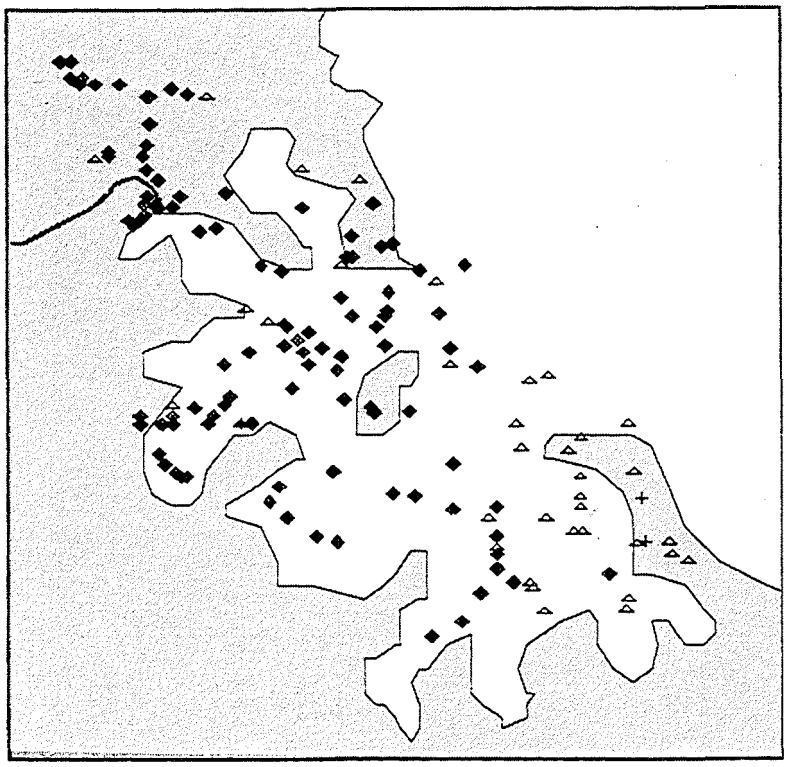
NOAA Technical Memorandum NOS ORCA 76

**National Status and Trends Program**
for Marine Environmental Quality

# Inventory of Chemical Concentrations in Coastal and Estuarine Sediments



Silver Spring, Maryland
January, 1994

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Coastal Monitoring and Bioeffects Assessment Division
Office of Ocean Resources Conservation and Assessment
National Ocean Service

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**U.S. Department of Commerce**
**Silver Spring, MD**

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# Inventory of Chemical Concentrations in Coastal and Estuarine Sediments

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Silver Spring, Maryland
January, 1994

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# ABSTRACT

This report describes the results of an inventory of sediment contamination undertaken by the National Status and Trends (NS&T) Program. The resulting COastal SEdiment Database (COSED) of chemical concentrations, consisting of nearly 13,500 coastal sediment samples along the continental US coast, was compiled from various electronic information systems (NOAA/NS&T, STORET, ODES, the Environmental Protection Agency (EPA) Region 4, EMAP/EC, SFTB). Data on the concentrations of over 80 analytes, including metals, pesticides, polyaromatic hydrocarbons (PAH), and polychlorinated biphenyls (PCB), and physical sample parameters were assessed relative to the NS&T "High" concentrations, which correspond to the geometric mean plus one standard deviation of all NS&T site means The spatial distribution among all COSED sites reveals more areas with "High" concentrations along the coasts of the Northeast and Gulf of Mexico than in the Southeast or West Coasts The greatest numbers of sites with concentrations greater than five times the "High" (5xHigh) were near densely populated areas in poorly flushed water bodies (harbors, intracoastal waterways, etc.). The most common chemicals at these "5xHigh" levels were metals, in decreasing frequency: Hg, Cd, Sn and Ag. Total PAH was the organic compound group most commonly found in the "5xHigh" range.

It is recommended that the random dataset being generated by the EMAP/EC be used to establish the areal extent of chemical concentrations. While EMAP/EC does not provide data on small spatial scales, its random sampling scheme is ideal for large scale and national assessments. Based on EMAP data, more than 90% of the corresponding coastal and estuarine areas have concentrations below "High", while "5xHigh" concentrations are exceeded only in a very small fraction of the area.

# INTRODUCTION

Coastal and estuarine areas are of interest due to their ecologic, economic, and recreational importance. Rivers carry suspended particles into these areas where, under the influence of salinity and lower current speeds, they usually settle to the seafloor. These particles can carry chemical contaminants discharged to the rivers, and, along with direct inputs of contaminants, increased marine traffic, growing human populations, and atmospheric deposition, contribute to coastal sediment contamination

The magnitude and extent of sediment contamination has been a subject of major emphasis in recent years. Concerns raised by scientists and the public over contaminated sediment management and remediation have increased the costs of industrial and municipal waste treatment and, especially, the cost of dredging navigable waters. However, while some efforts have been undertaken to categorize sediments in the U.S. (Bolton et al, 1984; Lyman et al, 1987; NOAA, 1991), the extent of sediment contamination remains largely undefined. A detailed evaluation of coastal sediment contamination has therefore been mandated by the Water Resources Development Act of 1992 (WRDA), which requires NOAA and USGS to assist the EPA in conducting a comprehensive national survey of data regarding aquatic sediment quality in the United States.

There is a large body of data, generated in the past, for use in defining the extent of coastal and estuarine sediment contamination in the US. The goal of this work has been collection, evaluation, and organization of these data to make that assessment. While precise distributions of contamination over local spatial scales will usually not be derivable from data collected at fairly low spatial resolution, the available data do allow national and regional assessments.

This report was compiled from existing data for the coastal and estuarine United States, retrieved primarily from computerized information systems. Six sources were used, two from NOAA and four from EPA. The NOAA sources were the National Status and Trends Program (NS&T) and data from San Francisco and Tampa Bays used for two NOAA reports, Long et al. (1988) and Long et al. (1991), respectively. Data used for those two reports were provide by E. Long (NOAA, Seattle) and have been digitized and combined into a dataset called "SFTB". The EPA sources were the Storage and Retrieval of U.S. waterways parametric data (STORET), the Ocean Data Evaluation System (ODES), EPA Region 4 compiled data (REGION4), and the estuarine component of the Environmental Monitoring and Assessment Program (EMAP/EC).

In 1984, NOAA initiated the National Status and Trends program (NS&T) to monitor contaminants in fish, mollusks, and sediment at over 300 coastal stations. Sites were chosen to represent rather large areas and are therefore not in industrial waterways or near discharge pipe outputs. Recently, the NS&T program has been extended to intensively sample, on small spatial scales, some enclosed water bodies near populated areas that were expected to be heavily contaminated (e.g. Boston

Harbor, Hudson Estuary, San Francisco Bay, and Tampa Bay). While chemical data are collected in these intensive surveys, they were primarily designed to search for biological effects of contamination. Sediment chemical data exist for 17 elements and 60 organic parameters, making this database one of the most complete of its kind. Quality assurance (QA) efforts are essential to the program, and are designed to produce nationally uniform analytical results of known and accepted quality.

SFTB data were extracted from reports on sediment chemistry in San Francisco Bay (Long et al. 1988) and in Tampa Bay (Long et al., 1991). These data were taken from reports in the technical literature that contained both chemical measurements and results of biological effect measurements. Only the chemical information from the SFTB database was included in COSED.

STORET, according to an EPA definition, is ". . a computerized management information system residing on EPA's computer at Research Triangle Park, North Carolina. It is made up of several software modules which allow the user to store and retrieve water quality information.. " Although STORET contains over 190 million parametric observations, only a small portion of them are sediment data. The data belongs to the agency providing it and are only managed by EPA, thus, quality assurance rests with the data submitter. Numerous chemical and biological parameters are included in STORET, but most sediment datasets contain only a minimum number of chemical parameters. It is important to note that the majority of data in STORET were collected as a regulatory requirement of EPA. As a result, there is a strong tendency for STORET data to be from samples collected near individual point sources of contaminants. We data was retrieved only when described in STORET by the keywords: "Ocean", "Nearshore", "Offshore", "Estuarine" and "Saltwater Wetlands".

ODES provides a centralized system for data management and analysis. It is designed for supporting decision-makers associated with marine and estuarine monitoring programs. ODES contains data mainly from the following EPA programs: 301(h) and 403(c), National Estuarine Program, EPA Regional Ocean Dumping Program, and Great Lakes National Program It also resides at the EPA's computer at Research Triangle, NC. Technical staff run QA and error checking programs, and a brief description of the sampling and analytical methods is provided for many datasets. Over 100 datasets contain sediment chemical information. Like STORET data, the ODES data is dominated by samples taken near points of wastewater discharge.

The Region 4 Coastal Sediment Quality Inventory, provided by C. Fox (USEPA, Washington, DC), was compiled with data from State and Federal agencies (EPA, 1992). It is a dBase III+ file containing chemical data paired, where possible, with biological information. Data sources were primarily: the Florida Department of Environmental Regulation, hard copy reports from EPA, Army Corps of Engineers, and general literature Acceptance of data was based on accurate geographical information of the sampling site, and an effort was made to correct erroneous latitude and longitude values. Only the chemical data from the Region4 database was included in COSED.

EMAP/EC sampling and analytical techniques are largely similar to NS&T, but site selection has been based on a rigorous statistical scheme that emphasizes geographically random site selection (Holland, 1990). Sampling occurs in estuaries and in tidal reaches of rivers over large regions of the United States. To date, sampling has been done in the Virginian Province (mouth of Chesapeake Bay, VA to Provincetown, MA) and the Louisianian Province (all of the Coastal Gulf of Mexico except southern Florida). Sediment chemistry data obtained from 1990 to 1991 sampling in the Virginian Province and from 1991 and 1992 sampling from the Louisianian Province, has been included in COSED.

Within the EMAP/EC and NS&T datasets, it is possible to distinguish between sites selected specifically to test for biological effects at elevated levels of contamination and sites selected randomly or selected to be representative. Site selection in the EMAP/EC Program is random for all sites except those considered index sites or test and evaluation sites These later sites, chosen for a number of different reasons include some where elevated levels of contamination were deliberately being sought, are not random and indicated as such in the EMAP/EC database Sites of the Mussel Watch Project within the NS&T Program are not random because they were chosen for the sake of annually collecting indigenous mussels or oysters. They are, however, considered to be representative of their general surroundings Sites of the Benthic Surveillance Project, include many chosen specifically to examine biological effects at extreme levels of contamination In comparing among datasets, we have differentiated between the EMAP/EC random and non-random sites and between the Mussel Watch and Benthic Surveillance sites It is possible, with closer scrutiny, to subdivide the Benthic Surveillance dataset to separate representative sites from those deliberately chosen for their contamination.

That has not been done because, if it were, the same subdividing would have to be applied to the ODES, STORET, EPA Region4, and SFTB datasets. In those cases, though, sufficient information is not available.

## DATA REDUCTION

with the addition

The chemicals of interest (Table **1**) were those routinely analyzed by the NS&T Program, as well as kepone and toxaphene. Data for 1975 to 1992 were retrieved from STORET and ODES using tools supplied in those software packages. Those files were downloaded to a personal computer for further evaluation. All other data were available in IBM-PC or Macintosh format. Every dataset was examined individually and converted to a common format using an X-Base (FoxBase+/Mac or FoxPro/PC), then all data were combined into COSED.

Some general guidelines were followed for conversion of data values to a common format:

- Values entered in original databases as less than a detection limit were converted to zeros.

should not be used

- Values in STORET labeled as "estimated" rather than measured were converted to zeros.

- All concentrations were converted to ppm-dry (µg/g) for elements and ppb-dry (ng/g) for organic compounds.

- Data were converted to a horizontal format, so that there is a single record for each sample, and examination of the data does not require the use of a relational database.

- Multiple samples from the same site were treated as individual records

# Table 1

## Elements and Compounds included in COSED

Elements

**Al, Ag, As, Cd, Cr, Cu, Fe, Hg, Mg, Ni, Pb, Sb, Se, Si, Sn, Zn.**

Organic Compounds

PAH
*2-ring compounds*: **acenaphthene, biphenyl, naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, and 2-6-dimethylnaphthalene;**
*3-ring compounds*: **acenaphthene, acenaphthylene, anthracene, flourene, phenanthrene, and 1-methylphenanthrene;**
*4-ring compounds*: **benz[a]anthracene, chrysene, flouranthene, and pyrene;**
*5-ring compounds*: **dibenz[a,h]anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo[a]pyrene, benzo[e]pyrene, and perylene;**
*6-ring compounds*: **benzo(ghi)perylene, indeno.**

PCB **A total of 18 individual PCB congeners.**

DDT **DDT and its metabolites DDE and DDD.**

Chlorinated Pesticides : **Aldrin, dieldrin, endrin, cis-chlordane, trans-chlordane, hexachlorobenzene, heptachlor and heptachlor epoxide, kepone, lindane, mirex, and toxaphene.**

- Values appearing as zero in COSED were treated as missing (i e. ignored) when average concentrations were calculated. However, if all attempts to measure a chemical at a given site yielded less than detectable concentrations, a concentration of zero was used for comparisons with other sites.

Although there are methods for dealing with values below the detection limit (DL), their complexity and relative error increases when there are multiple DLs for each variable (Helsel, 1990). This is the case in COSED, because data were gathered from various databases which, themselves, carry data from many sources Occasionally, DLs were reported that were even higher than the NS&T "High" values. While concentrations reported as below DLs are carried in COSED as zeros, in this analysis they have been treated as missing data

Data were converted to a horizontal format with each sample occupying one 120-field record containing all the physical and chemical information for this sample. The alternative or "vertical" method of data storage, where each chemical is carried as a separate record, requires that data for each sample be split among as many records as there were measured chemicals. The "horizontal" approach is preferred by most analysts, because it does not require use of relational databases and allows use of spreadsheets and statistical programs for complex data manipulation and queries. Since "horizontal" files require an equal number of fields in each record, there are records with many empty fields. This method of storing data might appear to increase the size of a file over that of a "vertical" database, but, because all descriptive information about each sample appears only once, "horizontal" files are usually smaller.

Following the initial manipulation, data analysis was performed with individual element concentrations and on aggregated groups of organic compounds, as was done with the NOAA NS&T data, i.e .

*•Total DDT (TDDT) = sum of concentrations of DDT (1,1'-[2,2,2-trichloroethylidene]bis[4-chlorobenzene]) and its metabolites DDE (1,1'-[dichloroethylidene]bis[4-chlorobenzene]) and DDD (1,1'-[2,2,-dichloroethylidene]bis[4-chlorobenzene]) and*

*•Total chlordane (TCdane) = sum of concentrations of two major constituents of chlordane mixtures, cis-chlordane and trans-nonachlor and two minor components, heptachlor and heptachlorepoxide, and*

*•Total polychlorinated biphenyls (TPCB) = TPCB if listed as such in the original data source. If homolog data were provided, TPCB = sum of the concentrations of PCB homologs at each level of chlorination. If congener data were provided, TPCB=2x$\Sigma$congeners, an approximation based on regressions developed between homolog and congener data (NOAA,1990), and*

*•Total polycyclic aromatic hydrocarbons (TPAH) = sum of concentrations of 18 PAH compounds. While the low-molecular weight PAHs (LPAH) is the sum of concentrations of the 2- and 3-ring compounds, and high-molecular weight PAHs (HPAH) is the sum of 4- or more ring compounds.*

Concentrations of aggregated groups might not be exactly comparable among all datasets because not all records have data for the same number of individual compounds This, however, is a conservative approach, because organic chemical data from sources other than NS&T and EMAP/EC invariably contain data on fewer individual chemicals.

The total number of samples in the database was 13,433, containing 315,770 individual parameter measurements, of which 175,117 were above detection limits. Sample dates were between 1975 and 1992. Only 19% of the samples were from the NS&T and EMAP datasets, but they contributed over 86% of the individual parameters, indicating that most of the other programs analyzed samples for a smaller number of chemicals. While the number of samples in the SFTB dataset is small, it does contain information for a large number of parameters. The number of occurrences per analyte, presented in Figure **1** and listed in Appendix **I**, indicated that metals were the most frequently sought and detected analytes. Analyses for chlorinated pesticides, other than DDT and its derivatives, were also frequent but concentrations were often below detection. The frequency of analysis of PAH compounds varied with the compound, increasing for the heavier members of the group. PCBs and DDT derivatives were routinely found only in the NS&T, EMAP/EC, and SFTB datasets.

The STORET, ODES, and EPA REGION4 datasets combined provided 79% of the samples in COSED, but in most samples only a few chemicals were measured Furthermore, data records from those sources generally lacked important information, such as concentrations of aluminum, iron, total organic carbon (TOC), and grainsize. These parameters are valuable for comparison between different sites, because they help to account for differences in concentration that are due to natural, rather than man-made, causes. We will return to this point, but the initial analysis of COSED will be done with raw, unadjusted, concentration data. High DLs are another concern because results of surveys with high DLs instead of the real concentrations are effectively biased toward the higher end of the concentration range. However, that should not affect the results of this report since we are emphasizing areas with elevated levels of contamination. Records with missing station names and coordinates were found frequently in ODES. In about 200 cases, conventional coordinates could be calculated from the state plane coordinates provided by Tetra

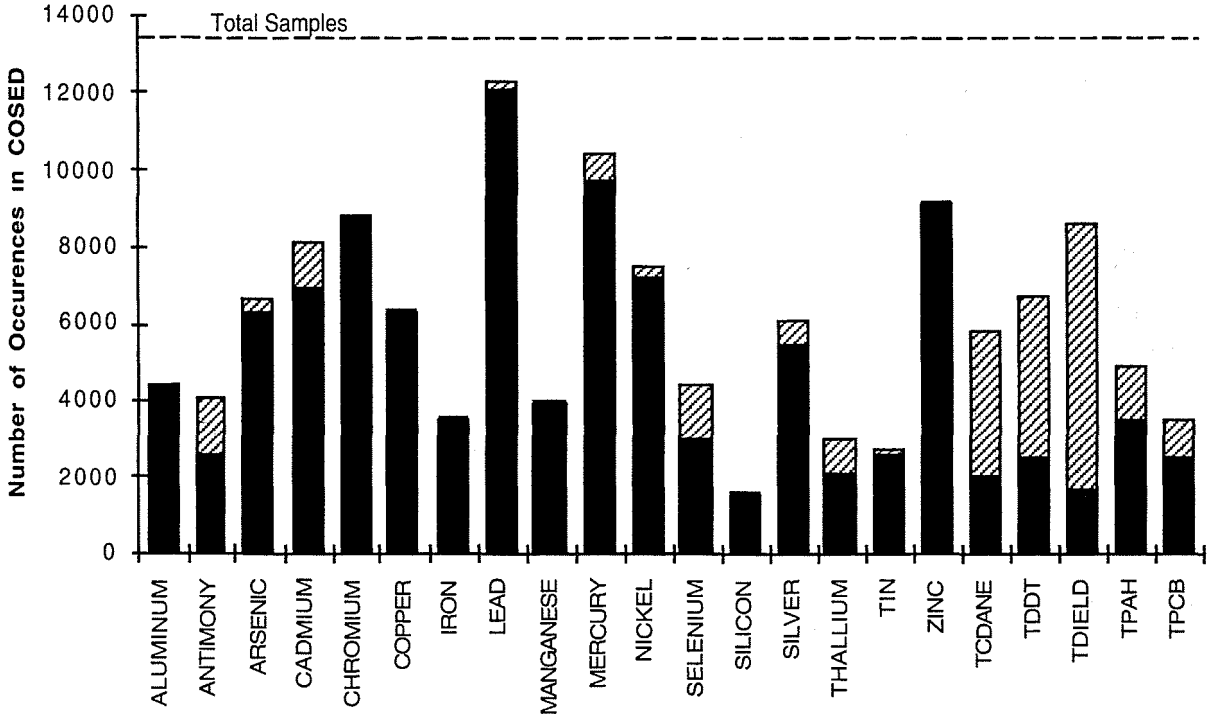



Figure **1**. Number of times that each analyte was above (solid column) and below (hatched column) detection in COSED. The dotted line represents the total number of samples. Lead was determined in most of the samples, metals in general were most often found, while organics were often below detection.

