220	260	160
9566	Site 17	14	180	140	25
9567	Site 20	64.046	330	320.222	170
9598	Site 21	50	200	130	220
9568	Site 26	20	20	50.544	55.126
9569	Site 31	22	110	130	50
9570	Site 36	23	56	93	43
9526	Site 56	36	41	110	36
9529b	Site 57	3.5	10	11	10
9528					
9527					
	1941A	20.819	27.2312	73.01	41.1288
	1941A	20.771	28.0662	67.7868	41.991
SRM Rep 1	1941A	22.6054	29.0584	73.4116	33.7054
SRM Rep 2	PC1	2	11.7422	21.671	17.1184
SRM Rep 3	PC2	4.6582	15.8232	28.2296	20.4504
PC1	MS1	400	410	440	400
PC2	MS2	370	410	410	290
MS1	MB1	2	2	2	2
MS2	MB2	2	2	2	10.819
MB1	PB1	10	10	26.626	10
MB2	PB2	10	10	10	10
PB1	PC1	10	1.5	14	36
PB2					

Appendix G. Newark Bay all chem/toxicity contd.					
Lab Number:	Submitter no.	Phenanthrene	Anthracene	Fluoranthene	Pyrene
		1/2mdl, ng/g	1/2mdl, ng/g	1/2mdl, ng/g	1/2mdl, ng/g
9561	Site 1	25100	2300	22800	29300
9562	Site 3	7400	2200	13900	12000
9563	Site 5	2400	420	6200	5600
9593	Site 7A	2200	430	4800	4400
9594	Site 7B	2000	390	5100	4800
9595	Site 7C	740	390	3300	3000
9596	Site 8A	800	460	3300	3100
9597	Site 8B	1800	580	4800	5400
	Ave. 10	416.67	126.67	1400	1233.27
	Site 11	1400	370	4100	3500
	Site 12	110	43.11	340	310
9565	Site 14	1600	970	5900	4200
9566	Site 17	240	470	2500	2000
9567	Site 20	1800	960	5600	4600
9598	Site 21	770	630	5400	5700
9568	Site 26	260	150	1200	1100
9569	Site 31	550	400	900	680
9570	Site 36	520	310	1000	1000
9526	Site 56	480	490	640	700
9529b	Site 57	26	31	100	150
9528					
9527					
	1941A	250	95.2534	460	380
	1941A	260	98.571	460	360
SRM Rep 1	1941A	250	82.0958	459.706	390
SRM Rep 2	PC1	190	23.7292	410	330
SRM Rep 3	PC2	200	30.393	330	330
PC1	MS1	420	380	460	420
PC2	MS2	340	290	360	350
MS1	MB1	6.4092	2	11.8636	8.0404
MS2	MB2	2	5.7188	9.7008	7.2562
MB1	PB1	10	10	10	10
MB2	PB2	10	10	10	10
PB1	PC1	290	10	440	460
PB2					

Appendix G. Newark Bay all chem/toxicity contd.				
Lab Number:	Submitter no.	Benzo(a)-anthracene	Chrysene	Benzo(b)-fluoranthene
		1/2mdl, ng/g	1/2mdl, ng/g	1/2mdl, ng/g
9561	Site 1	11300	14200	8000
9562	Site 3	7500	7400	7500
9563	Site 5	3000	3600	3400
9593	Site 7A	2600	3000	2900
9594	Site 7B	2000	2500	2600
9595	Site 7C	790	1300	1200
9596	Site 8A	1000	1500	1300
9597	Site 8B	1800	2800	1900
	Ave. 10	613.31	733.33	819.99
	Site 11	1800	2200	2400
	Site 12	220	250	190
9565	Site 14	3400	3600	3800
9566	Site 17	770	670	720
9567	Site 20	3400	3100	2900
9598	Site 21	2900	3100	2500
9568	Site 26	600	650	600.372
9569	Site 31	640	760	160
9570	Site 36	660	810	850
9526	Site 56	410	540	650
9529b	Site 57	58	79	88
9528				
9527				
	1941A	280	350	610
	1941A	270	350	670.244
SRM Rep 1	1941A	290	380	700
SRM Rep 2	PC1	190	260	270
SRM Rep 3	PC2	169.5394	230.446	250
PC1	MS1	400	420.156	460
PC2	MS2	350	360	440
MS1	MB1	2	5.7898	6.6024
MS2	MB2	2	5.3004	7.0114
MB1	PB1	10	10	10
MB2	PB2	10	10	10
PB1	PC1	230	380	350
PB2				

Appendix G. Newark Bay all chem/toxicity contd.				
Lab Number:	Submitter no.	Benzo(k)-fluoranthene	Benzo(e)pyrene	Benzo(a)pyrene
		1/2mdl, ng/g	1/2mdl, ng/g	1/2mdl, ng/g
9561	Site 1	7700	8000	9800
9562	Site 3	6800	6800	7900
9563	Site 5	3300	3600	3600
9593	Site 7A	2900	2900	2900
9594	Site 7B	2300	2700	2100
9595	Site 7C	1300	1400	1000
9596	Site 8A	1400	1600	1300
9597	Site 8B	2000	2100	1700
	Ave. 10	786.66	816.67	750
	Site 11	2100	2200	2000
	Site 12	220	269.578	250
9565	Site 14	3800	3800	4000
9566	Site 17	670	770	780
9567	Site 20	3000	2600	3200
9598	Site 21	2800	2600	2800
9568	Site 26	680	560	540
9569	Site 31	270	480	450
9570	Site 36	760	790	740
9526	Site 56	390	600	550
9529b	Site 57	92	88	77
9528				
9527				
	1941A	490	550.328	400
	1941A	420	530	370
SRM Rep 1	1941A	580	630	400
SRM Rep 2	PC1	260	270	210
SRM Rep 3	PC2	220	230	190
PC1	MS1	480	460	460
PC2	MS2	420	420	409.874
MS1	MB1	7.8326	6.764	5.9786
MS2	MB2	8.15	2	8.3128
MB1	PB1	10	10	10
MB2	PB2	10	32.444	10
PB1	PC1	380	320	250
PB2				