Tech Inc , but records were excluded from COSED if conventional coordinates were not given or calculable.

## ANALYSIS

Once COSED was compiled, it was attempted to use it to estimate contaminants of concern, frequency of elevated levels of these contaminants, and the extent of chemical contamination in the coastal United States. Two sets of criteria were considered to categorize the raw sediment concentrations:

- The "High" concentration from the NS&T Mussel Watch sediment data (as calculated here) and,

- Effects Range-Low (ERL) and Effects Range-Median (ERM) values which are the low 10th and 50th percentile of the biological effects data, respectively, for each substance (Long et al, in press)

For each set of criteria, the critical concentrations for each chemical are shown in Table **2**. The NS&T "High" values were calculated following a modification of the NOAA (1991) procedure. Only data from Mussel Watch sites were used and the average analyte value per site was calculated. Mean concentrations were converted to the logarithms and then, using all sites, the ~~geometric~~ mean and standard deviation were calculated. The "High" values were defined as the mean plus one standard deviation and were converted to the original units (non-logarithmic). Since mean concentrations were approximately log-normally distributed, the "High" value corresponds to about the 85th percentile. No grainsize normalization was used in calculating "High" values, in contrast to NOAA (1991), because grainsize information was missing from most records in COSED. Thus, the unadjusted "High" values calculated here are about 50% lower than the ones reported in NOAA (1991) The NS&T Mussel Watch dataset was chosen for setting criteria for comparison because it does not contain sites deliberately chosen for their elevated concentrations and because its sites are distributed throughout the coastal United States. The EMAP dataset of randomly selected sites could serve just as well but, currently, it covers only the Virginian and Louisianian Provinces. To emphasize extreme concentrations that exist in COSED, "5xHigh" concentrations were defined as those exceeding five times "High" values.

The ERL and ERM values, also based on raw data, were derived from the Biological Effects Database for Sediments (BEDS) compiled by Long et al (in press) with data on sediment toxicity using estuarine and marine sediments. Data are entered into BEDS only if there are both chemical measurements and results of biological effects measurements. The biological effects may be bioassay results or some attribute of indigenous communities found with the sediment sample. For each chemical, cases for which there ~~was a~~ were biological effects were ranked by concentration, and the ERL and ERM are the 10th and 50th percentile concentrations in that ranking. Concentrations below the ERL value were rarely associated with biological effects. Concentrations in the range between ERL and ERM values occasionally co-occur with

# Table 2

## Criteria Applied to COSED

| Analyte | High | 5xHigh | Grain Adjusted High[1] | ER-L[2] | ER-M[2] |
|---|---|---|---|---|---|
| Antimony | 2.1 | 10.5 | | | |
| Arsenic | 13 | 65 | 24 | 8.2 | 70 |
| Cadmium | 0.54 | 2.7 | 1.2 | 1.2 | 9.6 |
| Chromium | 125 | 625 | 230 | 81 | 370 |
| Copper | 42 | 210 | 84 | 34 | 270 |
| Lead | 45 | 225 | 89 | 46.7 | 218 |
| Mercury | 0.22 | 1.1 | 0.49 | 0.15 | 0.71 |
| Nickel | 42 | 210 | 69 | 20.9 | 51.6 |
| Selenium | 0.92 | 4.6 | | | |
| Silver | 0.52 | 2.6 | 1.2 | 1 | 3.7 |
| Tin | 4 | 20 | 8.5 | | |
| Zinc | 135 | 675 | 270 | 150 | 410 |
| High MW PAH | 1730 | 8650 | 2900 | 1700 | 9600 |
| Low MW PAH | 450 | 2250 | 980 | 552 | 3160 |
| Total Chlordane | 4.5 | 22.5 | | | |
| Total DDT | 22 | 110 | 37 | 1.58 | 46.1 |
| Total Dieldin | 2.9 | 14.5 | | | |
| Total PAH | 2180 | 10900 | | 4022 | 44792 |
| Total PCBs | 80 | 400 | 200 | 22.7 | 180 |

Units are in µg/g (ppm) for inorganics, and ng/g (ppb) for organics.

[1] NOAA, 1991.

[2] Long et al, in press.

effects. Biological effects were often found to co-occur with concentrations above the ERM value. Usually the "High" concentrations based simply on the NS&T chemical data were within a factor of two of the ERL. The ERM values, on the other hand, were generally within a factor of two of "5xHigh" concentrations.

Each site within COSED has been put into one of three categories:

1) **Low**: Levels of all analytes below the NS&T "High" value as defined in Table **2**.

2) **High**: At least one analyte exceeds the corresponding "High" value.

3) **5xHigh**: At least one analyte concentration is greater than the "5xHigh".

# RESULTS

## CATEGORIZATION, AND DISTRIBUTION OF SITES

COSED is a sample-based database, thus each one of the multiple samples from the same site appears as one of the 13,443 individual entries. Sites, on the other hand, are distinguished solely on the basis of their coordinates. There are 3,878 separate sites, each with a distinct specification of latitude and longitude No attempt was made to combine sites that were nearby one another The average values for each site have been calculated using all data above the detection limit, and were used for all subsequent site characterizations. Table **3** lists the total numbers of samples and sites in COSED and the numbers in each category. Half the sites are represented by single samples, 35% were sampled two to five times, and three sites were sampled over 100 times. Most of the sites with more than five samples were retrieved from STORET or ODES and were located in Texas or Orange County, CA.

Table 3

COSED data statistics. Number of samples and sites in each category.

| | Samples | Sites |
|---|---|---|
| Low | 6715 | 1127 |
| High | 5525 | 2154 |
| 5xHigh | 1203 | 597 |
| Total | 13443 | 3878 |

With more than three thousand sites, COSED is, to our knowledge, the largest database for coastal sediment chemistry (The EPA is currently compiling a larger set, which will include COSED but will not be restricted to coastal sediments). The sites were not evenly distributed across ~~the~~ coast, but they were representative of a variety of coastal environments, including small and large estuaries, the intracoastal waterway, harbors, industrial waterways, waste dump sites, and open waters.

Although Table **3** shows a great many concentrations above "Low" values, e.g. 6,783 or 50% of the samples, this does not necessarily represent the average contamination level of the coastal areas. In many cases, data are from surveys specifically designed to collect samples near sources of contamination. Also, it should be recognized that current conditions may not be represented in all cases. Conceivably, since the time of collection, contaminant inputs may have changed and sediments represented in COSED could have been dispersed or buried by natural processes or even dredged from the site.

The spatial distribution of COSED sites are presented in Figures **2**, **4**, and **6.** The occasional problem of incorrect latitude or longitude is illustrated in Figure **4**, where two sites retrieved from STORET and presumably from Galveston Bay, are instead plotted in Northern Texas. The majority of "5xHigh", plotted in Figures **3**, **5**, and **7**, are near cities suggesting that anthropogenic input is greater near large population centers than elsewhere. Specifically, the greatest concentrations of "5xHigh" sites were in locations with high ship traffic, industrial activity, and relatively poor water flushing, as is the case of harbors, canals, and intracoastal waterways. Such areas were more commonly sampled along the coasts of the Northeast and Gulf of Mexico than in other parts of the country. More detailed maps and an investigation of some areas of interest will follow.

The tendency for contamination to be an urban problem has been observed by many others. Laflamme and Hites (1977), for example, found that the concentration of PAH increases with proximity to urban areas. Cantillo and O'Connor (1992) showed by factor analysis that chemical concentrations at NS&T sites are strongly influenced by proximity to population centers. Exceptions to that general rule found in COSED are in parts of eastern Florida and the New York Bight, where "5xHigh" sites exist in the open waters because of nearby discharge pipes or ocean dumping sites.

Table **4**, based on mean concentrations at each site, lists the numbers of "High" and "5xHigh" sites. All 597 "5xHigh" sites are listed in Appendix **II** with the analytes exceeding the corresponding "5xHigh" value. Note that percentages of exceedances for a given chemical were calculated relative to all sites where the chemical was detected, not simply the total number of sites. Mercury exceeded the "5xHigh" level at 7.3% of the sites where it was measured, followed by cadmium (7.1%), TPAH (5.5%), tin (4.7%), and silver (3.7%), suggesting that metals are found more frequently at "5xHigh" levels. The importance of this observation is that mercury and cadmium have

~~a greater chance of being found at "5xHigh" levels than any of the other analytes~~ The high frequencies with which mercury and cadmium were found at "5xHigh" concentrations also appeared in a comparison of NOAA NS&T results with data gleaned from the worldwide literature (Cantillo and O'Connor, 1992) Those authors suggested that because Hg and Cd were the elements of highest public concern, that they were frequently required to be measured in areas thought to be highly contaminated. Estimates of metal inputs into coastal waters of European signatories to the Oslo and Paris Conventions (Joint Monitoring Group, 1993), suggested that Hg and Cd were the two metals whose rates of input have been most elevated above natural rates The "5xHigh" Hg values may be of particular significance because the "5xHigh" concentration (1 1 ppm) is greater than the ER-M (0.71 ppm) th~~ought to~~ occurs in conjunction with biological effects.

that

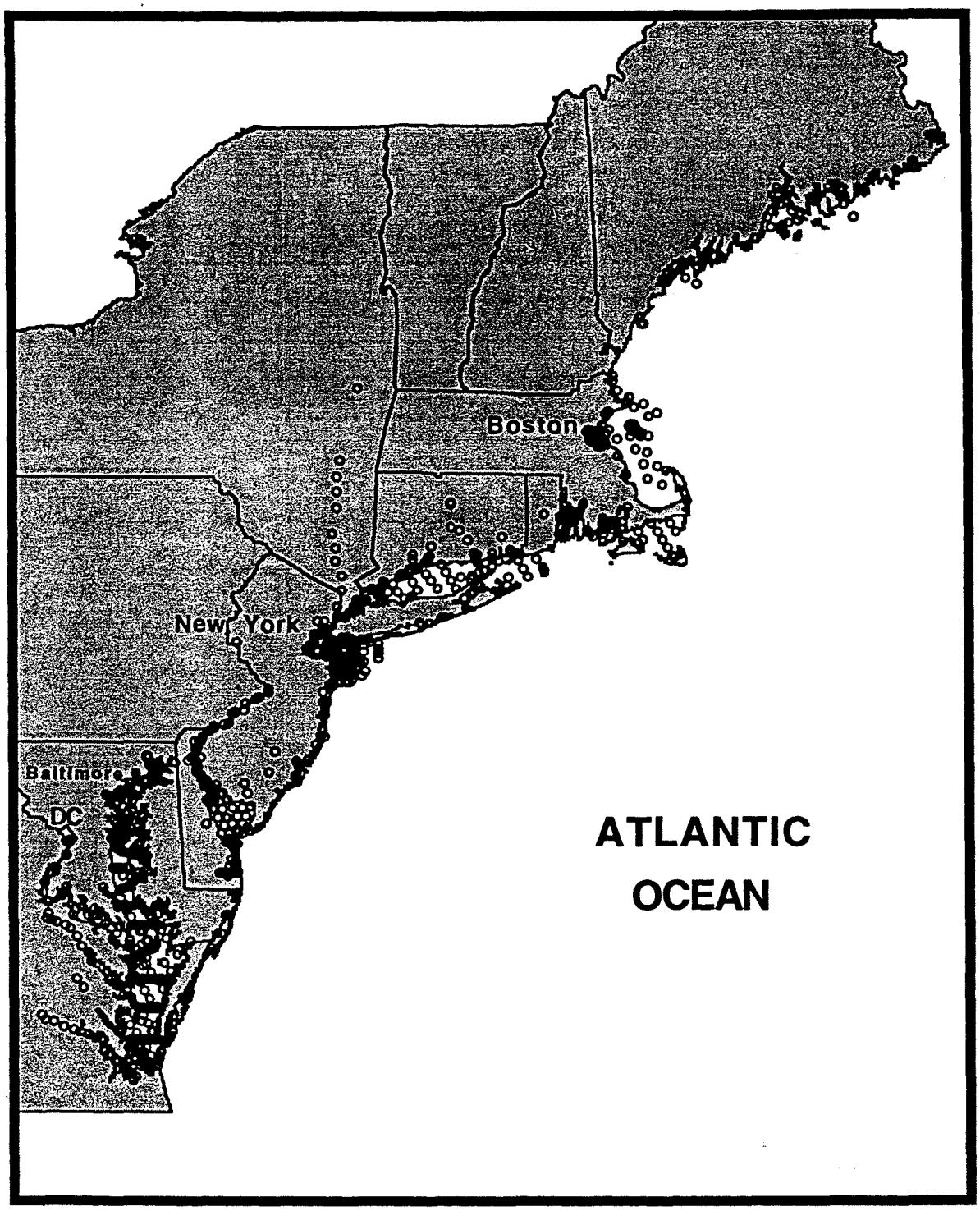



Figure 2. Sites from Northeast U.S. found in COSED.

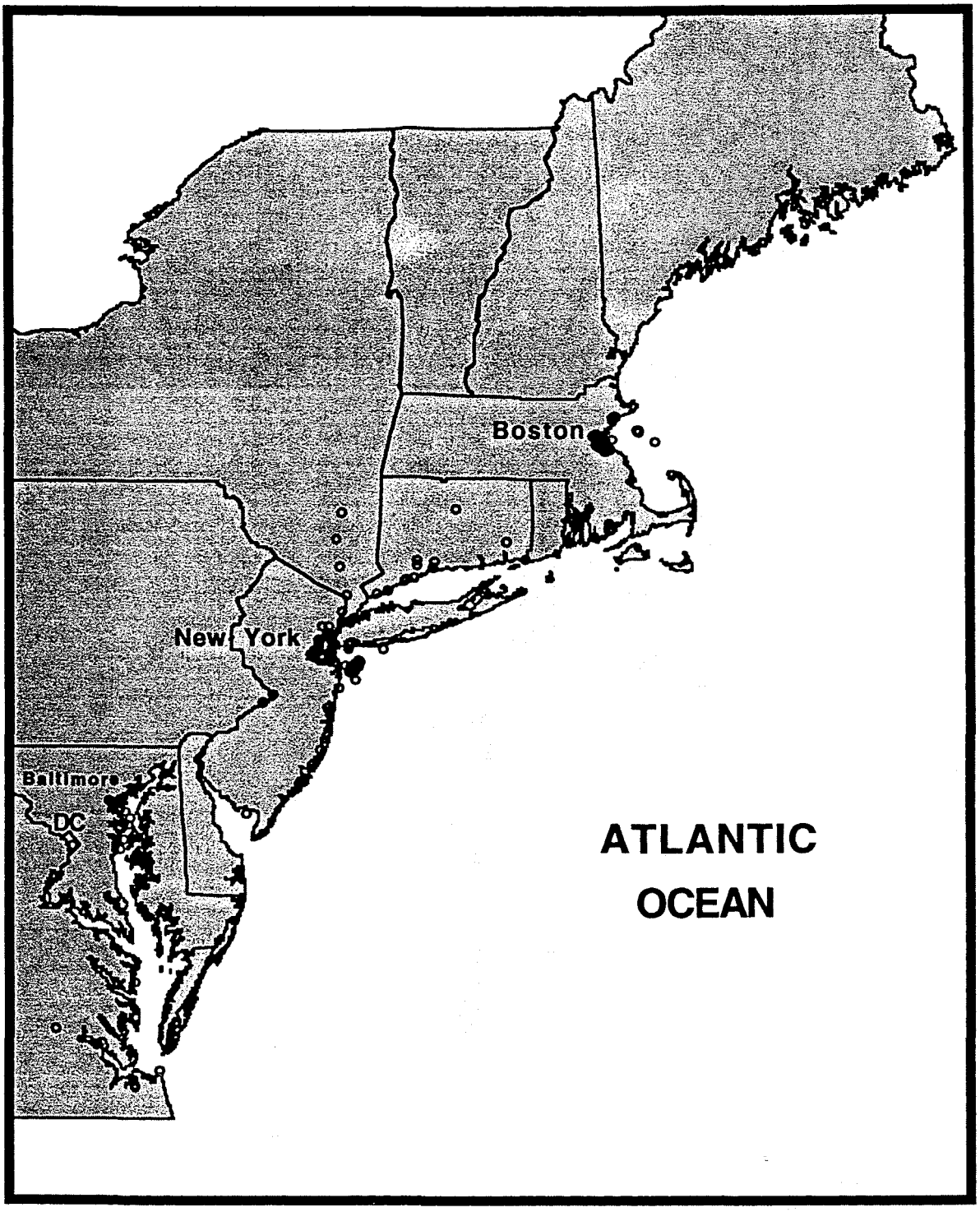



Figure 3. "5xHigh" sites from Northeast U.S. found in COSED.

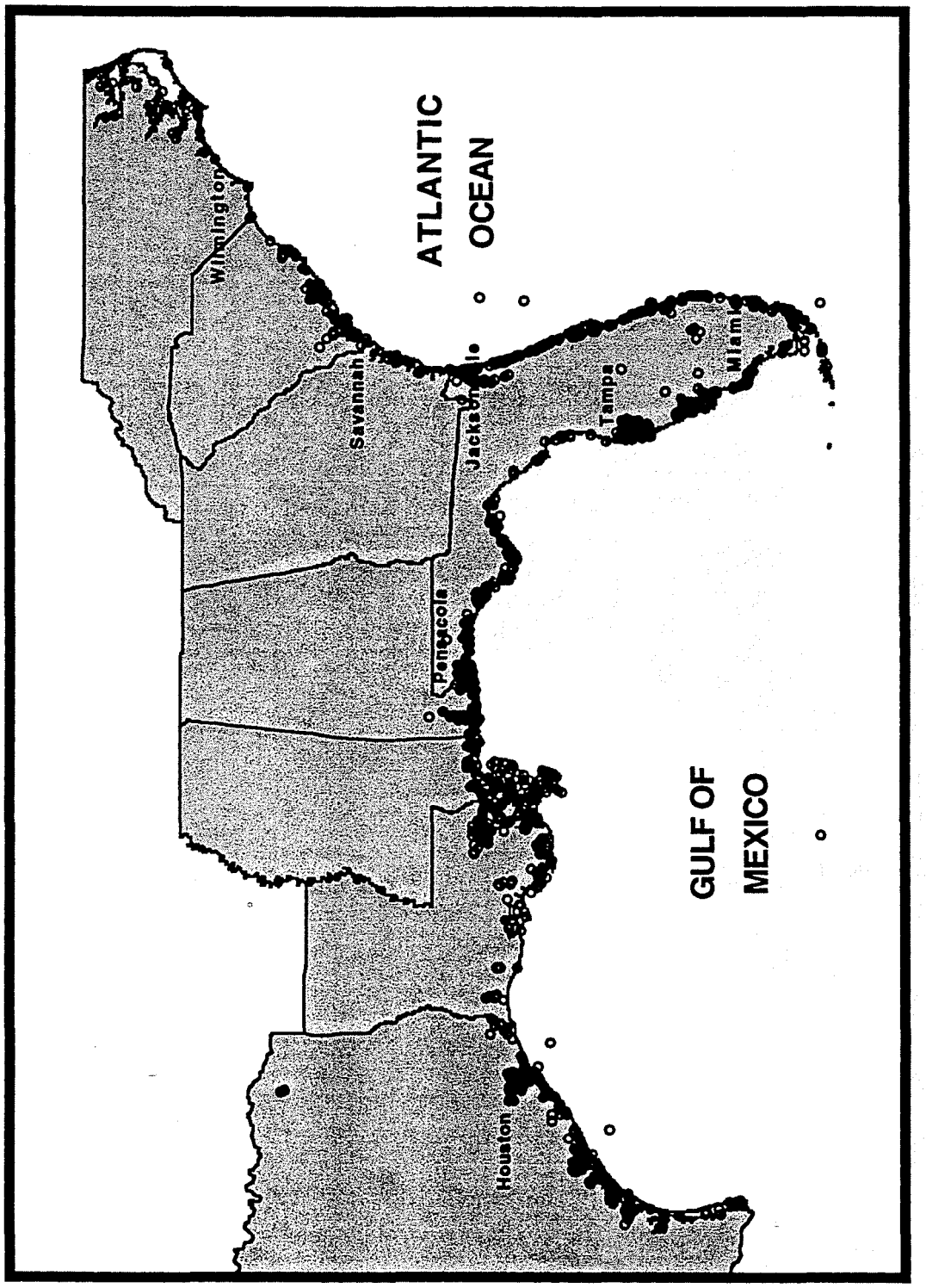



Figure **4**. Sites from U.S. Southeast and Gulf Coast found in COSED.

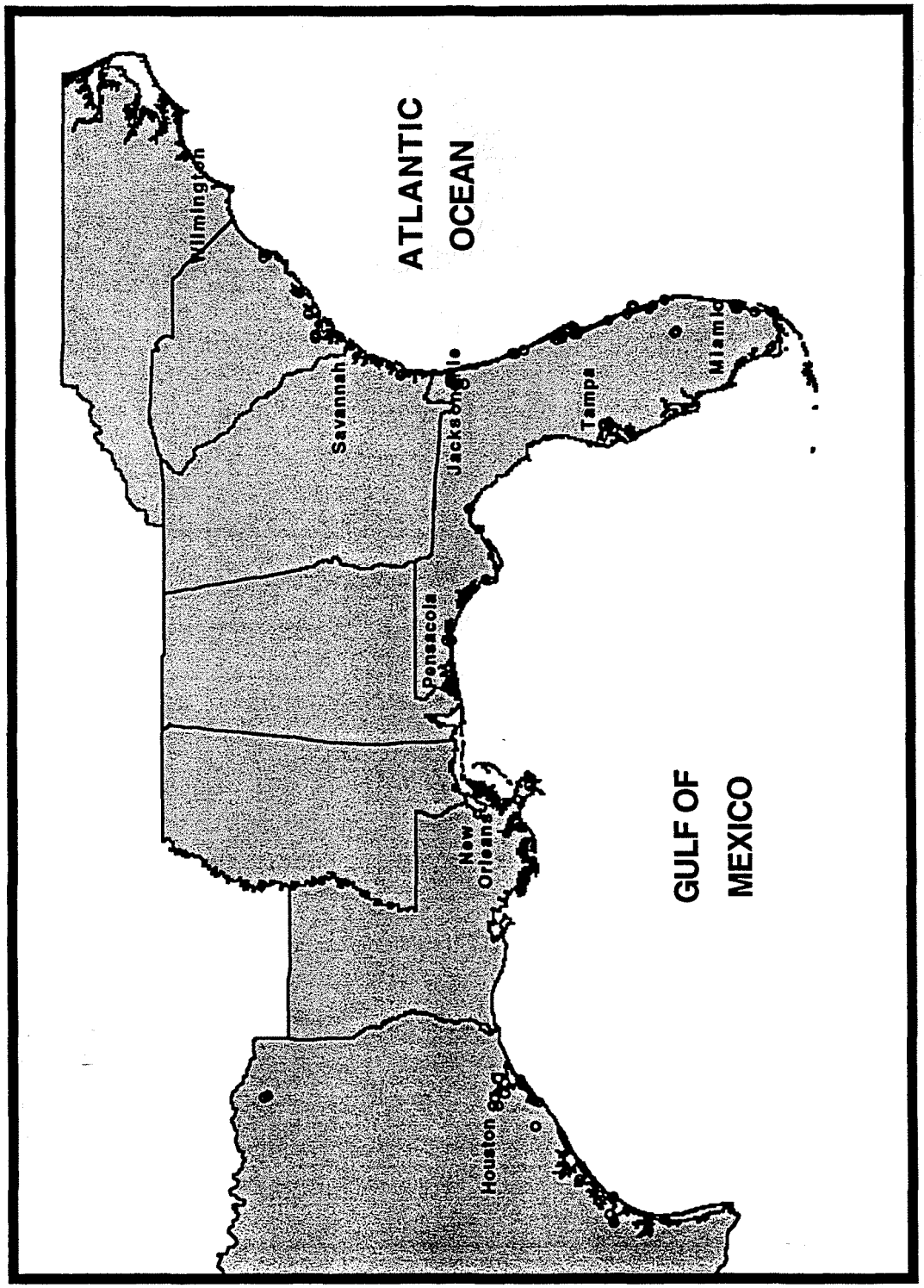



Figure 5. "5xHigh" sites from U.S. Southeast and Gulf Coast found in COSED.

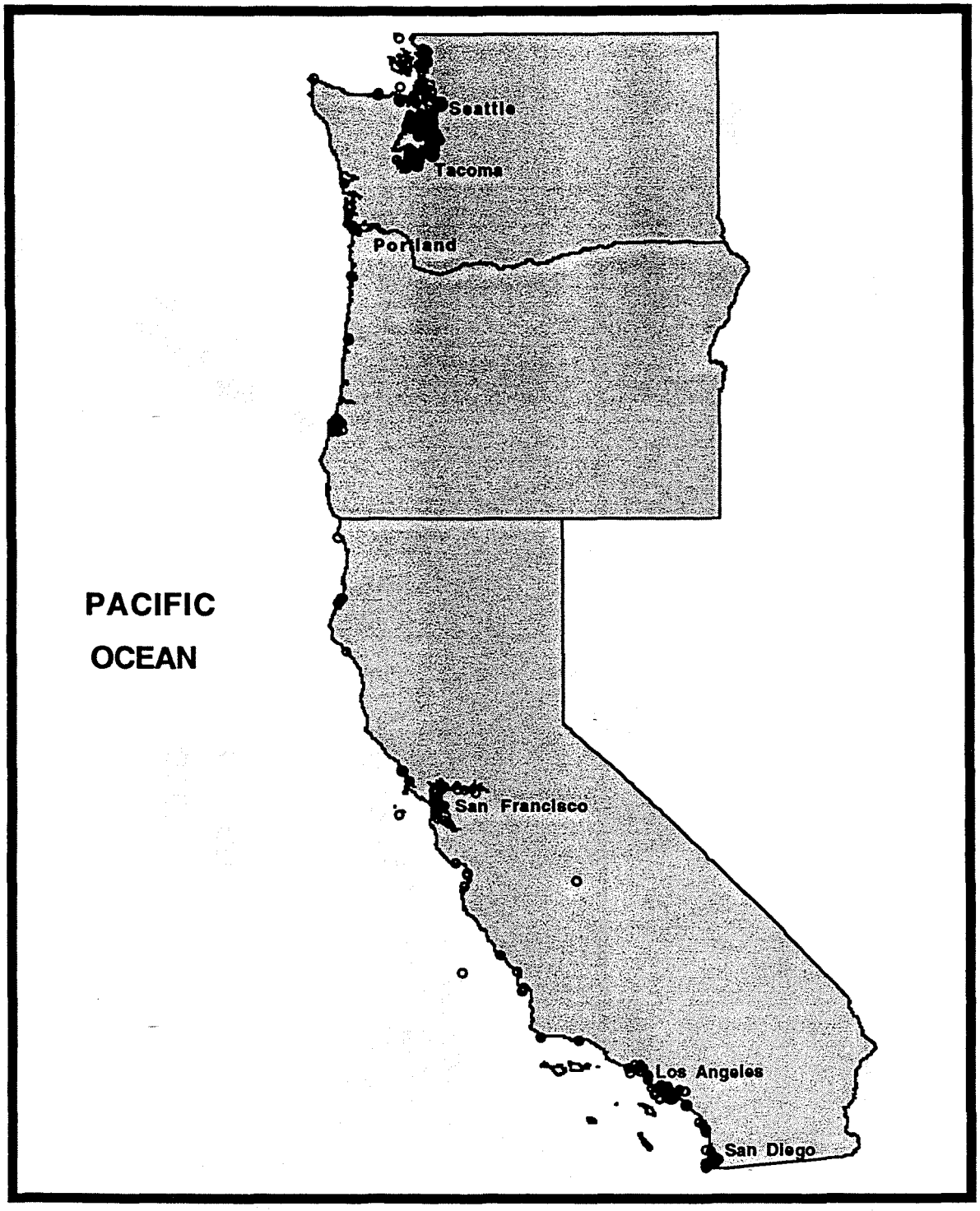



Figure 6. Sites from the U.S. West Coast found in COSED.

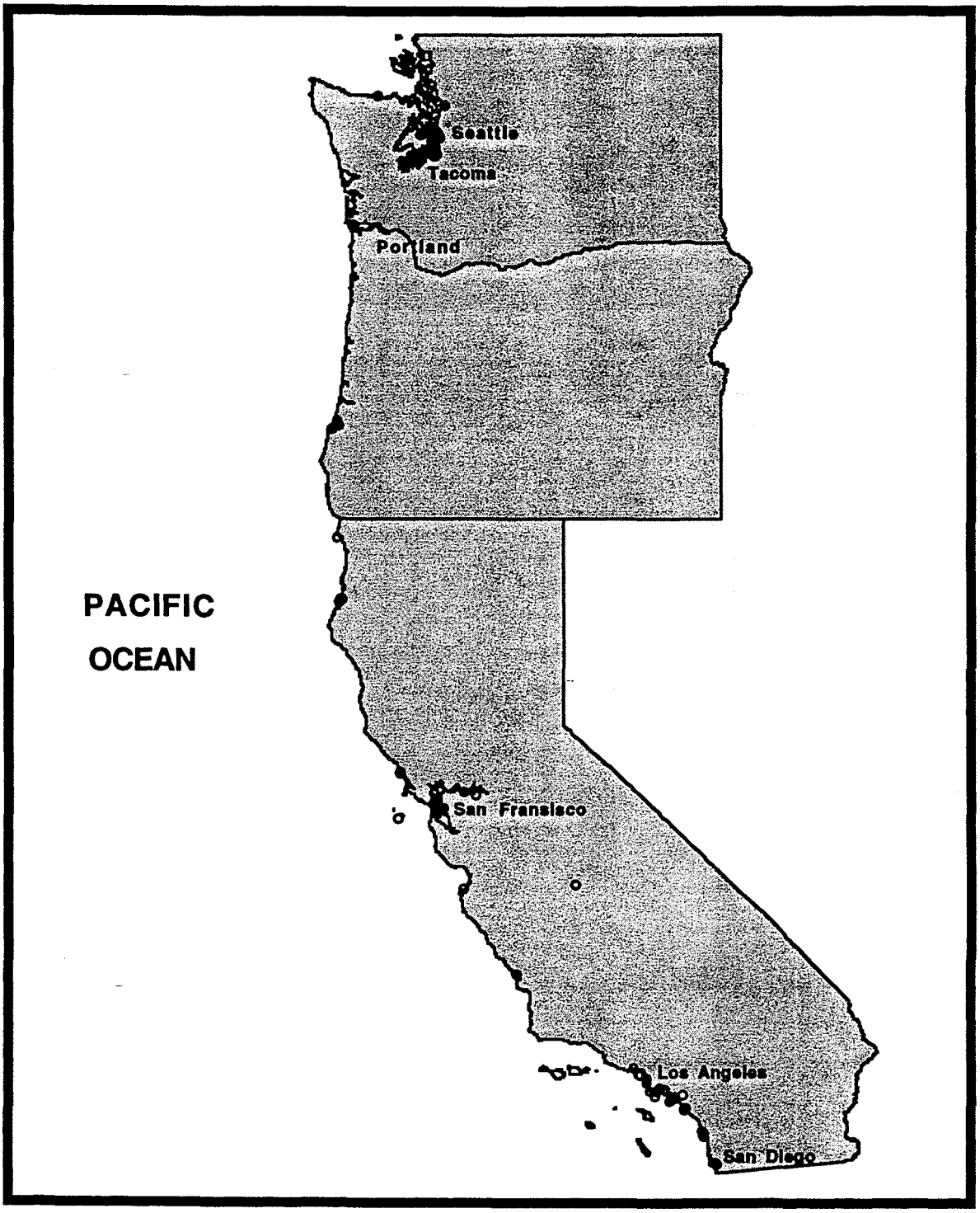



Figure 7. "5xHigh" sites from the U.S. West Coast found in COSED.

# Table 4

## Percentages of "High" and "5xHigh" sites in COSED

| | NS[1] | "HIGH" | | "5xHIGH" | |
|---|---|---|---|---|---|
| | | Sites | % of Total[2] | Sites | % of Total[2] |
| TOTAL | 3878 | 2154 | 56 | 597 | 15 |
| Ag | 2454 | 536 | 22 | 113 | 4.6 |
| As | 2399 | 440 | 18 | 40 | 1.7 |
| Cd | 3024 | 927 | 31 | 214 | 7.1 |
| Cr | 3436 | 380 | 11 | 26 | 0.8 |
| Cu | 2395 | 606 | 25 | 57 | 2.4 |
| Hg | 2885 | 873 | 30 | 211 | 7.3 |
| Ni | 3194 | 360 | 11 | 4 | 0.1 |
| Pb | 3702 | 847 | 23 | 110 | 3.0 |
| Sb | 1784 | 150 | 8.4 | 40 | 2.2 |
| Se | 1983 | 293 | 15 | 26 | 1.3 |
| Sn | 1455 | 295 | 20 | 68 | 4.7 |
| Zn | 3481 | 764 | 22 | 57 | 1.6 |
| High MW PAH | 2023 | 460 | 23 | 110 | 5.4 |
| Low MW PAH | 2011 | 445 | 22 | 113 | 5.6 |
| Total DDT | 2207 | 134 | 6.1 | 44 | 2.0 |
| Total CHLORDANE | 2012 | 166 | 8.3 | 37 | 1.8 |
| Total DIELDRIN | 2234 | 122 | 5.5 | 27 | 1.2 |
| Total PAH | 2032 | 471 | 23 | 112 | 5.5 |
| Total PCB | 1675 | 243 | 15 | 56 | 3.3 |

[1] NS· Numbers of Sites for which sediments have been analyzed for this chemical

[2] Percentage of NS

## INFLUENCE OF SURVEY DESIGN

To demonstrate the influence of survey design, the frequencies of "High" and "5xHigh" concentrations are listed, respectively, in Tables **5** and **6** for each chemical in each of the 8 datasets of COSED The row labeled 'Total Sites' is the number of sites that were included in the given database. Similarly "High" or "5xHigh" Sites is the number of sites that had at least one analyte above the "High" or "5xHigh" value, respectively. The remaining rows contain the percentage of sites in which the particular analyte was above the "High" or "5xHigh" value, and were calculated with a method similar to the one used in Table **4** For example, in EMAP/EC non-random sites (second column in Table **5**) there were 8 sites with "High" Ag, out of 126 measured Ag concentrations, which is 6 3%.

The EMAP/EC random dataset contains the lowest proportion of "High" concentrations for any chemical and reflects the fact that in other datasets those frequencies are higher because the sampling schemes forced them to be. The frequency of "High" concentrations of each chemical in the NS&T/MW is about 15%, consistent with the definition of "High" values and their derivation from that dataset. The frequencies in NS&T/MW exceed those in EMAP/EC random because, even though NS&T site selection seeks representativeness, there is an urban bias. Among the 224 sites in NS&T/MW, 45% are within 20 km of 100,000 people based on 1990 census data Since it is expected and was, in fact, shown (NOAA, 1991) that chemical concentrations at sites increase with the number of people residing near a site, the NS&T/MW dataset contains more "High" concentrations than the EMAP/EC random dataset.

All the other datasets in Table **5** contain sites preselected for their likelihood to have elevated chemical concentrations. Nevertheless, while the EMAP/EC non-random dataset has larger frequencies of "Highs" than its random counterpart, it does not have higher proportions than NS&T/MW. This is because not all the non-random EMAP sites were chosen for their expected elevated contaminant levels. Some were chosen for expected low levels to test for differences in biological effects between extremes of contamination, some were chosen to test for biological effects unrelated to chemical contamination and some were chosen to lie in deposition areas. Similarly, while NS&T/BS data have more "Highs" than NS&T/MW, there are many sites within

# Table 5

Percentages of "High" concentrations in COSED by dataset.

| | EMAP | EMAP | SFTB | NS&T /BS | NS&T /MW | ODES | REGION4 | STORET | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| Random | No | Yes | No | No | No[1] | No | No | No | |
| Total Sites | 141 | 500 | 74 | 436 | 224 | 618 | 445 | 1440 | 3878 |
| %"High" Sites | 39 | 38 | 78 | 65 | 55 | 84 | 42 | 51 | 56 |
| Ag | 6 | 8 | 64 | 19 | 16 | 26 | 15 | 34 | 22 |
| As | 11 | 8 | 34 | 12 | 13 | 34 | n/a | 21 | 18 |
| Cd | 15 | 12 | 33 | 28 | 16 | 59 | 25 | 34 | 31 |
| Cr | 7 | 3 | 47 | 25 | 14 | 20 | 6 | 4 | 11 |
| Cu | 11 | 10 | 61 | 28 | 18 | 49 | 11 | 30 | 25 |
| Hg | 17 | 12 | 64 | 28 | 15 | 46 | 25 | 41 | 30 |
| Ni | 8 | 5 | 66 | 13 | 13 | 10 | 1 | 14 | 11 |
| Pb | 12 | 12 | 32 | 20 | 13 | 52 | 11 | 21 | 23 |
| Sb | 4 | 1 | 33 | 6 | 15 | 7 | n/a | 20 | 8 |
| Se | 11 | 6 | 23 | 6 | 14 | 21 | n/a | 32 | 15 |
| Sn | 14 | 17 | 57 | 22 | 12 | n/a | n/a | 42 | 20 |
| Zn | 21 | 17 | 42 | 29 | 15 | 35 | 9 | 20 | 22 |
| High MW PAH | 10 | 9 | 57 | 24 | 18 | 45 | 28 | 26 | 23 |
| Low MW PAH | 13 | 12 | 38 | 21 | 17 | 48 | 14 | 26 | 22 |
| Total PAH | 4 | 2 | 36 | 12 | 14 | 1 | 1 | 6 | 6 |
| Total Chlordane | 6 | 2 | 21 | 14 | 14 | 71 | 11 | 5 | 8 |
| Total Dieldrin | 4 | 1 | 58 | 7 | 13 | 10 | 4 | 2 | 6 |
| Total DDT | 11 | 9 | 52 | 24 | 18 | 46 | 28 | 26 | 23 |
| Total PCB | 8 | 5 | 43 | 37 | 15 | 0 | 7 | 9 | 15 |

1 Not random, but representative sites.
Percentages are based on number of sites analyzed for the particular chemical, a number usually less than the total number of sites.

# Table 6

Percentages of "5High" concentrations in COSED by dataset.

| | EMAP | EMAP | SFTB | NS&T/ BS | NS&T/M W | ODES | REGION4 | STORET | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| Random | No | Yes | No | No | No[1] | No | No | No | |
| Total Sites | 141 | 500 | 74 | 436 | 224 | 618 | 445 | 1440 | 3878 |
| %"5xHigh" Sites | 11 | 6.2 | 32.4 | 17 | 11 | 35 | 7.6 | 12 | 15 |
| Ag | 4.0 | 2.4 | 4.8 | 5.0 | 4.0 | 3.8 | 0.7 | 8.6 | 4.6 |
| As | 0.0 | 0.0 | 4.1 | 0.0 | 0.0 | 5.0 | n/a | 2.4 | 1.7 |
| Cd | 3.5 | 2.0 | 4.8 | 2.9 | 0.4 | 22 | 2.9 | 6.5 | 7.1 |
| Cr | 1.4 | 0.0 | 0.0 | 2.1 | 0.9 | 0.7 | 0.4 | 0.7 | 0.8 |
| Cu | 1.4 | 1.4 | 0.0 | 1.4 | 0.0 | 5.9 | 1.1 | 15 | 2.4 |
| Hg | 5.1 | 2.6 | 15 | 4.4 | 1.8 | 20 | 3.1 | 6.6 | 7.3 |
| Ni | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.2 | 0.0 | 0.2 | 0.1 |
| Pb | 2.9 | 0.6 | 2.7 | 0.0 | 0.0 | 9.5 | 2.2 | 2.6 | 3.0 |
| Sb | 0.0 | 0.2 | 30 | 0.8 | 0.0 | 3.6 | n/a | 5.4 | 2.2 |
| Se | 0.7 | 0.2 | 0.0 | 0.0 | 0.0 | 1.2 | n/a | 5.8 | 1.3 |
| Sn | 4.3 | 1.4 | 0.0 | 3.3 | 0.9 | n/a | n/a | 24 | 4.7 |
| Zn | 1.4 | 0.6 | 1.4 | 0.2 | 0.0 | 3.9 | 0.5 | 2.3 | 1.6 |
| High MW PAH | 3.5 | 1.4 | 10 | 1.9 | 1.8 | 11 | 9.0 | 13 | 5.4 |
| Low MW PAH | 4.3 | 1.6 | 8.0 | 3.6 | 1.8 | 18 | 2.2 | 8.1 | 5.6 |
| Total PAH | 2.1 | 0.2 | 12 | 3.9 | 2.2 | 1.1 | 0.0 | 2.6 | 2.0 |
| Total Chlordane | 0.7 | 0.2 | 12 | 0.2 | 2.7 | 42 | 5.6 | 1.6 | 1.8 |
| Total Dieldrin | 0.7 | 0.0 | 25 | 0.0 | 0.4 | 5.5 | 1.9 | 0.2 | 1.2 |
| Total DDT | 3.5 | 1.4 | 10 | 2.7 | 1.8 | 12 | 6.7 | 13 | 5.5 |
| Total PCB | 2.8 | 1.2 | 14 | 8.5 | 2.3 | 0.0 | 2.0 | 1.2 | 3.5 |

[1] Not random, but representative sites.
Percentages are based on number of sites analyzed for the particular chemical, a number usually less than the total number of sites.

that dataset that were chosen to be representative rather than particularly contaminated For the SFTB, ODES, Region4, and STORET datasets there is no information to indicate the motivation for site selection. We know that some of the SFTB and Region4 sets contain data from files of the U.S Army Corps of Engineers that was collected in the context of dredging slips and piers and is therefore likely to be fairly contaminated. We know that STORET and ODES contain data collected in the context of compliance monitoring of point sources of chemical discharges. The information, however, needed to sort through those datasets to extract what might be considered data that represents background conditions, is not readily available.