Appendix G. Newark Bay all chem/toxicity contd.				
Lab Number:	Submitter no.	Perylene	Indeno-123cd pyrene	Dibenz(a,h)-anthracene
		1/2mdl, ng/g	1/2mdl, ng/g	1/2mdl, ng/g
9561	Site 1	2200	7000	810
9562	Site 3	2000	6100	1300
9563	Site 5	740	2700	570
9593	Site 7A	640	2200	500
9594	Site 7B	660	2600	410
9595	Site 7C	750	1700	460
9596	Site 8A	820	1700	500
9597	Site 8B	920	2000	540
	Ave. 10	196.67	563.33	166.7
	Site 11	580	1700	520
	Site 12	210	180	64.666
9565	Site 14	1300	2700	530
9566	Site 17	760	1300	250
9567	Site 20	859.616	2100	700
9598	Site 21	680	1800	370
9568	Site 26	140	360	100
9569	Site 31	440	630	210
9570	Site 36	300	590	120
9526	Site 56	290	360	120
9529b	Site 57	13	47	2
9528				
9527				
	1941A	269.56	510	140
	1941A	250	480	150
SRM Rep 1	1941A	280	580	180
SRM Rep 2	PC1	110	210	41.7132
SRM Rep 3	PC2	100	180	48.7332
PC1	MS1	420	460	460
PC2	MS2	400	430	440
MS1	MB1	2	5.9982	2
MS2	MB2	7.476	5.7294	5.4408
MB1	PB1	10	10	10
MB2	PB2	10	10	10
PB1	PC1	160	190	28
PB2				

Appendix G. Newark Bay all chem/toxicity contd.					
Lab Number:	Submit. no.	Benzo(g,h,i)-perylene 1/2mdl, ng/g	Total G-eq analyzed	total LMPAH, ng/g	total HMPAH, ng/g
9561	Site 1	6000	5	40388	127110
9562	Site 3	5200	0.2	13310	84400
9563	Site 5	2400	0.2	4539.9	38710
9593	Site 7A	2100	0.2	4230	31840
9594	Site 7B	2100	5	3994	29870
9595	Site 7C	1100	5	2259	17300
9596	Site 8A	1100	5	2473	18620
9597	Site 8B	1400	5	3941	27360
	Ave. 10	470	0.5	1435.83	8549.93
	Site 11	1400	0.2	3150	24500
	Site 12	140	0.5	676.078	2644.244
9565	Site 14	2400	0.2	4620	39430
9566	Site 17	890	5	1581	12080
9567	Site 20	1900	0.5	4601.956	33959.616
9598	Site 21	1400	0.2	3180	32050
9568	Site 26	380	0.5	914.086	6910.372
9569	Site 31	480	5	1673	6100
9570	Site 36	370	5	1486	7990
9526	Site 56	270	5	1483	5520
9529b	Site 57	13	5	165	807
9528					
9527					
	1941A	440	5	1454.6618	4879.888
	1941A	430	5	1430.0886	4740.244
SRM Rep 1	1941A	510	5	1409.9732	5379.706
SRM Rep 2	PC1	190	5	472.105	2751.7132
SRM Rep 3	PC2	170.4846	5	576.208	2449.2032
PC1	MS1	450	5	5480.398	5350.156
PC2	MS2	409.69	5	4340	4789.564
MS1	MB1	5.6154	5	41.5914	70.485
MS2	MB2	5.3214	5	46.3864	73.6992
MB1	PB1	10	1	114.805	120
MB2	PB2	10	1	201.191	142.444
PB1	PC1	97	5	455	3285
PB2					

Appendix G. Newark Bay all chem/toxicity contd.					
Lab Number:	Submitter no.	sum total PAH, ng/g	acenaphthene, ng/goc	acenaphthene, ug/goc	phenanthrene, ng/goc
9561	Site 1	167498	90000	90	1255000
9562	Site 3	97710	18000	18	148000
9563	Site 5	43249.9	3934.43	3.93	39344.26
9593	Site 7A	36070	3448.28	3.45	37931.03
9594	Site 7B	33864	8750	8.75	83333.33
9595	Site 7C	19559	6956.52	6.96	32173.91
9596	Site 8A	21093	7083.33	7.08	33333.33
9597	Site 8B	31301	10416.67	10.42	75000
	Ave. 10	9985.76	1047.4	1.05	9920.83
	Site 11	27650	2352.94	2.35	27450.98
	Site 12	3320.322	647.29	0.65	6470.59
9565	Site 14	44050	5116.28	5.12	37209.3
9566	Site 17	13661	7500	7.5	10000
9567	Site 20	38561.572	19411.76	19.41	105882.35
9598	Site 21	35230	13333.33	13.33	51333.33
9568	Site 26	7824.458	909.09	0.91	11818.18
9569	Site 31	7773	5238.1	5.24	26190.48
9570	Site 36	9476	2333.33	2.33	21666.67
9526	Site 56	7003	1640	1.64	19200
9529b	Site 57	972	2127.66	2.13	5531.91
9528					
9527					
	1941A	6334.5498			
	1941A	6170.3326			
SRM Rep 1	1941A	6789.6792			
SRM Rep 2	PC1	3223.8182			
SRM Rep 3	PC2	3025.4112			
PC1	MS1	10830.554			
PC2	MS2	9129.564			
MS1	MB1	112.0764			
MS2	MB2	120.0856			
MB1	PB1	234.805			
MB2	PB2	343.635			
PB1	PC1	3740			
PB2					

Appendix G. Newark Bay all chem/toxicity contd.					
Lab Number:	Submitter no.	phenanthrene, ug/goc	fluoranthene, ng/goc	fluoranthene, ug/goc	
9561	Site 1	1255	1140000	1140	
9562	Site 3	148	278000	278	
9563	Site 5	39.34	101639.34	101.64	
9593	Site 7A	37.93	82758.62	82.76	
9594	Site 7B	83.33	212500	212.5	
9595	Site 7C	32.17	143478.26	143.48	
9596	Site 8A	33.33	137500	137.5	
9597	Site 8B	75	200000	200	
	Ave. 10	9.92	33333.33	33.33	
	Site 11	27.45	80392.16	80.39	
	Site 12	6.47	20000	20	
9565	Site 14	37.21	137209.3	137.21	
9566	Site 17	10	104166.67	104.17	
9567	Site 20	105.88	329411.76	329.41	
9598	Site 21	51.33	360000	360	
9568	Site 26	11.82	54545.45	54.55	
9569	Site 31	26.19	42857.14	42.86	
9570	Site 36	21.67	41666.67	41.67	
9526	Site 56	19.2	25600	25.6	
9529b	Site 57	5.53	21276.6	21.28	
9528					
9527					