It must be recognized that the COSED database cannot be used simply as a collection of numbers that, in the aggregate, define the extent of sediment contamination in the coastal United States If it were simply used in that fashion, it would give the impression that elevated levels of contamination are common throughout the coastal nation. That would be wrong because many of the datasets embedded within COSED are biased, by site selection, towards elevated concentrations. Table **6** corresponds to Table **5** except that frequencies were calculated for "5xHigh" sites rather than "High" ones The same types of bias are still evident, but, because frequencies of "5xHigh" concentrations are generally low, they do not show as much difference between datasets as do the frequencies of "High" concentrations.

The 597 "5xHigh" sites listed in Tables **3** and **4** are not distributed evenly along the coastal U S , rather, they are clustered in relatively small areas. Approximately 50% of them are located in just three places. Boston Harbor, Southern California, and Puget Sound (see Appendix III). The New York Bight has also been sampled extensively over the years, and 40 "5xHigh" sites are in this locality, while more than 20 "5xHigh" sites are located in San Francisco Bay. Excluding the above 300 "5xHigh" sites, the remaining 180 are clustered into smaller groups and distributed along the coastal line. This is demonstrated in the last two columns of Appendix **II**, examination of which reveals that most "5xHigh" sites have several other neighboring "5xHigh" sites within a 10 km radius.

## AREAL EXTENT OF CHEMICAL CONCENTRATIONS

Converting COSED to an estimate of the areal extent of chemical concentrations is, in principle, possible The procedure would be to lay a grid of squares (or any shape) over a map of the U S coast and, using COSED, assign concentrations for each chemical to each square within the grid. The coastal area with Cu concentrations ≥ 50 μg/g, for example, would be the sum of areas of squares with assigned concentrations ≥ 50 μg/g. However, two considerations argue against doing that. First, it would be computationally tedious because the size of the squares would have to change with location as the spatial density of the sites changed. Squares could be very small where COSED has many records over small spatial scales. Squares would need to be very large, on the other hand, where data are sparse The second reason for not attempting this spatial analysis is because the EMAP/EC Program was designed specifically to provide statistically rigorous estimates of environmental conditions on a spatial basis. It is unnecessary to try to extract information from COSED that EMAP/EC is already providing

The EMAP/NC Program sampling design is based on a grid pattern of hexagons that is mapped onto the coast prior to any data collection Sampling sites are chosen by randomly selecting hexagons. A central assumption is that, in the aggregate, it is possible to calculate the areal extents of every attribute measured in each hexagon It is never assumed that the attribute, i e , Cu concentration, measured at one site in the hexagon represents the mean for the entire hexagon. It is argued that over large regional scales encompassing many hexagons, that one can use the data to calculate the percentage of area with Cu concentrations in a given range We can combine all the EMAP data in COSED that is from randomly selected sites to calculate cumulative fractions of total estuarine area in the combined Virginian and Louisianian Provinces that is covered with sediment at concentrations below any given value. Figure **8** is the result of that calculation for Cu and shows, for example, that over 90% of the total estuarine area in those combined provinces has surface sediment with concentrations less than 50 μg/g

Table **7** lists the percentage of area that exceeds the "high" concentration for each chemical. The percentages are less than those in the corresponding column in Table **5** because not every concentration in the EMAP/EC-random dataset is associated with the same size area. All concentrations from large estuaries are from randomly selected 280 $km^2$ hexagons but there are also randomly selected small

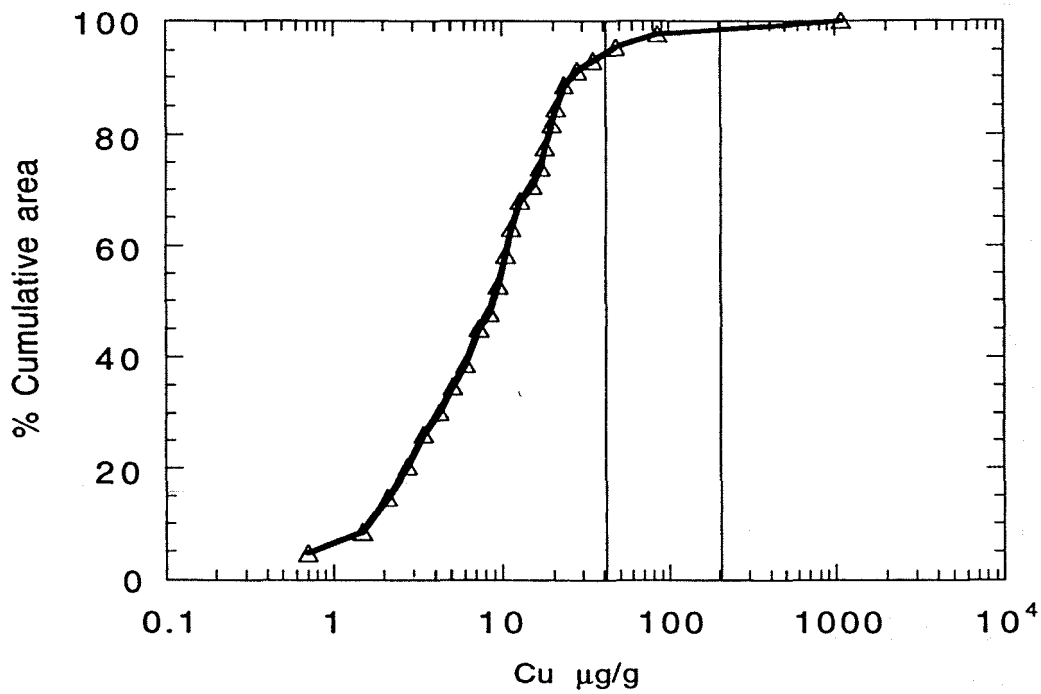



Figure 8. Cumulative estuarine area in combined Virginian and Louisianian Provinces as a function of Cu concentration (µg/g dry) in sediment. The two vertical lines represent the "High" (lower concentration) and "5xHigh" (greater concentration) from the NS&T/MW dataset.

estuaries and tidal rivers that have smaller and, unique areal extents in the range of 1 to 270 $km^2$.

The EMAP data are ideal for making these types of areal estimates over large regions of the country. At the moment, there are no EMAP data for the Southeast, the West Coast, or the Northeast Coast from Cape Cod to Canada. When these Provinces have been sampled, it will be possible to construct tables and figures of cumulative areas on a national scale.

# Table 7

EMAP % area above "High" or "5xHigh"

| Analyte | "High" | "5xHigh" |
|---|---|---|
| Ag | 1.3 | 0.1 |
| As | 7.3 | 0 |
| Cd | 4.5 | 1 |
| Cr | 1.5 | 0 |
| Cu | 5 | 1.4 |
| Hg | 6.8 | 1.2 |
| Ni | 1.9 | 0 |
| Pb | 6.1 | 0.3 |
| Sb | 1.2 | 0.7 |
| Se | 4.4 | 0.7 |
| Sn | 10.7 | 1.5 |
| Zn | 9.3 | 0.3 |
| High MW PAH | 1.6 | 0.4 |
| Low MW PAH | 4.4 | 0.7 |
| Total Chlordane | 1.2 | 0.5 |
| Total DDT | 0.3 | 0 |
| Total Dieldrin | 0.1 | 0 |
| Total PAH | 2.7 | 0 |
| Total PCB | 1.2 | 0.2 |

With more data, Figure **8** will shift to the right or left but it is unlikely that concentrations of Cu, or any other chemical, corresponding to "5xHigh" or ER-M (210 and 270µg/g, respectively) concentrations will account for more than a very small portion of the total coastal area. Cumulative plots for all contaminants from EMAP data have been calculated in Appendix **III**, and it was observed that in all cases only a small percentage of the area had concentrations above the "5xHigh". This simply reiterates the theme that extreme concentrations are of limited spatial extent.

## "HIGH" CONCENTRATIONS AND CONTAMINATION

The analysis of COSED has been based on raw data because the majority of records have no entries for aluminum, iron, grain-size, or total organic carbon that might have been used to adjust concentrations for their natural components It is worth investigating, however, whether "High" concentrations are due to contamination and not natural factors.

Because they are associated with surfaces, concentrations of trace chemicals in sediment tend to increase as particle size decreases Even under pristine conditions there will be a range of trace element concentrations that roughly parallels the portion of fine-grained particles in a sediment sample One way of accounting for this effect is to "normalize" trace concentrations against the concentrations of a major element whose concentration also increases as particles become smaller Candidates for this major element have been aluminum (Goldberg et al , 1979, Windom et al , 1989; Hanson et al , 1993), iron (Kennicutt et al, 1994), and lithium (Loring, 1990) The basic idea of all these authors has been to establish the "natural" relationship of the minor to major element by regression over a range of concentrations in sediments known *a priori* to be free of contamination (e.g. Cu=mAl+b where m and b are the slope and intercept, respectively, of a linear regression). With the relationship established for each trace element, contamination can then be declared to exist when a concentration is found that exceeds the predicted "natural" value. This approach assumes that the major element concentration is too high to be affected by human activity, and that the samples selected for establishing the relationship are unaffected by humans This selection is to some extent subjective, but is generally valid based as it is on sites that are far from industrial sources of contamination

Within all of COSED, 99% of the Al concentrations are less than 10% (10,000 ppm-dry) and 99% of the Fe concentrations are less than 6% (6,000 ppm-dry). In Table **8,** some of the relationships that have been established were applied to the "High" concentrations to calculate the corresponding concentration of aluminum or iron. For all elements, except As, it is clear that "High" concentrations are beyond the range where they can be considered natural.

Since all the relationships used in Table **8** are entirely or predominantly based on pristine sites in the Southeast and Gulf coasts, it must be recognized that the

# Table 8

## Normalization Parameter Concentrations for "High" to be Consistent with Natural Levels

| | | Al%[1] | Al%[1] | Al%[2] | Fe%[3] |
|---|---|---|---|---|---|
| | NS&T/MW "High" /ppm | GA/SC | Florida | East-Gulf | East-Gulf |
| Ag | 0.52 | | | *58.* | |
| As | 13 | | 1.8 | 8.6 | 3.9 |
| Cd | 0.54 | | | *27.* | |
| Cr | 125 | | 13 | 14 | 7.3 |
| Cu | 42 | 24 | 16 | 21 | 11 |
| Hg | 0.22 | | | *21* | |
| Mn | 875 | 15 | 18 | *9..5* | 4.5 |
| Ni | 42 | 10 | 14 | 13 | 6.6 |
| Pb | 45 | 12 | 13 | 14 | 7.8 |
| Se | 0.92 | | | *19.* | |
| Sn | 4.0 | | | 10 | 6.3 |
| Zn | 135 | 12 | 11 | 11 | 5.8 |

Numbers in italics denote low correlation coefficients in the linear models.

[1] Windom et al (1989).

[2] Hanson et al (1993).

[3] Work in progress by the authors

natural concentrations in other parts of the United States may be higher than predicted by the equations behind Table 8. It should also be recognized that the correlation coefficients for those equations are weak (i e less than 0.3) for Ag, Cd, Hg, and Se. Nevertheless, while absolute certainty does not apply in every case, it does appear that "High" concentrations do not occur naturally Concentrations above "5xHigh" are certainly due to contamination.

## CHEMICAL CONCENTRATIONS AND TOXICITY

The central reason for interest in chemical concentrations is not for their own sake, but because there should be a connection between them and biological effects. Those effects, not the chemicals themselves, are the problem. Converting the areal estimates of chemical concentrations to the areal extent of the problem requires a basis for selecting concentrations of concern.

If the ER-M concentrations of Long et al. (in press) actually correspond to concentrations above which biological effects can be expected, then the frequencies of "5xHigh" concentrations might parallel the occurrences of biologically effective concentrations, since the ERM concentrations are within a factor of two of "5xHigh" (Table **2**). The EMAP dataset provides a test of this possibility because results of chemical analyses are accompanied by an estimate of whether the sample was toxic. A sample was declared toxic if there was less than 80% survival of amphipods during ten-day exposures. Unfortunately, Table **9** shows that chemical concentrations are not particularly strong predictors of toxicity. The frequency of toxicity does increase with concentration, but concentrations in the highest range (either "5xHigh" or ER-M depending on chemical) do not correspond to more than about a 50% frequency of toxicity and, concentrations in the lowest range (below "High" or ER-L) still test as toxic in about 15% of the cases. For some chemicals, there are fewer than ten samples with concentrations in the highest range and no percentages were calculated.

While measures of toxicity based on bioassays do not lead to useful connections between concentration and effects, it does appear that observations of actual effects of chemical contamination among indigenous organisms is limited to urban areas where concentrations are very high. Therefore, while the spatial extent of chemical concentrations on large scales can be quantified from EMAP/EC data and on estuarine scale with the use of the rest of COSED, chemical data corresponding to biological damage among indigenous organisms needs to be collected through directed sampling over relatively small scales.

# Table 9

Toxic/total and percentages of toxic sites for all EMAP sites with concentrations[1] per chemical in various categories.

| | ≥ER-M | ≥"5xHigh" | ≥"High" | ≥ER-L | <"High" | <ER-L |
|---|---|---|---|---|---|---|
| | Toxic /Total | Toxic /Total | Toxic /Total | Toxic /Total | Toxic /Total | Toxic /Total |
| Ag | 5/9 | 6/10 | 11/31 | 10/22 | 64/438 | 65/448 |
| As | 0/0 | 0/0 | 7/47 | 21/130 | 69/421 | 55/338 |
| Cd | 2/2 | 5/12 | 20/58 | 15/35 | 65/527 | 70/550 |
| Cr | 3/3 | 2/2 | 9/13 | 19/76 | 82/595 | 72/532 |
| Cu | 3/3 | 4/4 | 19/50 | 21/73 | 74/557 | 72/534 |
| Hg | 13/28 | 8/14 | 20/63 | 36/125 | 72/512 | 56/450 |
| Ni | 7/15 | 0/0 | 11/33 | 49/245 | 79/560 | 41/348 |
| Pb | 5/6 | 4/4 | 21/62 | 21/64 | 72/540 | 72/538 |
| Zn | 7/13 | 2/5 | 23/84 | 23/87 | 70/526 | 70/523 |
| High MW PAH | 7/11 | 6/10 | 20/46 | 21/54 | 70/537 | 69/529 |
| Low MW PAH | 5/10 | 5/10 | 22/60 | 24/65 | 69/534 | 67/529 |
| Total PAH | 2/4 | 6/10 | 19/45 | 16/35 | 72/549 | 75/559 |
| Total DDT | 5/8 | 3/3 | 7/10 | 46/158 | 65/437 | 26/289 |
| Total PCB | 8/15 | 4/5 | 10/21 | 23/82 | 68/487 | 55/426 |
| | | | | | | |
| | %toxic | %toxic | %toxic | %toxic | %toxic | %toxic |
| Ag | | 60 | 35 | 45 | 15 | 15 |
| As | | | 15 | 16 | 16 | 16 |
| Cd | | 42 | 34 | 43 | 12 | 13 |
| Cr | | | 69 | 25 | 14 | 14 |
| Cu | | | 38 | 29 | 13 | 13 |
| Hg | 46 | 57 | 32 | 29 | 14 | 12 |
| Ni | 47 | | 33 | 20 | 14 | 12 |
| Pb | | | 34 | 33 | 13 | 13 |
| Zn | 54 | | 27 | 26 | 13 | 13 |
| High MW PAH | 64 | 60 | 43 | 39 | 13 | 13 |
| Low MW PAH | 50 | 50 | 37 | 37 | 13 | 13 |
| Total PAH | | 60 | 42 | 46 | 13 | 13 |
| Total DDT | | | 70 | 29 | 15 | 9 |
| Total PCB | 53 | | 48 | 28 | 14 | 13 |

[1] Concentrations marking categories are listed in Table **2.**
%Toxic were calculated only when total samples were more than ten.