Appendix H. Concentrations of dioxins and furans (pg/g).				
NFCR	GC/MS Set:			
Number:	DF07, Inj.No.		Submitter Number, Sample Location:	
9561	49		Site 1 Upper Passaic R	
9562	47		Site 3 Passaic River	
9563	46		Site 5 Lower Passaic R, Upstream of Pt Source	
9593	40		Site 7A Lower Passaic R Pt Source	
9593	GC/QMS		Site 7A Lower Passaic R Pt Source	
9594-1	41		Site 7B Lower Passaic R Pt Source	Replicate 1
9594-2	42		Site 7B Lower Passaic R Pt Source	Replicate 2
9594-3	44		Site 7B Lower Passaic R Pt Source	Replicate 3
9595	45		Site 7C Lower Passaic R Pt Source	
9596	37		Site 8A Lower Passaic R Pt Source	
9597	39		Site 8B Lower Passaic R Pt Source	
9564-1	34		Site 10 Lower Passaic R Below Pt Source	Replicate 1
9564-2	35		Site 10 Lower Passaic R Below Pt Source	Replicate 2
9564-3	36		Site 10 Lower Passaic R Below Pt Source	Replicate 3
9565	32		Site 11 Lower Passaic R Below Pt Source	
9566	27		Site 12 Hackensack R, N of Berry's Creek	
9567	26		Site 14 Hackensack R, N of Berry's Creek	
9598	25		Site 17 Hackensack R,S of Berry's Ck, N of	
9568	24		Site 20 Mouth of Hackensack River, Upper Newark Bay	
9569	31		Site 21 Mouth of Passaic River, Upper Newark Bay	
9570	22		Site 26 Upper Newark Bay	
9526	17		Site 31 Upper-Mid Newark Bay	
9529	21		Site 36 Lower-Mid- Newark Bay	
9528	20		Site 56 Lower Newark Bay, Port Richmond,	
9527	19		Site 57 Upper New York Harbor	
9527	GC/QMS		Site 57 Upper New York Harbor	
QUALITY ASSURANCE SAMPLES				
Proc Blank 1	GC/QMS		Procedural Blank 1	
Proc Blank 1	5		Procedural Blank 1	
Proc Blank 2	6		Procedural Blank 2	
Matrix Blank 1	GC/QMS		356C Pond Sediment Blank 1	
Matrix Blank 1	7		356C Pond Sediment Blank 1	
Matrix Blank 2	9		356C Pond Sediment Blank 2	
Matrix Spike 1	GC/QMS		356C Pond Sediment Spike 1 50pg/g;250pg/g Cl◊d8Ÿ	
Matrix Spike 2	GC/QMS		356C Pond Sediment Spike 2 50pg/g;250pg/g Cl◊d8Ÿ	
Matrix Spike 1	10		356C Pond Sediment Spike 1 50pg/g;250pg/g Cl◊d8Ÿ	
Matrix Spike 2	11		356C Pond Sediment Spike 2 50pg/g;250pg/g Cl◊d8Ÿ	
Pos Ctrl 1	GC/QMS		235C Positive Control Sediment from Saginaw Bay	
Pos Ctrl 1	12		235C Positive Control Sediment 1 from Saginaw Bay	
Pos Ctrl 2	14		235C Positive Control Sediment 2 from Saginaw Bay	
NIST 1941A	GC/QMS		NIST Standard Reference Material 1941A	
NIST 1941A-1	15		NIST Standard Reference Material 1941A-1	
NIST 1941A-2	16		NIST Standard Reference Material 1941A-2	
	PIA			
	24858	2		
	24859	4		

Appendix H. Concentrations of dioxins and furans (pg/g) contd.							
NFCR	GC/MS Set:	DIOXINS					
Number:	DF07, Inj.No.	2,3,7,8-		1,2,3,7,8-		1,2,4,7,8-	
		Tetrachloro-DD		Pentachloro-DD		Pentachloro-DD	
9561	49	99		2.2	NQ	1.3	
9562	47	270		4.4	NQ	1.1	NQ
9563	46	450		7.8		0.5	ND
9593	40	390		8.1		13	
9593	GC/QMS	480		8		15	
9594-1	41	430		8.3		9.0	
9594-2	42	340		10		8.8	
9594-3	44	360		8.2		12	
9595	45	620		12		23	
9596	37	440		10		13	
9597	39	300		7.0		8.5	
9564-1	34	310		7.3		9.4	
9564-2	35	350		9.1		13	
9564-3	36	430		7.5		8.6	
9565	32	280		9.1	NQ	12	
9566	27	7.4		0.5	NQ	0.8	
9567	26	62		3.3		3.4	
9598	25	29		1.0	NQ	1.4	NQ
9568	24	38		1.2	NQ	1.6	NQ
9569	31	140		1.9	NQ	1.9	
9570	22	470		6.5		8.6	
9526	17	62		3	NQ	4.1	
9529	21	55		4.0		5.4	
9528	20	30		3.0		4.0	
9527	19	3.6		0.7		0.8	NQ
9527	GC/QMS	2		1	ND	3	
QUALITY ASSURANCE SAMPLES							
Proc Blank 1	GC/QMS	2	ND	1	ND	9	ND
Proc Blank 1	5	0.4	NQ	0.3	ND	0.3	ND
Proc Blank 2	6	0.3	NQ	0.3	ND	0.3	ND
Matrix Blank 1	GC/QMS	2	ND	4	ND	3	NQ
Matrix Blank 1	7	0.3	ND	0.5	NQ	0.5	NQ
Matrix Blank 2	9	0.4		0.5	ND	0.5	NQ
Matrix Spike 1	GC/QMS	64		46		66	
Matrix Spike 2	GC/QMS	64		48		66	
Matrix Spike 1	10	47		46		38	
Matrix Spike 2	11	45		45		37	
Pos Ctrl 1	GC/QMS	19		12		17	
Pos Ctrl 1	12	25		14		13	
Pos Ctrl 2	14	21		14		14	
NIST 1941A	GC/QMS	2	NQ	3	NQ	10	
NIST 1941A-1	15	1.9		5.6		5.3	
NIST 1941A-2	16	1.9		5.1		5.0	
	PIA						
	24858	32					
	24859	24					