## SPECIFIC CASES

While COSED was developed to provide a national assessment, there are sufficient data to define extents of contamination on estuarine scales Tables **10-14** provide the total number of samples and sites in five specific regions, along with numbers of sites where mean concentrations exceed "5xHigh" levels. Figures **9-14** are maps where sites are plotted as "Low", "High", or "5xHigh" depending on contaminant levels. In addition, all "5xHigh" sites are presented in Appendix **II**, along with all the contaminants over "5xHigh" level, and the number of "5xHigh" sites within a 10 or 20 km radius

### *Boston Harbor*

MacDonald (1991), using sediment and tissue data collected by various surveys at 448 separate stations, concluded that contamination was widespread in biota and sediments. COSED data yielded the same conclusion As seen in Figure **9**, almost all the stations had high levels of contamination, even when they were located outside the harbor. Along with Long Island Sound and New York Bight, this is one of only three cases in our database that almost every sediment sample exceeds the "High" level. Within the harbor, levels of contamination were higher in the North side as seen by the number of the "5xHigh" stations, as seen in Table **10**. Metals, in particular Hg, Cd, and Pb were the most commonly found contaminants throughout the harbor, with Hg being present at above "5xHigh" levels at over 60% of the sites The highest levels of pollutants were found in the enclosed waterways, e.g. the Mystic River

Table 10

Total number of sites in Boston Harbor with at least one chemical at "5xHigh" levels, and total concentrations per chemical

| | |
|---|---|
| Total | 150 |
| "5xHigh" | 109 |
| Ag | 13 |
| Cd | 55 |
| Cu | 14 |
| Hg | 96 |
| Pb | 29 |
| Sb | 1 |
| Sn | 7 |
| Zn | 6 |
| High MW PAH | 1 |
| Low MW PAH | 3 |
| Total DDT | 1 |
| Total PAH | 1 |
| Total PCB | 5 |

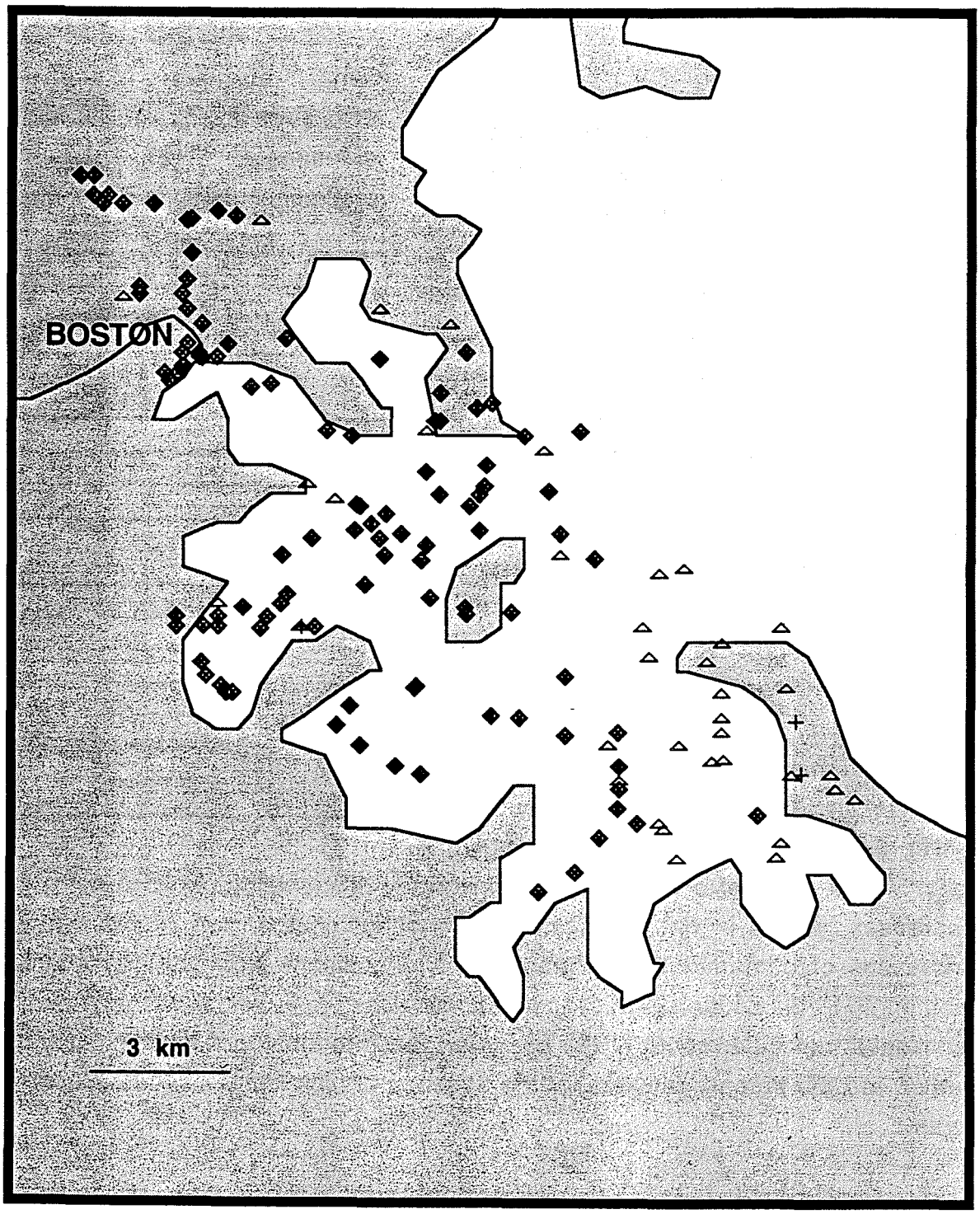



Figure 9. Boston Harbor sites included in COSED. Sites have been divided into "Low" (crosses), "High" (triangles), and "5xHigh" (diamonds) categories, based on NS&T/MW "High" concentrations.

### *Chesapeake Bay*

There is a large number of sampling sites throughout the Chesapeake Bay, as seen in Figure **10**. The majority of the sites in the middle and lower bay have low levels of pollutants, while contaminated sediments are more common in the upper bay. A few "5xHigh" spots were found in the Chesapeake Bay, mostly in Baltimore harbor, with one each in Norfolk harbor; James River; lower, middle, and upper bay; and Washington D.C. (Anacostia River). However, these are small areas that should not alter the overall picture, and apparently do not contribute great levels of contamination to the bay Higher concentrations of chemical substances in the upper estuary are attributed to natural and anthropogenic sources alike. The major supplier of fresh water is the Susquehanna River, discharging into the northern part of the bay. Scavenging of dissolved contaminants by precipitating particles as the salinity increases results in fine sediment accumulation in this part of the estuary and increases of contamination Atmospheric depositions from the city of Baltimore contribute to the contaminant concentrations in the upper part of the bay, too. Sandy sediments near the mouth of the bay, along with the influx of relatively clean ocean water, are the primary reasons for the absence of high levels of contaminants in this area.

## Table 11

Total number of sites in Chesapeake Bay with at least one chemical at "5xHigh" levels, and total concentrations per chemical.

| | Sites |
|---|---|
| Total | 370 |
| "5xHigh" | 24 |
| Ag | 5 |
| Cd | 8 |
| Cr | 1 |
| Cu | 8 |
| Hg | 1 |
| Pb | 2 |
| Sb | 2 |
| Se | 2 |
| Sn | 10 |
| Zn | 9 |
| High MW PAH | 3 |
| Low MW PAH | 8 |
| Total PAH | 4 |
| Total PCB | 3 |

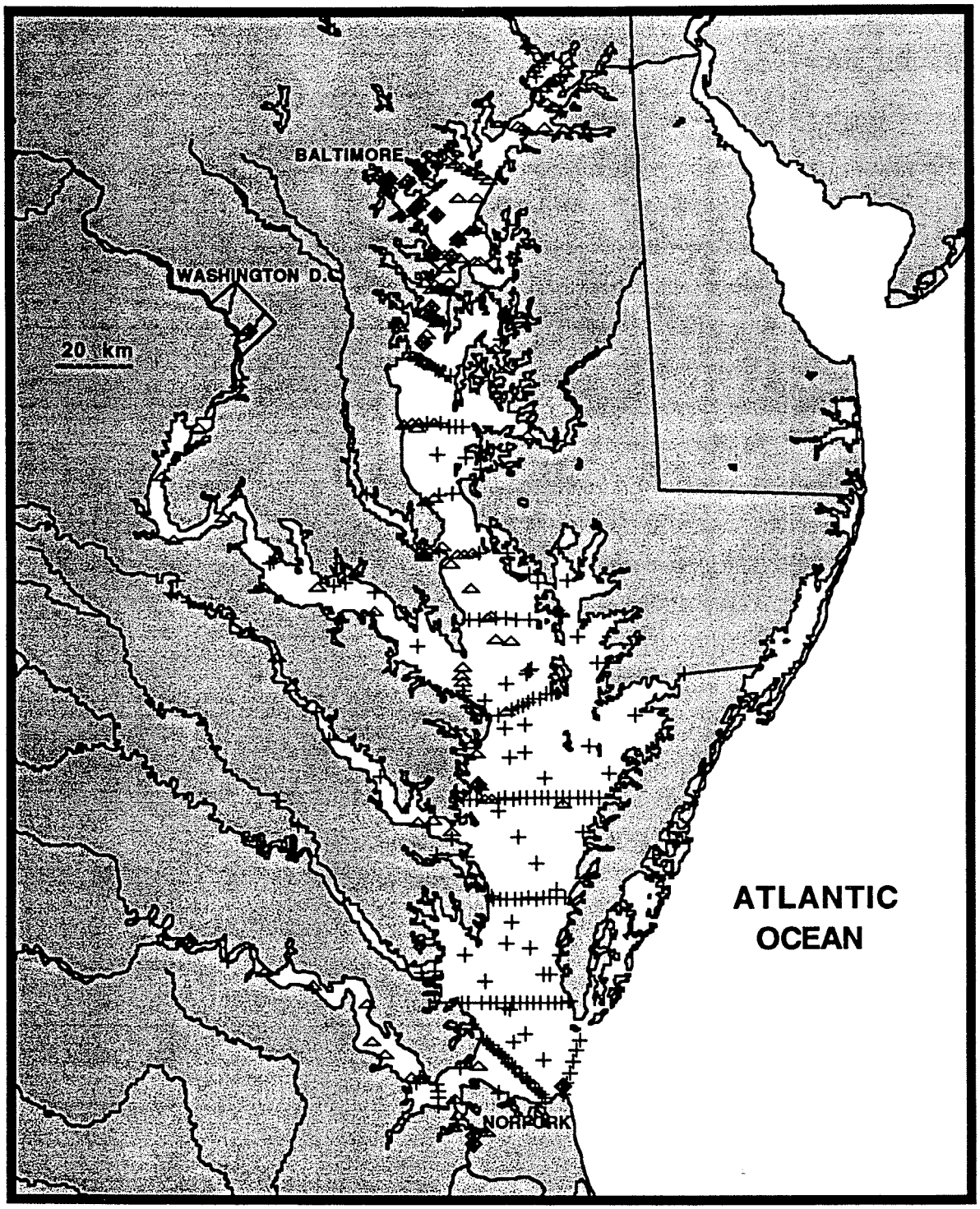



Figure 10. "Low" (crosses), "High" (triangles), and "5xHigh" (diamonds) sites from Chesapeake Bay included in COSED.

### *Tampa Bay*

Tampa Bay is characterized by chemical concentrations that vary strongly with location In agreement with Long et al (1991), the highest levels of contamination are found throughout Hillsborough Bay, and most of the "5xHigh" spots are located in the inner part of this bay (Figure **11**). Two more "5xHigh" sites and two "High" sites are located in the Manatee River, along with several low-level sites Exceptions to the general rule are several sites with "High" concentration levels in the middle Tampa Bay area. Old Tampa Bay appears to be relatively clean, but limited number of stations there, and also in Boca Ciega Bays, make any conclusion difficult. In contrast to other highly contaminated areas, "5xHigh" spots in Tampa Bay do not have contaminant concentrations reaching extreme levels Cadmium was the most common contaminant, and was present in seven sites Pesticides and other organic contaminants were found occasionally in Tampa Bay, as seen in Table **12**.

## Table 12

Total number of sites in Tampa Bay with at least one chemical at "5xHigh" levels, and total concentrations per chemical.

| | Sites |
|---|---|
| Total | 125 |
| "5xHigh" | 11 |
| Cd | 7 |
| Cu | 1 |
| Hg | 3 |
| Pb | 3 |
| Zn | 1 |
| High MW PAH | 2 |
| Low MW PAH | 2 |
| Total Chlordane | 4 |
| Total DDT | 2 |
| Total Dieldrin | 3 |
| Total PAH | 2 |
| Total PCB | 4 |

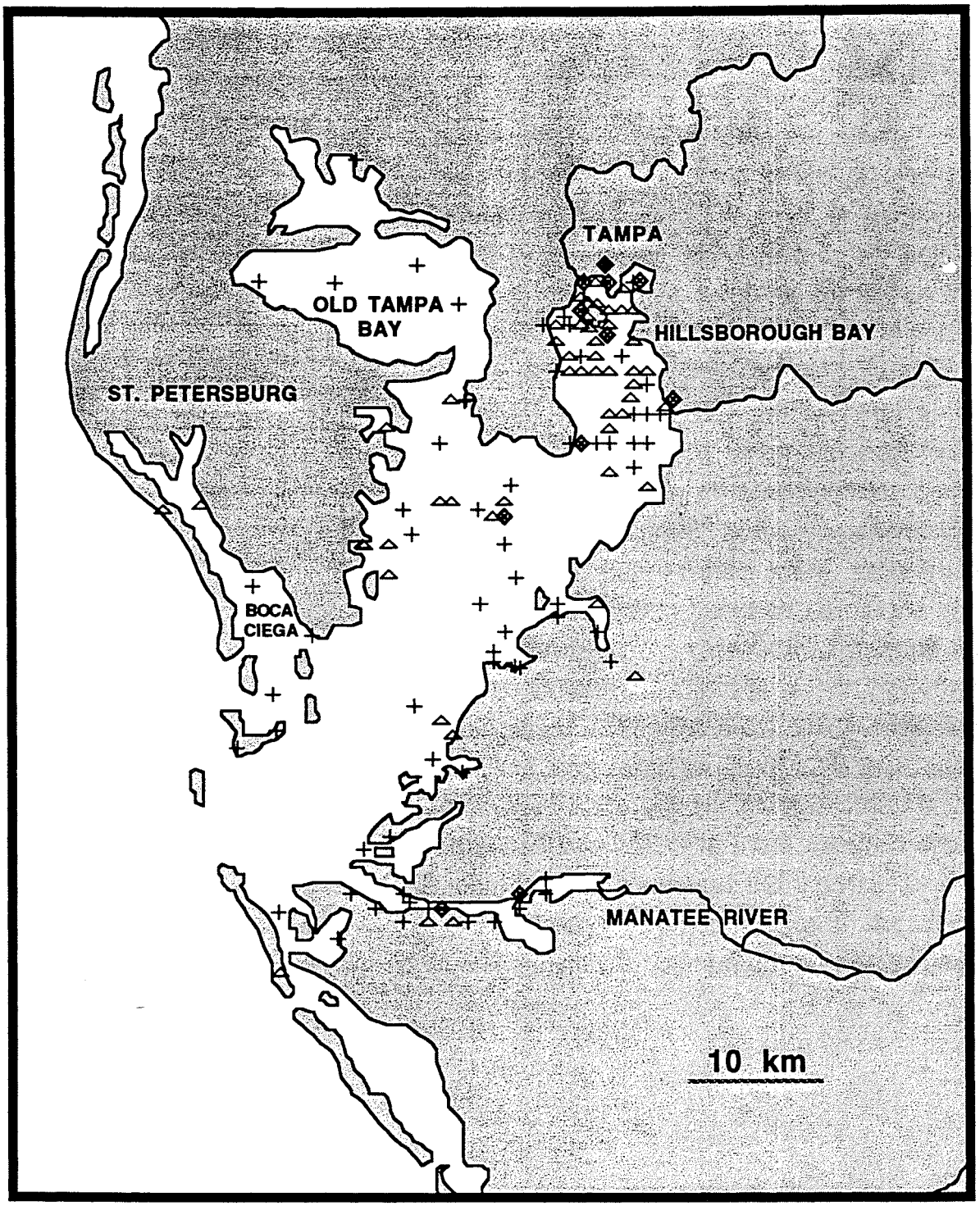



Figure 11. "Low" (crosses), "High" (triangles), and "5xHigh" (diamonds) sites from Tampa Bay appearing in COSED.

***Santa Monica & San Pedro Bay.***

There are several "5xHigh" sites along the coastal line of southern California in our database, as seen in Figure **7**. Specifically, in San Pedro and Santa Monica Bays there are numerous samples of high contaminant concentration. Besides the sites near the coast, we find "5xHigh" sites as far as 12 miles out into the Gulf of Santa Catalina Pesticides are some of the most frequently found contaminants, in particular total DDT, which was present at "5xHigh" levels at 20% of the sites. Many samples were "5xHigh", but one should be cautious in interpreting these findings as widespread contamination Although there are 1726 samples in the database, there were only 142 unique sites, thus many sites were sampled tens of times. Over 1200 samples, i.e. the great majority of these samples, were 301h sewage discharge program samples, from 53 sites. There are 49 "5xHigh" Cd samples, but all of them are located at 4 sites, as can be seen in Table **13**. Since, in some reports, the unique locations may not be given, statistics based solely on the number of samples should be viewed with skepticism.

## Table 13

Total number of sites in Southern California with at least one chemical at "5xHigh" levels, and total concentrations per chemical

| | Sites |
|---|---|
| Total | 142 |
| "5xHigh" | 46 |
| Ag | 4 |
| Cd | 4 |
| Cr | 1 |
| Cu | 1 |
| Hg | 3 |
| Sb | 1 |
| Se | 1 |
| Sn | 11 |
| Tl | 12 |
| Total Chlordane | 3 |
| Total DDT | 20 |
| Total Dieldrin | 2 |

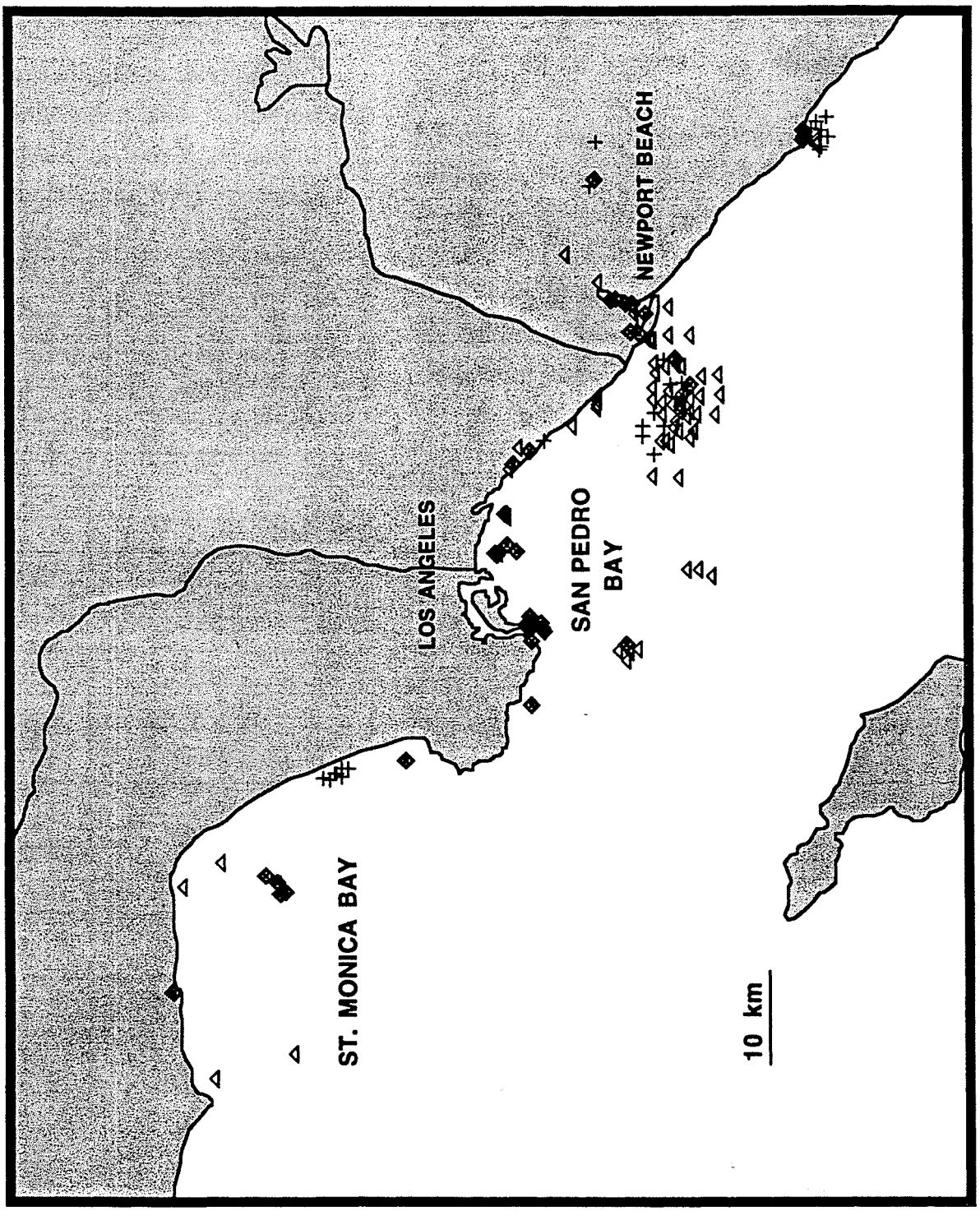



Figure **12.** Sites from Southern California divided in "Low" (crosses), "High" (triangles), and "5xHigh" (diamonds) as explained in the text.