Appendix H. Concentrations of dioxins and furans (pg/g) contd.							
NFCR Number:	GC/MS Set: DF07, Inj.No.	1,2,3,4,7,8-Hexachloro-DD		1,2,3,6,7,8-Hexachloro-DD		1,2,3,7,8,9-Hexachloro-DD	
9561	49	1.6		7.5		4.3	NQ
9562	47	4.1	NQ	33		4.5	NQ
9563	46	8.0		44		26	
9593	40	7.7		29		20	
9593	GC/QMS	8		57		28	
9594-1	41	9.6		29		25	
9594-2	42	11		37		39	
9594-3	44	8.4		31		25	
9595	45	9.7		39		29	
9596	37	9.7		38		29	
9597	39	8.2		32		22	
9564-1	34	7.1		34		22	
9564-2	35	7.8		34		24	
9564-3	36	7.3		33		24	
9565	32	8.3		31		24	
9566	27	0.7	NQ	2.9		2.0	
9567	26	3.5		17		12	
9598	25	1.2		4.1		2.8	
9568	24	1.2		6.2		4.0	
9569	31	2.3	NQ	8.0		5.9	NQ
9570	22	5.5		32		21	
9526	17	3.2		15		11	
9529	21	4.1		17		13	
9528	20	3.2		16		12	
9527	19	0.7	NQ	2.4	NQ	1.4	NQ
9527	GC/QMS	1	NQ	3		0.9	NQ
QUALITY ASSURANCE SAMPLES							
Proc Blank 1	GC/QMS	1	ND	0.9	ND	1	ND
Proc Blank 1	5	0.4	ND	0.3	ND	0.4	ND
Proc Blank 2	6	0.4	ND	0.8	NQ	0.4	ND
Matrix Blank 1	GC/QMS	2	ND	4	ND	4	ND
Matrix Blank 1	7	0.9	NQ	1.8		1.9	
Matrix Blank 2	9	1.0	NQ	1.6	NQ	1.7	
Matrix Spike 1	GC/QMS	80		69		76	
Matrix Spike 2	GC/QMS	81		69		76	
Matrix Spike 1	10	47		44		48	
Matrix Spike 2	11	44		46		46	
Pos Ctrl 1	GC/QMS	0.5	NQ	100		40	
Pos Ctrl 1	12	7.5		43		24	
Pos Ctrl 2	14	8.3		46		25	
NIST 1941A	GC/QMS	14		37		32	
NIST 1941A-1	15	9.1		21		23	
NIST 1941A-2	16	9.6		21		23	

Appendix H. Concentrations of dioxins and furans (pg/g) contd.							
NFCR	GC/MS Set:					FURANS	
Number:	DF07, Inj.N	1,2,3,4,6,7,8-		Octa		2,3,7,8-	
		Heptachloro-DD		chloro-DD		Tetrachloro-DF	
9561	49	180		1,900		71	
9562	47	450		4,800		160	
9563	46	720		7,100		190	
9593	40	590		6,400		170	
9593	GC/QMS	700		5,960		190	
9594-1	41	740		7,000		220	
9594-2	42	860		9,700		270	
9594-3	44	660		6,700		170	
9595	45	790		8,100		230	
9596	37	870		8,700		230	
9597	39	780		7,700		170	
9564-1	34	630		6,700		250	
9564-2	35	660		6,300		230	
9564-3	36	610		5,900		220	
9565	32	660		7,400		220	
9566	27	63		1,200		10	
9567	26	400		5,000		89	
9598	25	71		1,100		29	
9568	24	110		1,400		41	
9569	31	140		1,800		140	
9570	22	620		5,900		370	
9526	17	310		3,100		92	
9529	21	350		3,600		66	
9528	20	410		4,800		56	
9527	19	42		510		9.5	
9527	GC/QMS	55		580		7	
QUALITY ASSURANCE SAMPLES							
Proc Blank 1	GC/QMS	0.7	ND	3		0.7	ND
Proc Blank 1	5	1.0	NQ	17		1.3	
Proc Blank 2	6	1.3		16		0.6	NQ
Matrix Blank 1	GC/QMS	79		2,610		0.5	ND
Matrix Blank 1	7	44		1,400		1	NQ
Matrix Blank 2	9	46		1,500		1	NQ
Matrix Spike 1	GC/QMS	150		2,390		75	
Matrix Spike 2	GC/QMS	150		2,390		74	
Matrix Spike 1	10	93		1,800		46	
Matrix Spike 2	11	94		1,900		44	
Pos Ctrl 1	GC/QMS	980		8,940		720	
Pos Ctrl 1	12	840		7,400		1,400	
Pos Ctrl 2	14	840		7,100		410	
NIST 1941A	GC/QMS	710		7,670		130	
NIST 1941A-1	15	520		6,400		120	
NIST 1941A-2	16	560		7,100		130	

Appendix H. Concentrations of dioxins and furans (pg/g) contd.

NFCR Number:	GC/MS Set: DF07, Inj.No.	1,2,3,7,8-Pentachloro-DF		2,3,4,7,8-Pentachloro-DF		1,2,3,4,7,8-Hexachloro-DF	
9561	49	2.8		6.2		19	
9562	47	8.7	NQ	36		120	
9563	46	14		33		220	
9593	40	12		27		170	
9593	GC/QMS	13		29		200	
9594-1	41	13		29		230	
9594-2	42	14		28		220	
9594-3	44	13		31		210	
9595	45	19		41		370	
9596	37	16		43		350	
9597	39	11		25		170	
9564-1	34	23		47		340	
9564-2	35	22		52		460	
9564-3	36	22		43		360	
9565	32	18		40		380	
9566	27	1.3		2.0		16	
9567	26	9.0		22		230	
9598	25	2.7		5.5		45	
9568	24	5.4		8.4		75	
9569	31	5.2		8.4		69	
9570	22	15		36		200	
9526	17	10		15		95	
9529	21	7.5		14		90	
9528	20	6.4		9.4		32	
9527	19	1.1		1.4		4.3	
9527	GC/QMS	0.8	NQ	0.3	NQ	3	
QUALITY ASSURANCE SAMPLES							
Proc Blank 1	GC/QMS	2	ND	2	ND	0.8	NQ
Proc Blank 1	5	0.4		0.4		1.5	
Proc Blank 2	6	0.3	ND	0.3	ND	0.9	
Matrix Blank 1	GC/QMS	1	ND	0.9	ND	2	ND
Matrix Blank 1	7	0.3	ND	0.5	NQ	0.7	NQ
Matrix Blank 2	9	0.4	NQ	0.5	NQ	1.1	
Matrix Spike 1	GC/QMS	61		63		70	
Matrix Spike 2	GC/QMS	62		65		69	
Matrix Spike 1	10	45		46		46	
Matrix Spike 2	11	43		43		45	
Pos Ctrl 1	GC/QMS	480		320		360	
Pos Ctrl 1	12	730		580		660	
Pos Ctrl 2	14	190		150		220	
NIST 1941A	GC/QMS	210		57		440	
NIST 1941A-1	15	140		48		320	
NIST 1941A-2	16	150		51		350	