### *Puget Sound*

Data from a large number of stations have been found for Puget Sound, mainly located in Inlets and Bays, as seen in Figures **13** and **14a-b** Over 30% of the sites exceeded the NS&T "High" concentrations for Pb, although Cd was the most commonly found element at the "5xHigh" level, followed by PAHs, Pb, As, and Cu Most of the "5xHigh" cases were found in Commencement Bay and Duwamish waterway Other areas of concern were in Bainbridge island, Sinclair Inlet, and Case Inlet In general, although Puget Sound appears to be heavily contaminated, it is the region between Commencement Bay and Bainbridge Island that bears the majority of the contaminated sites with the remaining bay being moderately contaminated. Previous works support these results for example, Paulson et al (1989) determined that high concentrations of dissolved Cd, Cu, Pb, and Zn were emitted from anthropogenic sources, shipyards, and other industrial areas, in Elliott Bay and the Duwamish Waterway A smaller number of samples from COSED, in the Hood Canal, indicate relatively clean sediments in this area

## Table 14

Total number of sites in Puget Sound with at least one chemical at "5xHigh" levels, and total concentrations per chemical.

| | Sites |
|---|---|
| Total | 634 |
| "5xHigh" | 135 |
| Ag | 5 |
| As | 23 |
| Cd | 63 |
| Cu | 14 |
| Hg | 7 |
| Ni | 1 |
| Pb | 28 |
| Sb | 10 |
| Se | 3 |
| Sn | 17 |
| Tl | 1 |
| Zn | 13 |
| High MW PAH | 51 |
| Low MW PAH | 58 |
| Total Chlordane | 2 |
| Total PAH | 55 |
| Total PCB | 1 |

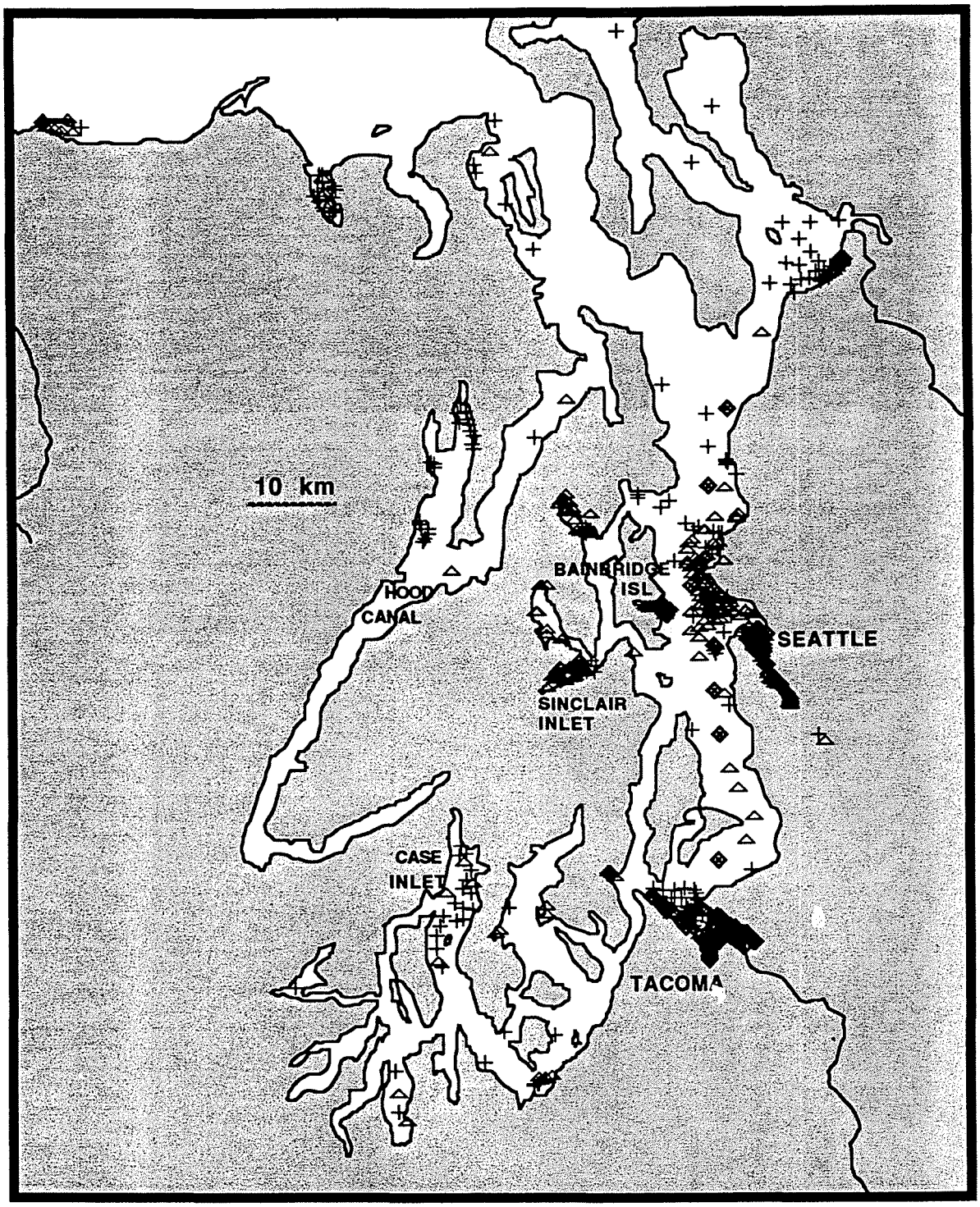
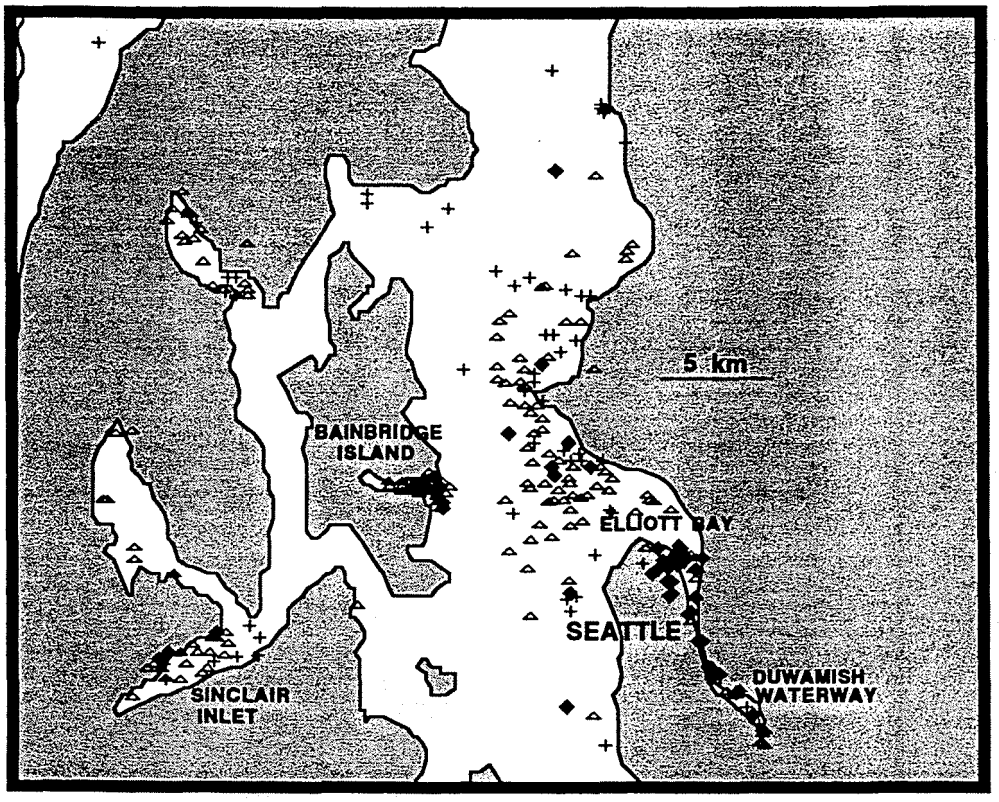
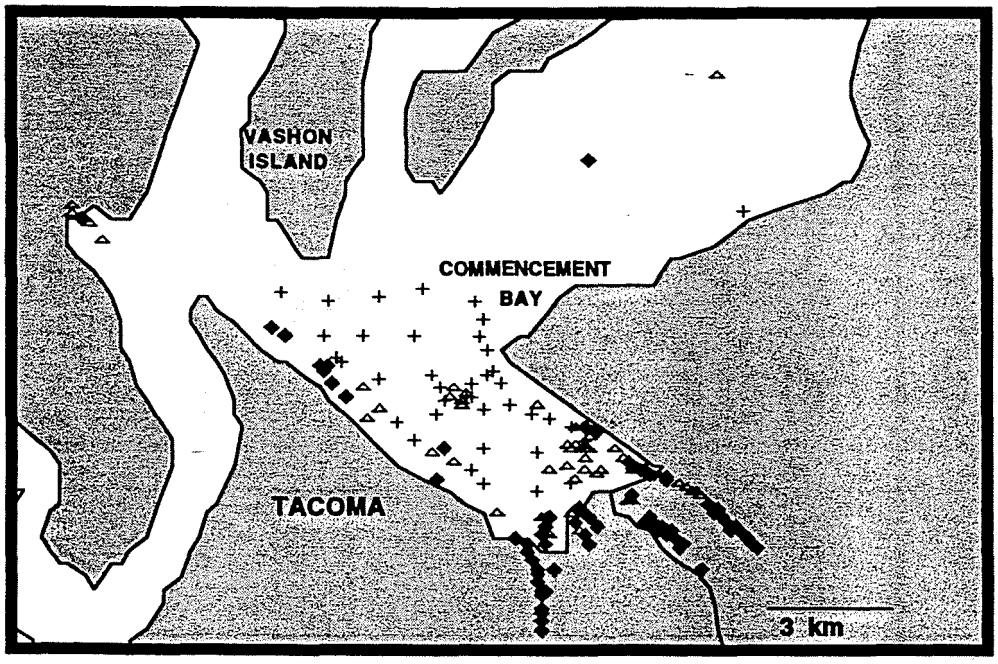



Figure 13. Puget Sound sites included in COSED categorized as "Low" (crosses), "High" (triangles), and "5xHigh" (diamonds).




(a)




(b)

Figure 14. Details of Puget Sound sites included in COSED: a) Seattle area, and b) Tacoma and Commencement Bay.

# CONCLUSIONS

COSED has been compiled for sediment chemistry in the coastal U.S. The data reveals a number of sites with contaminant concentrations above "5xHigh" levels (five times the NS&T "High" value). Two general conclusions can be drawn from this work:

- Most of the "5xHigh" sites were located near large cities, suggesting anthropogenic sources for these contaminats.

- The spatial scale of contamination varies depending on location, but in general, it appears that smaller water bodies with high human activity and high mean residence times bear the majority of the pollution.

The extent of contamination in the coastal U.S. should be objectively assessed from a random, statistically unbiased dataset. This requires selection of sites without any preference to a specific type of location. Most of the data in COSED are, to various degrees, biased towards sites with elevated concentrations. The EMAP/EC sampling scheme, however, meets these requirements while assigning an areal extent to each measured concentration. The EMAP/EC dataset is, therefore, ideal for determining spatial extents for chemical concentrations over national and large regional scale. As the EMAP/EC Program expands to parts of the U. S. coast beyond the Virginian and Louisianian Provinces, it will become increasingly valuable.

While EMAP/EC data will provide a national assessment, directed sampling on local scales will be necessary to delineate the distributions of chemical concentrations that are sufficient to cause biological effects.

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# APPENDIXES

# APPENDIX I

## Number of all parameter occurrences in COSED

| PARAMETER | DETECTED | BELOW DETECTION | TOTAL |
|---|---|---|---|
| *HIGH MW PAH* | *3162* | *1580* | *4742* |
| *LOW MW PAH* | *2930* | *1906* | *4836* |
| *TOTAL PAH* | *3400* | *1472* | *4872* |
| *TOTAL CHLORDANE* | *1970* | *3824* | *5794* |
| *TOTAL DIELDRIN* | *1643* | *6936* | *8579* |
| *TOTAL AROCHLORS* | *8* | *863* | *871* |
| *TOTAL DDT* | *2440* | *4271* | *6711* |
| *TOTAL PCB* | *2441* | *1078* | *3519* |
| *TOTAL PCB ANALOGS* | *1276* | *193* | *1469* |
| *GRAINSIZE* | *2917* | *55* | *2972* |
| TOTAL ORGANIC CARBON (TOC) | 2450 | 29 | 2479 |
| ALUMINUM | 4365 | 31 | 4396 |
| ANTIMONY | 2551 | 1507 | 4058 |
| ARSENIC | 6206 | 460 | 6666 |
| CADMIUM | 6920 | 1181 | 8101 |
| CHROMIUM | 8674 | 178 | 8852 |
| COPPER | 6251 | 96 | 6347 |
| IRON | 3505 | 61 | 3566 |
| LEAD | 11995 | 344 | 12339 |
| MANGANESE | 3898 | 61 | 3959 |
| MERCURY | 9671 | 729 | 10400 |
| NICKEL | 7150 | 357 | 7507 |
| SELENIUM | 2920 | 1547 | 4467 |
| SILICON | 1525 | 64 | 1589 |
| SILVER | 5442 | 683 | 6125 |
| THALLIUM | 2006 | 999 | 3005 |
| TIN | 2512 | 252 | 2764 |
| ZINC | 9082 | 82 | 9164 |
| ACENAPTHENE | 1246 | 1725 | 2971 |
| ACENATHYLENE | 1254 | 2518 | 3772 |
| ANTHRACENE | 1999 | 2499 | 4498 |
| ANTHRACENE-PHENANTHRENE | 44 | 21 | 65 |
| BENZ[a]ANTHRACENE | 2236 | 2149 | 4385 |
| BENZO[a]PYRENE | 2272 | 2148 | 4420 |
| BENZO[ b]FLUORANTHENE | 1006 | 2027 | 3033 |

**Entries in italics have been calculated and are not included in the Grand Total.**

Number of parameters in COSED

| PARAMETER | DETECTED | BELOW DETECTION | TOTAL |
|---|---|---|---|
| BENZOFLUORANTHENE MIXTURE | 877 | 860 | 1737 |
| BENZO[e]PYRENE | 2000 | 605 | 2605 |
| BENZO[GHI]PERYLENE | 1333 | 2243 | 3576 |
| BENZOPERYLENE MIXTURE | 35 | 248 | 283 |
| BIPHENYL | 1203 | 1357 | 2560 |
| BENZO[k]FLUORANTHENE | 899 | 2061 | 2960 |
| CARBAZOLE | 0 | 238 | 238 |
| CHRYSENE | 2493 | 2204 | 4697 |
| CHRYSENE-BENZ[a]ANTHRACENE | 27 | 33 | 60 |
| DIBENZ[a h] ANTHRARACENE | 1554 | 2751 | 4305 |
| DIMETHYLNAPTHALENE | 1243 | 1315 | 2558 |
| FLUORANTENE | 2829 | 1904 | 4733 |
| FLUORENE | 1689 | 2461 | 4150 |
| INDENO | 1344 | 2506 | 3850 |
| LINDANE | 682 | 4113 | 4795 |
| 1-METHYLNAPHTHALENE | 1379 | 1521 | 2900 |
| 2-METHYLNAPHTHALENE | 1796 | 1630 | 3426 |
| 1-METHYLPHENANTHRENE | 1471 | 1085 | 2556 |
| NAPTHALENE | 2134 | 1964 | 4098 |
| PERYLENE | 1954 | 676 | 2630 |
| PHENANTH | 2679 | 1953 | 4632 |
| PYRENE | 2886 | 1855 | 4741 |
| TRIMETH | 888 | 1207 | 2095 |
| ALDRIN | 548 | 7949 | 8497 |
| CIS-CHLORDANE | 1474 | 2793 | 4267 |
| CHLORDANE MIX | 239 | 1494 | 1733 |
| TRAN-CHLORDANE | 5 | 105 | 110 |
| CIS-NONACHLOR | 138 | 282 | 420 |
| DIELDRIN | 1374 | 6527 | 7901 |
| ENDRIN | 221 | 5269 | 5490 |
| ENDRIN-ALDRIN | 0 | 193 | 193 |
| HEPTACHLOREPOXIDE | 456 | 4744 | 5200 |
| HEPTACHLOR | 523 | 4859 | 5382 |
| HEXACHLOROBENZENE | 1229 | 3084 | 4313 |
| KEPONE | 0 | 21 | 21 |
| MIREX | 474 | 2769 | 3243 |
| TOXAPHENE | 35 | 865 | 900 |
| TRANS-NONACHLOR | 1184 | 1500 | 2684 |
| O,P,DDD | 893 | 1634 | 2527 |

Number of parameters in COSED

| PARAMETER | DETECTED | BELOW DETECTION | TOTAL |
|---|---|---|---|
| O,P,DDE | 508 | 2032 | 2540 |
| O,P,DDT | 440 | 1746 | 2186 |
| P,P,DDD | 1485 | 1122 | 2607 |
| P,P,DDE | 1738 | 855 | 2593 |
| P,P,DDT | 1067 | 1600 | 2667 |
| DDE | 9 | 204 | 213 |
| DDT | 7 | 204 | 211 |
| DDTS | 412 | 3394 | 3806 |
| PCB8 | 609 | 1286 | 1895 |
| PCB18 | 587 | 1586 | 2173 |
| PCB28 | 865 | 1308 | 2173 |
| PCB44 | 780 | 1392 | 2172 |
| PCB52 | 900 | 1288 | 2188 |
| PCB66 | 819 | 1352 | 2171 |
| PCB101 | 1069 | 1117 | 2186 |
| PCB105 | 691 | 1482 | 2173 |
| PCB11077 | 295 | 757 | 1052 |
| PCB118 | 975 | 1197 | 2172 |
| PCB126 | 179 | 927 | 1106 |
| PCB128 | 718 | 1469 | 2187 |
| PCB138 | 1244 | 944 | 2188 |
| PCB153 | 1073 | 1115 | 2188 |
| PCB170 | 709 | 1412 | 2121 |
| PCB180 | 978 | 1210 | 2188 |
| PCB187 | 847 | 1326 | 2173 |
| PCB195 | 639 | 1533 | 2172 |
| PCB206 | 735 | 1452 | 2187 |
| PCB209 | 790 | 1395 | 2185 |
| PCBS | 270 | 714 | 984 |
| GRAVEL | 541 | 527 | 1068 |
| SAND | 1313 | 9 | 1322 |
| SILT | 1392 | 38 | 1430 |
| CLAY | 1065 | 34 | 1099 |
| | | | |
| **GRAND TOTAL** | **175117** | **140653** | **315770** |