Appendix H. Concentrations of dioxins and furans (pg/g) contd.							
NFCR Number:	GC/MS Set: DF07, Inj.No.	1,2,3,6,7,8-Hexachloro-DF		1,2,3,7,8,9-Hexachloro-DF		2,3,4,6,7,8-Hexachloro-DF	
9561	49	5.5		0.4	ND	4.2	
9562	47	29		0.4	ND	2.2	
9563	46	47		0.9	NQ	9.4	
9593	40	40		1.5		19	
9593	GC/QMS	28		8	NQ	5	NQ
9594-1	41	49		1.2	NQ	9.8	
9594-2	42	47		1.2	NQ	23	
9594-3	44	45		1.1		9.5	
9595	45	74		1.2		34	
9596	37	68		1.4		12	
9597	39	38		1.2		9.2	
9564-1	34	70		1.5		28	
9564-2	35	84		1.5		34	
9564-3	36	71		1.4		29	
9565	32	72		1.5		30	
9566	27	3.1		0.4	ND	1.8	
9567	26	36		0.8		14	
9598	25	7.6		0.4	ND	3.1	
9568	24	14		0.4	ND	5.6	
9569	31	12		0.7	NQ	5.8	
9570	22	35		1.2	NQ	18	
9526	17	21		1.5		9.5	
9529	21	17		0.7		9.7	
9528	20	8.9		0.4	ND	6.4	
9527	19	1.2	NQ	0.4	ND	1.2	
9527	GC/QMS	0.9	NQ	5	NQ	0.5	NQ
QUALITY ASSURANCE SAMPLES							
Proc Blank 1	GC/QMS	0.4	ND	2	NQ	1	NQ
Proc Blank 1	5	0.6		0.4	ND	0.5	NQ
Proc Blank 2	6	0.5	NQ	0.4	ND	0.4	ND
Matrix Blank 1	GC/QMS	2	ND	2	ND	1	ND
Matrix Blank 1	7	0.4	NQ	0.4	ND	0.4	NQ
Matrix Blank 2	9	0.8		0.4	ND	0.5	NQ
Matrix Spike 1	GC/QMS	63		64		69	
Matrix Spike 2	GC/QMS	62		64		69	
Matrix Spike 1	10	46		45		56	
Matrix Spike 2	11	48		44		46	
Pos Ctrl 1	GC/QMS	69		0.4	NQ	9	
Pos Ctrl 1	12	120		9.8		60	
Pos Ctrl 2	14	51		4.2		26	
NIST 1941A	GC/QMS	100		54		66	
NIST 1941A-1	15	81		31		16	
NIST 1941A-2	16	90		34		18	

Appendix H. Concentrations of dioxins and furans (pg/g) contd.							
NFCR Number:	GC/MS Set: DF07, Inj.No.	1,2,3,4,6,7,8-Heptachloro-DF		1,2,3,4,7,8,9-Heptachloro-DF		Octa chloro-DF	
9561	49	82		5.3		210	
9562	47	480		19		770	
9563	46	940		26		1,300	
9593	40	830		21		1,200	
9593	GC/QMS	600		28		1,580	
9594-1	41	1,100		26		1,400	
9594-2	42	1,000		27		1,300	
9594-3	44	910		26		1,300	
9595	45	1,600		41		2,000	
9596	37	1,500		36		1,800	
9597	39	800		24		1,200	
9564-1	34	1,500		34		2,000	
9564-2	35	1,800		42		2,100	
9564-3	36	1,600		35		1,900	
9565	32	1,600		37		2,100	
9566	27	95		2.4		180	
9567	26	950		24		1,500	
9598	25	190		4.8		310	
9568	24	320		8.7		490	
9569	31	280		6.6		430	
9570	22	750		21		1,200	
9526	17	510		18		970	
9529	21	380		12		640	
9528	20	190		6.7		330	
9527	19	23		1.0		44	
9527	GC/QMS	14		2	NQ	33	
QUALITY ASSURANCE SAMPLES							
Proc Blank 1	GC/QMS	0.7	ND	0.6	ND	1	ND
Proc Blank 1	5	1.7		0.7	NQ	3.7	
Proc Blank 2	6	1.2		0.4	NQ	2.9	
Matrix Blank 1	GC/QMS	3		2	ND	10	
Matrix Blank 1	7	3.8		0.5	NQ	8.1	
Matrix Blank 2	9	3.8		0.6		8.2	
Matrix Spike 1	GC/QMS	60		60		360	
Matrix Spike 2	GC/QMS	60		61		350	
Matrix Spike 1	10	55		48		240	
Matrix Spike 2	11	52		46		240	
Pos Ctrl 1	GC/QMS	940		79		3,200	
Pos Ctrl 1	12	1,400		70		2,100	
Pos Ctrl 2	14	1,300		54		2,200	
NIST 1941A	GC/QMS	440		370		7,080	
NIST 1941A-1	15	450		260		5,300	
NIST 1941A-2	16	500		290		5,800	

Appendix I. H4IIE rat hepatoma bioassay.							
Table 1.	(F1) - Whole Extract						
NFCRC Sample ID	Field ID	Site Description		(pg/g)	(SD)	CV	
9561 (10/25)	Station #1	Upper Passaic R.		380	41	11%	
9562 (10/25)	Station #3	Passaic R., upstream of point source		40000	5800	15%	
9563 (10/25)	Station #5	Lower Passaic R., immediately upstream		42000	7500	18%	
9593 (10/25)	Station #7A	Lower Passaic R., point source		12000	1500	13%	
9594-1 (10/25)	Station #7B	Lower Passaic R., point source		8300	1200	14%	
9594-2 (10/25)	Station #7B	Lower Passaic R., point source		8800	1700	19%	
			Sample Mean	8500	330	4%	
9595 (10/25)	Station #7C	Lower Passaic R., point source		6700	1800	27%	
			Site Mean	9100	2600	29%	
9596 (10/25)	Station #8A	Lower Passaic R., point source		42000	5400	13%	
9597 (10/25)	Station #8B	Lower Passaic R., point source		8900	1400	16%	
9597 (10/25)	Station #8B	Lower Passaic R., point source		27000	5000	19%	
9597 (10/25)	Station #8B	Lower Passaic R., point source		93000	8900	10%	
			Site Mean	43000	36000	84%	
9564-1 (10/25)	Station # 10	Lower Passaic R., Immediately below point source		11000	1600	15%	
9564- 2 (10/25)	Station # 10	Lower Passaic R., immediately below point source		11000	1100	10%	
9564-3 (10/25)	Station # 10	Lower Passaic R., Immediately below point source		5900	710	12%	
			Sample Mean	9300	2900	31%	
9565 (10/25)	Station #11	Lower Passaic R., below point source		10000	1000	10%	
9566 (10/25)	Station #12	Hackensack R., North of Berry's Creek		500	67	13%	
9567 (10/25)	Station #14	Hackensack R., North of Berry's Creek		650	86	13%	
9598 (10/25)	Station #17	Hackensack R., North of Berry's Ck./ N. of Newark Bay		5000	520	10%	
9568 (10/25)	Station #20	Mouth, Hackensack R./Upper Newark Bay		710	48	7%	
9569 (10/25)	Station #21	Mouth, Passaic R./Upper Newark Bay		4500	860	19%	
9570 (10/25)	Station #26	Upper Newark Bay		3000	360	12%	
9526 (10/25)	Station #31	Upper/Mid Newark Bay		1700	210	12%	
9529 (10/25)	Station # 36	Lower/Mid Newark Bay		4200	430	10%	
9529 (10/25)	Station # 36	Lower/Mid Newark Bay		2900	290	10%	
9529 (10/25)	Station # 36	Lower/Mid Newark Bay		2500	300	12%	
			Sample Mean	3200	340	11%	
9528 (10/25)	Station #56	Lower Newark Bay, Port Richmond, Kill Van Kull		7100	840	12%	
9527 (10/25)	Station # 57	Upper New York Harbor		170	12	7%	
* Means were used for site averages						13%	Mean CV (precision)