# APPENDIX II

## Sites in COSED with at least one "5xHigh" substance.

| ORIGIN | LONGITUDE | LATITUDE | 5xHIGH | NE 10 | NE 20 |
|---|---|---|---|---|---|
| ODES | 70 3800 | 42 3317 | Ag | 0 | 0 |
| ODES | 70 5719 | 42 4189 | Cd | 2 | 2 |
| ODES | 70 5758 | 42 4272 | Zn,Pb | 1 | 1 |
| ODES | 70 5878 | 42 4272 | Zn,Pb | 1 | 1 |
| NS&T/BS | 70 8267 | 42 5367 | Cr,Cd | 5 | 5 |
| NS&T/BS | 70 8500 | 42 5383 | TPCB,Hg,Cr,Cd | 5 | 5 |
| NS&T/BS | 70 8600 | 42 5250 | Cr,Cd | 5 | 5 |
| ODES | 70 8653 | 42 3444 | Zn,Hg,Cd | 12 | 18 |
| NS&T/BS | 70 8667 | 42 5217 | Hg,Cr,Cd | 5 | 5 |
| NS&T/MW | 70 8670 | 42 5188 | Cr | 5 | 5 |
| NS&T/BS | 70 8733 | 42 5167 | TPCB,LPAH,Cr,Cd | 5 | 5 |
| NS&T/MW | 70 8783 | 41 5870 | TPCB | 2 | 2 |
| NS&T/BS | 70 8917 | 41 5833 | TPCB | 2 | 2 |
| ODES | 70 8958 | 42 2667 | Pb,Cd | 36 | 46 |
| EMAP/random | 70 9117 | 41 6425 | TCDANE,TPCB,Hg,Cu,Cd | 2 | 2 |
| ODES | 70 9278 | 42 2653 | Hg | 57 | 65 |
| ODES | 70 9325 | 42 2722 | Hg | 61 | 67 |
| ODES | 70 9328 | 42.2764 | Hg | 62 | 66 |
| ODES | 70 9333 | 42 2681 | Hg | 58 | 66 |
| ODES | 70 9333 | 42 2833 | Hg | 63 | 66 |
| ODES | 70 9375 | 42 2625 | Hg | 61 | 71 |
| ODES | 70 9389 | 42 3175 | Hg | 74 | 76 |
| ODES | 70 9431 | 42 3431 | Hg,Cd | 80 | 81 |
| ODES | 70 9444 | 42 2556 | Hg | 63 | 73 |
| ODES | 70 9472 | 42 2828 | Hg | 72 | 85 |
| ODES | 70 9472 | 42 2944 | Ag | 74 | 88 |
| ODES | 70 9486 | 42 3222 | Hg | 89 | 93 |
| ODES | 70 9514 | 42 3306 | Hg,Cd | 98 | 98 |
| ODES | 70 9542 | 42 2514 | Hg | 63 | 74 |
| ODES | 70 9583 | 42 3417 | Hg | 98 | 99 |
| ODES | 70 9597 | 42 2861 | Hg | 77 | 101 |
| ODES | 70 9611 | 42 3069 | Hg | 93 | 102 |
| NS&T/BS | 70 9667 | 42 2867 | Sn,Ag,Hg | 78 | 99 |
| NS&T/BS | 70 9667 | 42 3483 | Ag | 98 | 101 |
| ODES | 70 9681 | 42 3361 | Hg | 102 | 103 |
| NS&T/BS | 70 9683 | 42 3317 | TPCB,LPAH | 101 | 103 |
| ODES | 70 9700 | 42 3228 | Hg | 98 | 102 |
| NS&T/BS | 70 9700 | 42 3300 | TPCB,TDDT,HPAH,LPAH,Sn,Ag,Hg,Sb | 99 | 102 |
| ODES | 70 9708 | 42 3472 | Hg,Cd | 101 | 104 |
| ODES | 70 9722 | 42 3278 | Cd | 100 | 105 |
| NS&T/BS | 70 9733 | 42 3067 | TPCB,Sn,Ag,Hg | 95 | 106 |
| NS&T/MW | 70 9733 | 42 3583 | Ag | 99 | 104 |
| ODES | 70 9736 | 42 3078 | Hg | 96 | 105 |
| ODES | 70 9806 | 42 3300 | Hg,Cd | 102 | 104 |
| ODES | 70 9806 | 42 3447 | Ag,Cd | 102 | 105 |
| ODES | 70 9806 | 42 3500 | Hg,Cd | 100 | 105 |
| NS&T/BS | 70 9817 | 42 3450 | LPAH,Sn,Ag | 104 | 107 |
| ODES | 70 9828 | 42 3097 | Hg,Pb,Cd | 100 | 107 |
| ODES | 70 9833 | 42 3200 | Hg | 100 | 106 |
| ODES | 70 9833 | 42 3347 | Hg | 105 | 106 |
| ODES | 70 9847 | 42 2750 | Hg | 76 | 94 |
| ODES | 70 9847 | 42 3172 | Hg,Cd | 100 | 106 |
| ODES | 70 9864 | 42 2922 | Ag,Cd | 91 | 104 |

LPAH Low MW PAH, HPAH High MW PAH, TPAH Total PAH,
TCDANE Total Chlordane TDIELD Total Dieldrin TDDT Total DDT, TPCB Total PCB
Random = No Site selected for monitoring or regulatory requirements
Random = Yes Site selected randomly
NE10 and NE20 Number of neighboring "5xHigh" sites within 10 and 20 km, respectively

"5xHigh"sites in COSED

| ORIGIN | LONGITUDE | LATITUDE | 5xHIGH | NE 10 | NE 20 |
|---|---|---|---|---|---|
| NS&T/BS | 70 9867 | 42 2917 | Sn,Ag,Hg | 91 | 105 |
| ODES | 70 9903 | 42 3222 | Hg,Pb,Cd | 103 | 106 |
| ODES | 70 9917 | 42 2764 | Hg | 84 | 94 |
| ODES | 70 9939 | 42 3264 | Hg,Pb,Cd | 106 | 107 |
| ODES | 70 9950 | 42 3181 | Hg | 103 | 106 |
| ODES | 70 9958 | 42 3217 | Hg,Cd | 102 | 106 |
| ODES | 70 9958 | 42 3569 | Hg | 98 | 104 |
| ODES | 70 9981 | 42 3244 | Hg,Cd | 106 | 107 |
| ODES | 71 0000 | 42 3125 | Hg | 101 | 107 |
| ODES | 71 0014 | 42 2806 | Hg | 88 | 95 |
| ODES | 71 0014 | 42 3278 | Hg | 105 | 105 |
| NS&T/BS | 71 0017 | 42 3283 | Sn,Ag | 107 | 107 |
| ODES | 71 0028 | 42 3228 | Hg,Cd | 106 | 106 |
| NS&T/BS | 71 0033 | 42 3417 | Sn,Ag,Cd | 101 | 106 |
| ODES | 71 0042 | 42 2883 | Hg,Cd | 92 | 103 |
| ODES | 71 0069 | 42 2847 | Hg | 90 | 98 |
| ODES | 71 0097 | 42 3431 | Hg,Cd | 100 | 106 |
| ODES | 71 0131 | 42 3042 | Cd | 98 | 105 |
| ODES | 71 0139 | 42 3217 | Hg,Cd | 106 | 106 |
| ODES | 71 0200 | 42 3106 | Hg | 105 | 107 |
| ODES | 71 0208 | 42 3606 | Hg,Cd | 98 | 105 |
| ODES | 71 0217 | 42 3181 | Hg,Cd | 106 | 106 |
| ODES | 71 0222 | 42 3083 | Hg | 104 | 107 |
| ODES | 71 0250 | 42 3522 | Hg | 98 | 106 |
| ODES | 71 0258 | 42 3061 | Hg | 103 | 106 |
| ODES | 71 0278 | 42 3033 | Hg | 102 | 107 |
| ODES | 71 0300 | 42 3514 | Hg,Cd | 98 | 106 |
| ODES | 71 0319 | 42 3078 | Hg,Pb,Cd | 103 | 105 |
| ODES | 71 0339 | 42 3853 | Hg | 80 | 94 |
| ODES | 71 0347 | 42 2911 | Hg | 88 | 98 |
| ODES | 71 0350 | 42 2911 | Hg,Cd | 88 | 98 |
| ODES | 71 0361 | 42 3597 | Hg,Cu,Cd | 94 | 99 |
| ODES | 71 0367 | 42 2911 | Hg,Pb,Cd | 88 | 98 |
| ODES | 71 0378 | 42 2922 | Hg | 88 | 98 |
| NS&T/MW | 71 0383 | 42 3042 | TPCB,Ag | 99 | 101 |
| ODES | 71 0389 | 42 3058 | Hg | 98 | 100 |
| ODES | 71 0389 | 42 3861 | Hg | 77 | 93 |
| ODES | 71 0394 | 42 3575 | Hg,Pb,Cu,Cd | 93 | 97 |
| ODES | 71 0417 | 42 2944 | Hg | 88 | 99 |
| ODES | 71 0422 | 42 3042 | Hg | 96 | 98 |
| ODES | 71 0431 | 42 2967 | Hg | 90 | 98 |
| ODES | 71 0431 | 42 3569 | Hg,Pb,Cu,Cd | 90 | 95 |
| ODES | 71 0431 | 42 3639 | Hg,Cd | 90 | 96 |
| ODES | 71 0436 | 42 3575 | Hg,Pb,Cu,Cd | 91 | 96 |
| ODES | 71 0439 | 42 3578 | Hg,Pb,Cu,Cd | 90 | 96 |
| ODES | 71 0458 | 42 3778 | Hg,Cd | 83 | 94 |
| ODES | 71 0458 | 42 3847 | Hg,Pb,Cd | 76 | 92 |
| ODES | 71 0472 | 42 3597 | Hg,Pb,Cu,Cd | 87 | 93 |
| ODES | 71 0472 | 42 3667 | Hg,Pb,Cd | 87 | 94 |
| ODES | 71 0472 | 42 3722 | Hg,Pb,Cd | 83 | 94 |
| ODES | 71 0472 | 42 3842 | Hg | 75 | 90 |
| ODES | 71 0475 | 42 3556 | Hg,Cd | 91 | 94 |
| ODES | 71 0486 | 42 3556 | Hg,Pb,Cd | 89 | 92 |
| ODES | 71 0486 | 42 3578 | Hg,Cd | 88 | 92 |
| ODES | 71 0486 | 42 3694 | Zn,Hg,Pb,Cu,Cd | 85 | 92 |
| ODES | 71 0500 | 42 3042 | Hg,Cd | 89 | 91 |
| ODES | 71 0500 | 42 3061 | Hg,Pb,Cd | 92 | 92 |
| ODES | 71 0500 | 42 3542 | Hg | 88 | 91 |
| ODES | 71 0514 | 42 3528 | Hg,Pb,Cu,Cd | 91 | 94 |
| ODES | 71 0528 | 42 3542 | Hg,Pb,Cu,Cd | 88 | 92 |
| ODES | 71 0556 | 42 3875 | Zn,Hg,Pb,Cu,Cd | 71 | 85 |
| ODES | 71 0597 | 42 3694 | Zn,Hg,Pb,Cu,Cd | 80 | 90 |
| ODES | 71 0597 | 42 3708 | Hg,Pb | 80 | 91 |

"5xHigh"sites in COSED

| ORIGIN | LONGITUDE | LATITUDE | 5xHIGH | NE 10 | NE 20 |
|---|---|---|---|---|---|
| ODES | 71.0639 | 42.3875 | Zn,Hg,Pb,Cd | 64 | 83 |
| EMAP/non-random | 71.0648 | 41.5234 | LPAH | 0 | 0 |
| ODES | 71.0681 | 42.3889 | Hg,Pb,Cu,Cd | 61 | 82 |
| ODES | 71.0694 | 42.3875 | Zn,Hg,Pb,Cd | 61 | 80 |
| ODES | 71.0722 | 42.3889 | Hg,Pb,Cd | 57 | 76 |
| ODES | 71.0722 | 42.3931 | Zn,Hg,Pb,Cu,Cd | 47 | 70 |
| ODES | 71.0750 | 42.3931 | Hg,Pb,Cu,Cd | 47 | 67 |
| ODES | 71.0958 | 42.3806 | Hg,Pb,Cd | 48 | 64 |
| EMAP/random | 71.1232 | 41.7667 | Ag,Hg | 1 | 2 |
| EMAP/non-random | 71.1637 | 41.7107 | Ag,Hg | 2 | 2 |
| EMAP/random | 71.2057 | 41.6982 | Hg | 1 | 2 |
| NS&T/BS | 71.3217 | 41.6583 | TPCB | 1 | 1 |
| NS&T/BS | 71.3533 | 41.6733 | Ag | 1 | 1 |
| STORET | 71.8497 | 41.3269 | Hg | 0 | 0 |
| STORET | 72.0756 | 41.4817 | TCDANE | 0 | 0 |
| STORET | 72.6433 | 41.7561 | TCDANE | 0 | 0 |
| EMAP/non-random | 72.8858 | 41.3133 | HPAH,LPAH | 1 | 1 |
| STORET | 72.9147 | 41.2622 | Pb | 1 | 1 |
| EMAP/random | 73.0720 | 41.2867 | Sn,Cu | 1 | 1 |
| STORET | 73.0797 | 41.3306 | TPCB | 1 | 1 |
| NS&T/MW | 73.1097 | 41.1678 | TCDANE,HPAH | 0 | 0 |
| EMAP/non-random | 73.2103 | 41.1597 | TPCB,TDDT,HPAH,LPAH,Zn,Sn,Pb,Cu,Cr,Cd | 2 | 2 |
| STORET | 73.2153 | 41.1561 | Zn,Pb,Cr | 2 | 2 |
| STORET | 73.2192 | 41.1506 | Zn,Pb,Cr | 2 | 2 |
| NS&T/MW | 73.4128 | 41.0567 | LPAH | 0 | 0 |
| STORET | 73.4667 | 40.5583 | Cd | 0 | 0 |
| STORET | 73.5381 | 41.0297 | TCDANE | 0 | 0 |
| NS&T/MW | 73.6690 | 40.8523 | Ag | 0 | 0 |
| STORET | 73.7450 | 40.4433 | Ag,Hg,Cd | 8 | 10 |
| STORET | 73.7500 | 40.3983 | Cd | 6 | 7 |
| STORET | 73.7500 | 40.4317 | Ag,Hg,Cd | 8 | 9 |
| STORET | 73.7500 | 40.4625 | Ag | 6 | 8 |
| STORET | 73.7867 | 40.4361 | Ag | 11 | 13 |
| STORET | 73.7889 | 40.3000 | Ag,Hg,Sb | 5 | 9 |
| STORET | 73.7917 | 40.3817 | Hg | 13 | 13 |
| STORET | 73.7917 | 40.3983 | TDDT,LPAH,Ag,Hg,Pb,Cd,Sb | 9 | 10 |
| NS&T/MW | 73.8012 | 40.8195 | Ag | 2 | 2 |
| STORET | 73.8200 | 40.3483 | Hg | 8 | 12 |
| STORET | 73.8200 | 40.3683 | Hg | 11 | 13 |
| STORET | 73.8200 | 40.3983 | Ag,Hg,Cd | 9 | 10 |
| STORET | 73.8300 | 40.4182 | Ag,Hg,Cd | 14 | 14 |
| STORET | 73.8500 | 40.3983 | Ag,Hg,Cd | 9 | 11 |
| STORET | 73.8533 | 40.3700 | Ag,Hg | 11 | 11 |
| EMAP/random | 73.8553 | 40.7768 | HPAH,LPAH,Sn,Ag,Hg,Cu,Cd | 4 | 4 |
| EMAP/non-random | 73.8615 | 40.7918 | TPCB,HPAH,LPAH,Sn,Ag,Hg | 3 | 4 |
| STORET | 73.8633 | 40.3608 | Ag,Hg,Pb | 10 | 11 |
| STORET | 73.8633 | 40.5592 | Ag,Hg,Cd | 0 | 0 |
| EMAP/random | 73.8928 | 41.0185 | TPCB,Ag,Hg | 0 | 0 |
| STORET | 73.9017 | 40.4167 | Ag | 6 | 7 |
| EMAP/random | 73.9317 | 40.7918 | TPCB,HPAH,LPAH,Ag,Hg,Pb | 2 | 3 |
| EMAP/non-random | 73.9385 | 40.7833 | HPAH,LPAH,Ag,Hg | 3 | 4 |
| EMAP/random | 73.9428 | 40.8833 | Ag | 0 | 3 |
| EMAP/random | 73.9452 | 41.7333 | TPCB | 0 | 0 |
| EMAP/random | 73.9667 | 41.2742 | TPCB,TDDT,Hg,Cd | 0 | 0 |
| STORET | 73.9833 | 40.2167 | Ag,Hg | 0 | 0 |
| EMAP/random | 73.9917 | 41.5160 | HPAH,LPAH | 0 | 0 |
| NS&T/BS | 74.0133 | 40.4533 | TPCB,Sn,Ag,Hg,Cu,Cd | 6 | 6 |
| NS&T/BS | 74.0183 | 40.5933 | TPCB,Ag,Hg | 3 | 5 |
| NS&T/MW | 74.0425 | 40.6897 | HPAH,LPAH,Sn,Ag,Hg | 4 | 5 |
| NS&T/MW | 74.0450 | 40.4878 | TPCB,Ag,Hg | 7 | 7 |
| NS&T/BS | 74.0483 | 40.5350 | TPCB,Sn,Ag,Hg | 8 | 8 |
| NS&T/MW | 74.0522 | 40.5662 | TPCB,HPAH,Ag,Hg | 6 | 7 |
| EMAP/non-random | 74.0747 | 40.6478 | TPCB,Sn,Ag,Hg,Pb,Cd | 5 | 5 |

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| ORIGIN | LONGITUDE | LATITUDE | 5xHIGH | NE 10 | NE 20 |
|---|---|---|---|---|---|
| EMAP/random | 74 0750 | 40 4600 | Sn,Ag,Hg | 9 | 9 |
| NS&T/BS | 74 0833 | 40 4667 | TPCB | 9 | 10 |
| NS&T/BS | 74 0850 | 40 4833 | Ag,Hg | 10 | 10 |
| EMAP/random | 74 0867 | 40 7500 | HPAH,LPAH | 3 | 3 |
| NS&T/BS | 74 0900 | 40 4917 | TPCB,Sn,Ag,Hg | 10 | 10 |
| EMAP/random | 74 1108 | 40 0517 | Cd | 0 | 0 |
| EMAP/non-random | 74 1163 | 40 7047 | Hg | 6 | 9 |
| STORET | 74 1178 | 40 6917 | Zn,Ag,Hg,Pb,Cr,Cd | 7 | 11 |
| NS&T/MW | 74 1572 | 40 5065 | TPCB,Sn,Ag,Hg | 12 | 16 |
| EMAP/non-random | 74 1650 | 40 7500 | TDIELD,TCDANE,TPCB,TDDT,HPAH,LPAH,Pb | 2 | 2 |
| NS&T/BS | 74 1700 | 40 4917 | TPCB,Ag,Hg,Cd | 13 | 16 |
| NS&T/BS | 74 1717 | 40 4917 | TPCB,Sn,Ag,Hg | 13 | 16 |
| STORET | 74 1761 | 40 6461 | TDDT,HPAH,LPAH,Zn,Ag,Hg,Pb,Cd,As | 12 | 14 |
| STORET | 74 1836 | 39 6936 | Hg | 0 | 0 |
| STORET | 74 1964 | 40 6378 | TDDT,HPAH,LPAH,Ag,Hg,Pb,Cd | 12 | 14 |
| STORET | 74 2006 | 40 5994 | TDDT,HPAH,Ag,Hg,Pb,Cd,As | 13 | 17 |
| EMAP/non-random | 74 2033 | 40 6217 | TDDT | 12 | 15 |
| STORET | 74 2039 | 40 6167 | TDDT,HPAH,LPAH,Zn,Ag,Hg,Pb,Cd | 12 | 15 |
| STORET | 74 2055 | 40 5911 | HPAH,Zn,Ag,Hg,Pb,Cd | 11 | 16 |
| STORET | 74 2056 | 40 5911 | Ag,Hg,Cd | 11 | 16 |
| STORET | 74 2056 | 40 5911 | Ag,Hg,Pb,Cr | 11 | 16 |
| STORET | 74 2119 | 40 5706 | Zn,Ag,Hg,Pb,Cd | 17 | 17 |
| STORET | 74 2119 | 40 5706 | Zn,Pb | 17 | 17 |
| STORET | 74 2120 | 40 5706 | Zn,Ag,Hg,Pb,Cd | 17 | 17 |
| STORET | 74 2189 | 40 5581 | Ag,Hg,Pb,Cd | 18 | 19 |
| STORET | 74 2494 | 40 5244 | Ag,Hg,Pb,As | 15 | 17 |
| STORET | 74 2517 | 40 5508 | HPAH,Zn,Ag,Hg,Pb,Cd | 17 | 19 |
| STORET | 74 2589 | 40 5017 | Ag,Hg,Pb,Cd | 10 | 14 |
| EMAP/non-random | 74 2638 | 40 4903 | Pb,Cd | 10 | 10 |
| EMAP/random | 74 3000 | 40 5112 | HPAH,LPAH,Pb,Sb | 8 | 12 |
| EMAP/random | 74 7280 | 40 1667 | Zn,Cd | 0 | 0 |
| EMAP/random | 74 8363 | 40 1012 | HPAH,LPAH,Cd | 0 | 0 |
| EMAP/random | 75 0310 | 39 1485 | Cd | 0 | 0 |
| EMAP/random | 76 0082 | 36 9563 | HPAH,LPAH | 0 | 0 |
| EMAP/random | 76 2768 | 37 7153 | Cd | 0 | 0 |
| NS&T/BS | 76 2900 | 36 8100 | HPAH,LPAH | 1 | 1 |
| EMAP/random | 76 2938 | 36 8318 | Cu | 1 | 1 |
| NS&T/BS | 76 3333 | 39 1017 | LPAH | 3 | 3 |
| STORET | 76 3533 | 39 0533 | Zn | 2 | 2 |
| NS&T/MW | 76 4012 | 39 1600 | LPAH | 3 | 5 |
| NS&T/BS | 76 4167 | 38 9283 | LPAH | 0 | 1 |
| STORET | 76 4167 | 39 0617 | Zn | 2 | 3 |
| EMAP/random | 76 4428 | 38 8382 | Sn | 0 | 1 |
| EMAP/random | 76 4433 | 39 2700 | Zn,Sn,Ag,Cu,Cd | 3 | 4 |
| EMAP/non-random | 76 4433 | 39 2700 | Sn,Ag,Cd | 3 | 4 |
| EMAP/random | 76 4500 | 39 2750 | TPCB,Zn,Sn,Ag,Hg,Cu,Cd | 4 | 5 |
| STORET | 76 4517 | 39 1917 | Zn,Pb | 7 | 8 |
| STORET | 76 4683 | 39 1733 | Zn | 4 | 9 |
| EMAP/non-random | 76 4915 | 39 2433 | Zn,Sn,Cr,Cd | 10 | 11 |
| NS&T/BS | 76 5500 | 39 2267 | TPCB,LPAH,Zn,Sn,Ag,Cu,Cd,Sb | 7 | 8 |
| EMAP/non-random | 76 5517 | 39 2533 | Sn,Se,Cu | 5 | 7 |
| EMAP/random | 76 5570 | 39 2463 | Sn,Se,Cu | 5 | 6 |
| NS&T/BS | 76 5633 | 39 2450 | TPCB,HPAH,LPAH,Sn,Cu,Cd,Sb | 5 | 6 |
| NS&T/BS | 76 5783 | 39 2583 | TPCB,LPAH,Sn | 5 | 5 |
| EMAP/random | 76 9975 | 38 8697 | Ag | 0 | 0 |
| EMAP/random | 77 1918 | 37 3197 | Pb | 0 | 0 |
| ODES | 78 8489 | 42 8606 | TDIELD | 4 | 4 |
| ODES | 78 8542 | 42 8631 | HPAH,LPAH,Hg | 4 | 4 |
| ODES | 78 8672 | 42 8569 | TDIELD,HPAH,LPAH,Zn,Hg,Pb,Cd | 3 | 3 |
| ODES | 78 8672 | 42 8619 | HPAH,LPAH,Pb | 3 | 3 |
| ODES | 78 8844 | 42 8778 | TCDANE,HPAH,LPAH | 4 | 4 |
| STORET | 79 2833 | 33 3667 | Zn,Pb | 0 | 0 |
| STORET | 79 9306 | 32 8417 | Hg | 1 | 1 |