Appendix I. H4IIE rat hepatoma bioassay contd.

Table 2. (F5) - PAH fraction.

NFCRC Sample ID	Field ID	Site Description		TCDD-EQ (pg/g)	(SD)	CV
9561 (12/6)	Station # 1	Upper Passaic R.		5800	1600	28%
9562 (12/6)	Station # 3	Passaic R., upstream of point source		6000	1600	27%
9563 (12/6)	Station # 5	Lower Passaic R., immediately upstream		22000	7600	35%
9593 (12/6)	Station # 7A	Lower Passaic R., point source		19000	3300	17%
9594-1 (12/6)	Station # 7B	Lower Passaic R., point source		5400	970	18%
9595 (12/6)	Station # 7C	Lower Passaic R., point source		5500	3500	64%
			Site Mean	10000	7900	79%
9596 (12/6)	Station # 8A	Lower Passaic R., point source		7200	2800	39%
9597 (12/6)	Station # 8B	Lower Passaic R., point source		7000	1200	17%
			Site Mean	7100	160	2%
9564-1 (12/6)	Station # 10	Lower Passaic R., immediately below point source		5000	1300	26%
9564-2(12/6)	Station # 10	Lower Passaic R., immediately below point source		5000	900	18%
9564-3 (12/6)	Station # 10	Lower Passaic R., immediately below point source		4500	1000	22%
			Sample Mean	4800	280	6%
9565 (12/6)	Station # 11	Lower Passaic R., below point source		21000	3800	18%
9566a (12/6)	Station # 12	Hackensack R., North of Berry's Creek		670	110	16%
9566b (12/6)	Station # 12	Hackensack R., North of Berry's Creek		1200	200	17%
9566c (12/6)	Station # 12	Hackensack R., North of Berry's Creek		64	18	28%
			Bioassay Mean	650	570	88%
9567 (12/6)	Station # 14	Hackensack R., North of Berry's Creek		18000	3300	18%
9598 (12/6)	Station # 17	Hackensack R., North of Berry's Ck./ N. of Newark Bay		4900	1200	24%
9568 (12/6)	Station # 20	Mouth, Hackensack R./Upper Newark Bay		11000	2200	20%
9569a (12/6)	Station # 21	Mouth, Passaic R./Upper Newark Bay		13000	2100	16%
9569b (12/6)	Station # 21	Mouth, Passaic R./Upper Newark Bay		8100	1700	21%
9569c (12/6)	Station # 21	Mouth, Passaic R./Upper Newark Bay		4600	860	18%
			Bioassay Mean	8500	3800	45%
9570 (12/6)	Station # 26	Upper Newark Bay		7000	1200	17%
9526 (12/6)	Station # 31	Upper/Mid Newark Bay		4500	3000	67%
9529 (12/6)	Station # 36	Lower/Mid Newark Bay		2000	440	22%
9528 (12/6)	Station # 56	Lower Newark Bay, Port Richmond, Kill Van Kull		2400	1300	54%
9527 (12/6)	Station # 57	Upper New York Harbor		87	23	26%
* Means were used for site averages						27% Mean CV (precision)

Appendix I. H4IIE rat hepatoma bioassay contd.

Table 3. (F7) - Bulk (>2-ortho-chloro-substituted) PCB fraction.

NFCRC Sample ID	Field ID	Site Description		TCDD-EQ (pg/g)	(SD)	CV	
9561 (3/7)	Station # 1	Upper Passaic R.		0.1	0.0	15%	
9562 (3/7)	Station # 3	Passaic R., upstream of point source		0.1	0.1	116%	
9563 (3/7)	Station # 5	Lower Passaic R., immediately uptream		0.0	0.0	671%	
9593 (3/7)	Station # 7A	Lower Passaic R., point source		0.2	0.1	48%	
9594 (3/7)	Station # 7B	Lower Passaic R., point source		0.2	0.0	19%	
9595 (3/7)	Station # 7C	Lower Passaic R., point source		1.4	0.2	14%	
			Site Mean	0.6	0.1	19%	
9596a (3/7)	Station # 8A	Lower Passaic R., point source		0.0	0.0	123%	
9596b (3/7)	Station # 8A	Lower Passaic R., point source		0.3	0.1	23%	
9596c (3/7)	Station # 8A	Lower Passaic R., point source		0.1	0.0	22%	
			Bioassay Mean	0.1	0.1	119%	
9597 (3/7)	Station # 8B	Lower Passaic R., point source		3.3	0.4	13%	
			Site Mean	1.7	2.2	131%	
9564 (3/7)	Station # 10	Lower Passaic R., immediately below point source		2.0	0.3	15%	
9565a (3/7)	Station # 11	Lower Passaic R., below point source		0.3	0.1	28%	
9565b (3/7)	Station # 11	Lower Passaic R., below point source		0.1	0.0	31%	
9565c (3/7)	Station # 11	Lower Passaic R., below point source		0.4	0.1	16%	
			Bioassay Mean	0.3	0.1	50%	
9566-1 (3/7)	Station # 12	Hackensack R., North of Berry's Creek		0.4	0.1	26%	
9566-2 (3/7)	Station # 12	Hackensack R., North of Berry's Creek		0.0	0.0	23%	
			Sample Mean	0.2	0.2	118%	
9567 (3/7)	Station # 14	Hackensack R., North of Berry's Creek		0.1	0.0	14%	
9598 (3/7)	Station # 17	Hackensack R., S. of Berry's Ck./N. of Newark Bay		0.2	0.1	24%	
9568 (3/7)	Station # 20	Mouth, Hackensack R./Upper Newark Bay		0.1	0.0	22%	
9569 (3/7)	Station # 21	Mouth, Passaic R./Upper Newark Bay		0.1	0.0	17%	
9570 (3/7)	Station # 26	Upper Newark Bay		0.1	0.1	71%	
9526 (3/7)	Station # 31	Upper/Mid Newark Bay		0.4	0.1	32%	
9529 (3/7)	Station # 36	Lower/Mid Newark Bay		0.2	0.0	21%	
9528-1 (3/7)	Station # 56	Lower Newark Bay, Port Richmond, Kill Van Kull		0.5	0.1	14%	
9528-2 (3/7)	Station # 56	Lower Newark Bay, Port Richmond, Kill Van Kull		0.1	0.1	101%	
			Sample Mean	0.3	0.1	22%	
9527 (3/7)	Station # 57	Upper New York Harbor		0.1	0.0	32%	
* Means were used for site averages						60%	Mean CV (precision)

Appendix I. H4IIE rat hepatoma bioassay contd.

Table 4. (F8) - Mono-ortho-chloro-substituted PCB fraction.

NFCRC Sample ID	Field ID	Site Description		TCDD-EQ (pg/g)	(SD)	CV	
9561a (2/18)	Station # 1	Upper Passaic R.		1.6	0.2	11%	
9561b (2/18)	Station # 1	Upper Passaic R.		2.6	0.3	10%	
9561c (2/18)	Station # 1	Upper Passaic R.		2.5	0.3	11%	
			Bioassay Mean	2.2	0.6	26%	
9562 (2/18)	Station # 3	Passaic R., upstream of point source		1.4	0.2	12%	
9563 (2/18)	Station # 5	Lower Passaic R., immediately upstream		7.4	0.8	11%	
9593 (2/18)	Station # 7A	Lower Passaic R., point source		16.8	1.9	11%	
9594 (2/18)	Station # 7B	Lower Passaic R., point source		11.3	1.3	12%	
9595 (2/18)	Station # 7C	Lower Passaic R., point source		13.3	1.4	10%	
			Site Mean	13.8	2.8	20%	
9596 (2/18)	Station # 8A	Lower Passaic R., point source		5.0	0.5	10%	
9597 (2/18)	Station # 8B	Lower Passaic R., point source		18.4	3.9	21%	
			Site Mean	11.7	9.5	81%	
9564 (2/18)	Station # 10	Lower Passaic R., immediately below point source		8.2	0.9	10%	
9565 (2/18)	Station # 11	Lower Passaic R., below point source		4.7	0.5	11%	
9566-1 (2/18)	Station # 12	Hackensack R., North of Berry's Creek		0.9	0.2	23%	
9566-2 (2/18)	Station # 12	Hackensack R., North of Berry's Creek		0.5	0.1	12%	
			Sample Mean	0.7	0.2	34%	
9567 (2/18)	Station # 14	Hackensack R., North of Berry's Creek		4.1	0.4	10%	
9598 (2/18)	Station # 17	Hackensack R., North of Berry's Ck./ N. of Newark Bay		1.9	0.2	10%	
9568a (2/18)	Station # 20	Mouth, Hackensack R./Upper Newark Bay		2.8	0.3	11%	
9568b (2/18)	Station # 20	Mouth, Hackensack R./Upper Newark Bay		5.7	0.6	10%	
9568c (2/18)	Station # 20	Mouth, Hackensack R./Upper Newark Bay		8.2	1.0	12%	
			Bioassay Mean	5.6	2.7	49%	
9569 (2/18)	Station # 21	Mouth, Passaic R./Upper Newark Bay		4.0	0.4	10%	
9570 (2/18)	Station # 26	Upper Newark Bay		18.1	2.6	15%	
9526 (2/18)	Station # 31	Upper/Mid Newark Bay		3.6	0.4	10%	
9529 (2/18)	Station # 36	Lower/Mid Newark Bay		4.0	0.4	11%	
9528-1 (2/18)	Station # 56	Lower Newark Bay, Port Richmond, Kill Van Kull		6.6	0.7	10%	
9528-2 (2/18)	Station # 56	Lower Newark Bay, Port Richmond, Kill Van Kull		2.7	0.3	10%	
			Sample Mean	4.7	2.8	59%	
9527 (2/18)	Station # 57	Upper New York Harbor		0.3	0.0	11%	
* Means were used for site averages						12%	Mean CV (precision)

Appendix I. H4IIE rat hepatoma bioassay contd.

Table 5. (F9) - Non-ortho-chloro-substituted PCB fraction.

NFCRC Sample ID	Field ID	Site Description		(pg/g)	(SD)	CV	
9561 (3/11)	Station # 1	Upper Passaic R.		7	3	39%	
9562 (3/11)	Station # 3	Passaic R., upstream of point source		20	3	14%	
9563a (3/11)	Station # 5	Lower Passaic R., immediately uptream		69	9	13%	
9563b (3/11)	Station # 5	Lower Passaic R., immediately uptream		68	9	13%	
9563c (3/11)	Station # 5	Lower Passaic R., immediately uptream		12	2	13%	
			Bioassay Mean	49	32	65%	
9593 (3/11)	Station # 7A	Lower Passaic R., point source		113	24	21%	
9594 (3/11)	Station # 7B	Lower Passaic R., point source		155	26	17%	
9595 (3/11)	Station # 7C	Lower Passaic R., point source		17	3	16%	
			Site Mean	95	70	74%	
9596a (3/11)	Station # 8A	Lower Passaic R., point source		78	12	15%	
9596b (3/11)	Station # 8A	Lower Passaic R., point source		97	16	16%	
9596c (3/11)	Station # 8A	Lower Passaic R., point source		81	11	14%	
			Bioassay Mean	85	10	12%	
9597 (3/11)	Station # 8B	Lower Passaic R., point source		192	41	21%	
9564 (3/11)	Station # 10	Lower Passaic R., immediately below point source		2	1	41%	
9565 (3/11)	Station # 11	Lower Passaic R., below point source		68	12	17%	
9566-1 (3/11)	Station # 12	Hackensack R., North of Berry's Creek		0	0	22%	
9566-2 (3/11)	Station # 12	Hackensack R., North of Berry's Creek		2	0	14%	
			Sample Mean	1	1	118%	
9567 (3/11)	Station # 14	Hackensack R., North of Berry's Creek		22	3	16%	
9598 (3/11)	Station # 17	Hackensack R., S. of Berry's Ck./N. of Newark Bay		5	1	20%	
9568 (3/11)	Station # 20	Mouth, Hackensack R./Upper Newark Bay		14	3	20%	
9569 (3/11)	Station # 21	Mouth, Passaic R./Upper Newark Bay		18	3	16%	
9570 (3/11)	Station # 26	Upper Newark Bay		86	12	14%	
9526 (3/11)	Station # 31	Upper/Mid Newark Bay		17	2	14%	
9529 (3/11)	Station # 36	Lower/Mid Newark Bay		10	1	15%	
9528-1 (3/11)	Station # 56	Lower Newark Bay, Port Richmond, Kill Van Kull		14	2	15%	
9528-2 (3/11)	Station # 56	Lower Newark Bay, Port Richmond, Kill Van Kull		10	2	16%	
			Sample Mean	12	3	25%	
9527 (3/11)	Station # 57	Upper New York Harbor		2	0	15%	
						18%	Mean CV (precision)
*Means were used for site averages							

Appendix I. H4IIE rat hepatoma bioassay contd.

Table 6. (F11) - Combined total PCB fraction.

NFCRC Sample ID	Field ID	Site Description		TCDD-EQ (pg/g)	(SD)	CV	
9561a (3/18)	Station # 1	Upper Passaic R.		103	8	8%	
9561b (3/18)	Station # 1	Upper Passaic R.		57	5	9%	
9561c (3/18)	Station # 1	Upper Passaic R.		87	6	7%	
			Bioassay Mean	82	23	28%	
9562 (3/18)	Station # 3	Passaic R., upstream of point source		96	8	9%	
9563 (3/18)	Station # 5	Lower Passaic R., immediately uptream		151	10	6%	
9593 (3/18)	Station # 7A	Lower Passaic R., point source		96	7	8%	
9594 (3/18)	Station # 7B	Lower Passaic R., point source		61	4	6%	
9595 (3/18)	Station # 7C	Lower Passaic R., point source		63	5	8%	
			Site Mean	73	20	27%	
9596 (3/18)	Station # 8A	Lower Passaic R., point source		332	34	10%	
9597 (3/18)	Station # 8B	Lower Passaic R., point source		391	34	9%	
			Site Mean	362	42	12%	
9564 (3/16)	Station # 10	Lower Passaic R., immediately below point source		16	1	7%	
9565 (3/16)	Station # 11	Lower Passaic R., below point source		204	16	8%	
9566-1 (3/18)	Station # 12	Hackensack R., North of Berry's Creek		8	1	8%	
9566-2 (3/16)	Station # 12	Hackensack R., North of Berry's Creek		14	1	7%	
			Sample Mean	11	4	41%	
9567 (3/18)	Station # 14	Hackensack R., North of Berry's Creek		42	2	6%	
9598a (3/18)	Station # 17	Hackensack R., S. of Berry's Ck./N. of Newark Bay		1	1	73%	
9598b (3/18)	Station # 17	Hackensack R., S. of Berry's Ck./N. of Newark Bay		81	5	7%	
9598c (3/18)	Station # 17	Hackensack R., S. of Berry's Ck./N. of Newark Bay		74	5	6%	
			Bioassay Mean	52	44	85%	
9568 (3/18)	Station # 20	Mouth, Hackensack R./Upper Newark Bay		80	8	10%	
9569 (3/18)	Station # 21	Mouth, Passaic R./Upper Newark Bay		111	10	9%	
9570 (3/18)	Station # 26	Upper Newark Bay		162	14	8%	
9526 (3/18)	Station # 31	Upper/Mid Newark Bay		19	1	8%	
9529 (3/18)	Station # 36	Lower/Mid Newark Bay		47	3	7%	
9528-1 (3/18)	Station # 56	Lower Newark Bay, Port Richmond, Kill Van Kull		46	4	8%	
9528-2 (3/18)	Station # 56	Lower Newark Bay, Port Richmond, Kill Van Kull		78	5	6%	
			Sample Mean	62	23	37%	
9527 (3/18)	Station # 57	Upper New York Harbor		2	0	9%	
* Means were used for site averages						10%	mean CV (precision)

Appendix I. H4IIE rat hepatoma bioassay contd.

Table 7. (F12) - PCDD/PCDF fraction.

NFCRC Sample ID	Field ID	Site Description	TEQ (pg/g)	TCDD-EQ (pg/g)
9561	Site 1	Upper Passaic R	156	70
9562	Site 3	Passaic River	520	204
9563	Site 5	Lower Passaic R, Upstream of Pt. Source, 5g	856	383
9593	Site 7A	Lower Passaic R, Pt. Source, 5g	748	440
9593	Site 7A	Lower Passaic R, Pt. Source, 5g	777	
9594	Site 7B	Lower Passaic R, Pt. Source, 5g, Rep 1	885	543
9594	Site 7B	Lower Passaic R, Pt. Source, 5g, Rep 2	784	
9594	Site 7B	Lower Passaic R, Pt. Source, 5g, Rep 3	748	
9595	Site 7C	Lower Passaic R, Pt. Source, 5g	1261	292
9596	Site 8A	Lower Passaic R, Pt. Source, 5g	1047	503
9597	Site 8B	Lower Passaic R, Pt. Source, 5g	648	541
9564	Site 10	Lower Passaic R, Below Pt Source, 5g, Rep 1	924	326
9564	Site 10	Lower Passaic R, Below Pt Source, 5g, Rep 2	1064	
9564	Site 10	Lower Passaic R, Below Pt Source, 5g, Rep 3	1063	
9565	Site 11	Lower Passaic R, Below Pt Source, 5g	911	305
9566	Site 12	Hackensack R, N of Berry's Creek, 5g	45	28
9567	Site 14	Hackensack R, N of Berry's Creek, 5g	424	63
9598	Site 17	Hackensack R, S of Berry's Creek, N of Newark Bay, 5g	105	20
9568	Site 20	Mouth of Hackensack R, Upper Newark Bay, 5g	164	32
9569	Site 21	Mouth of Passaic R, Upper Newark Bay, 5g	275	217
9570	Site 26	Upper Newark Bay, 5g	857	843
9526	Site 31	Upper-Mid-Newark Bay, 5g	274	36
9529	Site 36	Lower-Mid-Newark Bay, 5g	222	123
9528	Site 56	Lower Newark Bay, Port Richmond, Kill Van Kull, 5g	130	134
9527	Site 57	Upper New York Harbor, 5g	17	7
9527	Site 57	Upper New York Harbor, 5g	12	