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| ORIGIN | LONGITUDE | LATITUDE | 5xHIGH | NE 10 | NE 20 |
|---|---|---|---|---|---|
| STORET | 79 9700 | 32 7875 | HPAH | 1 | 1 |
| STORET | 80 0961 | 26 9485 | Cd | 0 | 0 |
| REGION4 | 80 1800 | 25 7800 | Hg | 7 | 7 |
| REGION4 | 80 1800 | 25 8500 | TCDANE,HPAH,Pb | 8 | 9 |
| REGION4 | 80 1800 | 26 0900 | TCDANE,Hg | 1 | 1 |
| STORET | 80 1813 | 27 4583 | Sn,Ag,Se,As,Sb | 10 | 10 |
| STORET | 80 1833 | 27 4783 | Sn,Ag,Se,As,Sb | 10 | 10 |
| REGION4 | 80 1900 | 25 7700 | TDIELD,TCDANE,TPCB,LPAH,Hg,Pb | 9 | 9 |
| STORET | 80 1914 | 27 1500 | Hg | 3 | 3 |
| STORET | 80 1922 | 27 1464 | Ag | 3 | 3 |
| STORET | 80 1947 | 27 1442 | Hg | 3 | 3 |
| STORET | 80 1953 | 27 4632 | Sn,Ag,Se,Sb | 9 | 9 |
| STORET | 80 1995 | 27 4760 | Sn,Ag,Se,Sb | 10 | 10 |
| REGION4 | 80 2000 | 25 7700 | Hg,Pb,Cu | 9 | 9 |
| STORET | 80 2000 | 27 4417 | Sn,Ag,Se,Sb | 7 | 7 |
| STORET | 80 2000 | 27 4545 | Sn,Ag,Se,As,Sb | 7 | 7 |
| STORET | 80 2000 | 27 4753 | Sn,Ag,Se,Sb | 6 | 6 |
| STORET | 80 2000 | 27 4822 | Sn,Se,Sb | 7 | 7 |
| STORET | 80 2022 | 26 0875 | Pb | 1 | 1 |
| STORET | 80 2062 | 27 4632 | Sn,Ag,Se,Sb | 9 | 9 |
| STORET | 80 2092 | 27 4753 | Sn,Ag,Se,As,Sb | 9 | 9 |
| REGION4 | 80 2100 | 25 7800 | HPAH,Hg,Pb,Cu,Cr,Cd | 8 | 8 |
| STORET | 80 2138 | 27 4575 | Sn,Ag,Se,Sb | 10 | 10 |
| REGION4 | 80 2200 | 25 7800 | TDIELD,TCDANE,HPAH,Hg,Pb,Cu,Cd | 8 | 8 |
| REGION4 | 80 2400 | 25 8000 | TPCB,Hg,Pb | 9 | 9 |
| REGION4 | 80 2500 | 25 7900 | HPAH,LPAH | 8 | 8 |
| REGION4 | 80 2500 | 25 8000 | HPAH,Pb,Cd | 8 | 8 |
| STORET | 80 2599 | 27 2069 | TCDANE | 3 | 3 |
| REGION4 | 80 2600 | 25 7900 | HPAH,Ag,Hg,Pb,Cu,Cd | 7 | 8 |
| REGION4 | 80 2600 | 25 8100 | HPAH | 9 | 9 |
| NS&T/MW | 80 3142 | 25 5232 | TCDANE | 0 | 0 |
| STORET | 80 3217 | 25 2228 | Cd | 3 | 3 |
| STORET | 80 3258 | 25 2233 | Cd | 2 | 2 |
| STORET | 80 3278 | 25 2233 | Cd | 1 | 1 |
| STORET | 80 3278 | 25 2239 | Cd | 2 | 2 |
| STORET | 80 3333 | 32 6333 | TDDT | 0 | 0 |
| STORET | 80 3483 | 27 5578 | Ag,Se | 0 | 0 |
| STORET | 80 4807 | 27 8576 | Ag,Se | 0 | 0 |
| REGION4 | 80 6000 | 28 4100 | Cd | 0 | 0 |
| STORET | 80 6847 | 26 7487 | TDDT | 1 | 1 |
| STORET | 80 6943 | 26 7761 | TDDT | 1 | 1 |
| STORET | 80 7261 | 32 5442 | As | 3 | 3 |
| STORET | 80 7275 | 28 3617 | Se | 1 | 1 |
| STORET | 80 7278 | 32 5336 | As | 2 | 2 |
| STORET | 80 7278 | 32 5378 | As | 2 | 2 |
| REGION4 | 80 7300 | 28 4100 | TDIELD,Hg | 1 | 1 |
| STORET | 80 7939 | 32 5286 | As | 3 | 3 |
| STORET | 80 8000 | 28 6153 | Cd | 1 | 1 |
| STORET | 80 8131 | 28 6867 | Se | 1 | 1 |
| STORET | 81 0117 | 29 2117 | Se | 0 | 0 |
| STORET | 81 0866 | 29 3418 | Se | 1 | 1 |
| STORET | 81 0922 | 29 3894 | Se | 1 | 1 |
| NS&T/BS | 81 2417 | 31 5383 | HPAH | 0 | 0 |
| STORET | 81 4700 | 31 1642 | TDDT | 1 | 1 |
| STORET | 81 5158 | 31 1875 | Ag,Se,Hg,Cd | 1 | 1 |
| STORET | 81 5528 | 30 3933 | Cd | 2 | 2 |
| NS&T/BS | 81 6083 | 30 3933 | LPAH | 2 | 4 |
| NS&T/BS | 81 6450 | 30 3950 | HPAH,LPAH | 3 | 4 |
| NS&T/BS | 81 6567 | 30 2400 | LPAH | 3 | 3 |
| REGION4 | 81 6700 | 30 3200 | HPAH | 3 | 4 |
| NS&T/BS | 81 6817 | 30 1617 | LPAH | 1 | 1 |
| REGION4 | 81 7000 | 30 3000 | HPAH | 2 | 4 |
| REGION4 | 82 3900 | 27 8600 | Cd | 4 | 7 |

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| ORIGIN | LONGITUDE | LATITUDE | 5xHIGH | NE 10 | NE 20 |
|---|---|---|---|---|---|
| SFTB | 82 4153 | 27 9417 | TDIELD,TCDANE,TPCB,Pb,Cd | 6 | 6 |
| REGION4 | 82 4400 | 27 9400 | Hg | 5 | 6 |
| SFTB | 82 4406 | 27 9042 | TCDANE,TPCB | 7 | 7 |
| SFTB | 82 4425 | 27 9528 | TDIELD,TCDANE,TPCB,TDDT,HPAH,LPAH,Zn, Pb,Cd | 5 | 6 |
| SFTB | 82 4586 | 27 9403 | TDIELD,TCDANE,TPCB,TDDT,HPAH,LPAH,Cd | 5 | 6 |
| REGION4 | 82 4600 | 27 8300 | Pb,Cu,Cd | 3 | 3 |
| REGION4 | 82 4600 | 27 9200 | Cd | 6 | 6 |
| REGION4 | 82 5100 | 27 5200 | Hg | 1 | 1 |
| REGION4 | 82 5200 | 27 7800 | Cd | 1 | 1 |
| REGION4 | 82 5700 | 27 5100 | Hg | 1 | 1 |
| ODES | 83 8422 | 43 6236 | As | 6 | 6 |
| ODES | 83 8567 | 43 6139 | TDIELD | 6 | 6 |
| ODES | 83 8611 | 43 6119 | Cd | 6 | 6 |
| ODES | 83 8633 | 43 6117 | TCDANE,Cd,As | 6 | 6 |
| ODES | 83 8694 | 43 6122 | TDIELD,TCDANE,Cd | 6 | 6 |
| ODES | 83 8861 | 43 6078 | TDIELD | 6 | 6 |
| ODES | 83 9094 | 43 5628 | TDIELD | 6 | 6 |
| REGION4 | 83 9900 | 30 0800 | Ag,Cd | 0 | 0 |
| REGION4 | 85 3200 | 29 8300 | Hg | 0 | 0 |
| REGION4 | 85 5700 | 30 1400 | Hg | 2 | 2 |
| REGION4 | 85 6300 | 30 1400 | Cd | 2 | 2 |
| NS&T/MW | 85 6320 | 30 1422 | TPCB | 3 | 3 |
| NS&T/MW | 85 6633 | 30 1500 | HPAH,LPAH | 3 | 3 |
| NS&T/MW | 86 4788 | 30 4808 | TCDANE,TDDT | 0 | 1 |
| REGION4 | 86 5000 | 30 3900 | HPAH | 0 | 1 |
| REGION4 | 87 2400 | 30 3900 | HPAH | 6 | 7 |
| REGION4 | 87 2500 | 30 4000 | Zn | 7 | 7 |
| STORET | 87 2556 | 30 4028 | Pb | 7 | 7 |
| REGION4 | 87 2600 | 30 4100 | Zn,Pb,Cr | 7 | 7 |
| EMAP/random | 87 2937 | 30 3702 | Hg | 8 | 9 |
| REGION4 | 87 3000 | 30 3600 | Cd | 7 | 8 |
| REGION4 | 87 3000 | 30 3700 | Cd | 7 | 8 |
| STORET | 87 3383 | 30 4333 | Ag,Sb | 8 | 9 |
| STORET | 87 3667 | 30 4250 | TDDT | 6 | 7 |
| REGION4 | 87 3800 | 30 4600 | HPAH,LPAH | 2 | 6 |
| ODES | 87 4361 | 41 6678 | TDIELD,HPAH,LPAH,Zn,Pb,Cd | 6 | 6 |
| ODES | 87 4392 | 41 6736 | TDIELD,TCDANE,HPAH,LPAH,Zn,Pb,Cu,Cd | 6 | 6 |
| STORET | 87 4500 | 30 3833 | Cd | 2 | 3 |
| ODES | 87 4514 | 41 6608 | TDIELD,TCDANE,HPAH,LPAH,Zn,Pb,Cu,Cd | 6 | 6 |
| EMAP/non-random | 87 4583 | 30 3425 | Hg | 1 | 2 |
| ODES | 87 4597 | 41 6550 | TDIELD,TCDANE,HPAH,LPAH,Zn,Ag,Hg,Pb, Cu,Cr,Cd | 6 | 6 |
| ODES | 87 4714 | 41 6397 | TDIELD,TCDANE,HPAH,LPAH,Zn,Ag,Hg,Pb, Cu,Cr,Cd | 6 | 6 |
| ODES | 87 4722 | 41 6458 | TDIELD,TCDANE,HPAH,LPAH,Zn,Ag,Hg,Pb, Cu,Cr,Cd,As | 6 | 6 |
| ODES | 87 4806 | 41 6469 | TDIELD,TCDANE,HPAH,LPAH,Zn,Ag,Hg,Pb, Cu,Cr,Cd | 6 | 6 |
| EMAP/non-random | 89 2520 | 29 1497 | Hg | 0 | 0 |
| EMAP/random | 89 4930 | 29 3433 | Hg | 0 | 0 |
| STORET | 94 7867 | 29 6650 | Ag | 0 | 1 |
| STORET | 94 7958 | 29 3125 | Ag | 1 | 1 |
| EMAP/random | 94 8740 | 29 5733 | LPAH | 0 | 1 |
| STORET | 94 8903 | 29 2903 | Cd | 1 | 1 |
| STORET | 95 0528 | 29 5583 | TCDANE,Zn | 0 | 0 |
| STORET | 95 0925 | 33 3222 | Ni | 1 | 1 |
| STORET | 95 1306 | 33 3889 | Ni | 1 | 1 |
| NS&T/BS | 95 1633 | 29 7433 | TCDANE,TPCB | 0 | 0 |
| STORET | 95 1792 | 29 0950 | Cd | 1 | 1 |
| STORET | 95 2208 | 29 0183 | Ag | 1 | 1 |
| STORET | 95 2889 | 29 7500 | TDIELD,TCDANE,TPCB,Ag,Hg,Cd | 1 | 1 |
| STORET | 95 2894 | 29 6736 | TCDANE | 1 | 1 |

"5xHigh"sites in COSED

| ORIGIN | LONGITUDE | LATITUDE | 5xHIGH | NE 10 | NE 20 |
|---|---|---|---|---|---|
| STORET | 95 6875 | 29 0708 | Ag,Cd | 0 | 0 |
| STORET | 96 7200 | 28 3689 | Hg | 0 | 0 |
| STORET | 97 0311 | 27 8278 | Ag | 0 | 0 |
| STORET | 97 3458 | 27 8750 | TCDANE | 0 | 0 |
| EMAP/random | 97 4537 | 27 0013 | Hg | 0 | 0 |
| STORET | 97 4667 | 27 8208 | Zn | 1 | 1 |
| STORET | 97 5200 | 27 8439 | Cd | 1 | 1 |
| STORET | 97 6433 | 27 2900 | Ag | 0 | 0 |
| STORET | 117 1000 | 32 6667 | HPAH | 8 | 8 |
| NS&T/BS | 117 1333 | 32 6817 | TPCB | 8 | 8 |
| NS&T/BS | 117 1367 | 32 6833 | Hg,Cu | 7 | 7 |
| NS&T/BS | 117 1367 | 32 6850 | TPCB | 6 | 6 |
| NS&T/BS | 117 1383 | 32 6850 | TPCB | 5 | 5 |
| NS&T/BS | 117 1383 | 32 6867 | TPCB,Hg,Cu | 6 | 6 |
| NS&T/BS | 117 1383 | 32 6883 | Hg | 4 | 4 |
| NS&T/BS | 117 1400 | 32 6883 | TPCB,LPAH,Cu | 6 | 6 |
| NS&T/BS | 117 1417 | 32 6883 | TPCB,HPAH | 6 | 6 |
| STORET | 117 6917 | 33 4614 | Sn | 3 | 3 |
| STORET | 117 6953 | 33 4600 | Hg | 3 | 3 |
| STORET | 117 7003 | 33 4606 | Sn | 3 | 3 |
| STORET | 117 7044 | 33 4619 | Cd | 3 | 3 |
| STORET | 117 7488 | 33 6524 | TDDT | 0 | 0 |
| STORET | 117 8861 | 33 6325 | Sn | 7 | 8 |
| STORET | 117 8881 | 33 6378 | Sn | 7 | 8 |
| STORET | 117 8919 | 33 6231 | TDDT,Sn | 7 | 8 |
| STORET | 117 8922 | 33 6183 | Sn,Se | 7 | 8 |
| STORET | 117 9031 | 33 6058 | Sn | 8 | 8 |
| STORET | 117 9247 | 33 6186 | Sn,Hg | 8 | 8 |
| STORET | 117 9261 | 33 6114 | Sn,Hg | 8 | 8 |
| ODES | 117 9536 | 33 5786 | TCDANE,Sb | 8 | 8 |
| ODES | 117 9844 | 33 5661 | TDIELD | 4 | 8 |
| STORET | 118 0594 | 33 7125 | TCDANE,Sn,Cu | 1 | 1 |
| STORET | 118 0736 | 33 7267 | TCDANE,Sn | 2 | 2 |
| NS&T/BS | 118 1670 | 33 7333 | TDDT | 13 | 14 |
| NS&T/MW | 118 1740 | 33 7237 | TDDT | 13 | 13 |
| NS&T/BS | 118 1767 | 33 7433 | TDDT | 13 | 13 |
| NS&T/BS | 118 1783 | 33 7417 | TDDT | 14 | 14 |
| NS&T/BS | 118 2500 | 33 7117 | TDDT | 13 | 14 |
| NS&T/BS | 118 2567 | 33 7017 | TDDT | 14 | 14 |
| NS&T/BS | 118 2567 | 33 7083 | TDDT | 13 | 13 |
| NS&T/BS | 118 2567 | 33 7133 | TDDT | 13 | 14 |
| NS&T/BS | 118 2570 | 33 7100 | TDDT | 16 | 16 |
| NS&T/BS | 118 2583 | 33 7083 | TPCB,TDDT | 14 | 14 |
| NS&T/BS | 118 2583 | 33 7117 | TDDT | 12 | 13 |
| NS&T/BS | 118 2617 | 33 7000 | TDDT | 16 | 16 |
| NS&T/BS | 118 2633 | 33 7117 | TDDT | 14 | 14 |
| NS&T/BS | 118 2667 | 33 6983 | TDDT | 15 | 16 |
| NS&T/MW | 118 2770 | 33 7103 | TDDT | 13 | 13 |
| ODES | 118 2811 | 33 6231 | Cd | 8 | 12 |
| NS&T/MW | 118 3500 | 33 7108 | TDIELD,TPCB,TDDT,Ag,Cd | 11 | 12 |
| NS&T/MW | 118 4140 | 33 8235 | TDDT | 0 | 0 |
| NS&T/BS | 118 5483 | 33 9517 | Ag | 3 | 3 |
| NS&T/BS | 118 5550 | 33 9417 | Ag | 3 | 3 |
| NS&T/BS | 118 5670 | 33 9333 | Cr | 3 | 3 |
| NS&T/BS | 118 5683 | 33 9383 | TDDT,Ag | 3 | 3 |
| STORET | 118 6814 | 34 0347 | Cd | 0 | 0 |
| STORET | 119 7472 | 36 6986 | Zn,Cd | 0 | 0 |
| ODES | 120 8772 | 35 3864 | TDIELD,TDDT,Ag,Se,Cd,Sb | 1 | 1 |
| ODES | 120 8772 | 35 3900 | TDDT | 1 | 1 |
| ODES | 120 8781 | 35 3875 | TDDT | 2 | 2 |
| STORET | 121 6400 | 37 9764 | Sb | 0 | 0 |
| STORET | 121 8592 | 38 0300 | Cr | 0 | 0 |
| STORET | 122 2174 | 47 9882 | HPAH,LPAH | 2 | 2 |

"5xHigh"sites in COSED

| ORIGIN | LONGITUDE | LATITUDE | 5xHIGH | NE 10 | NE 20 |
|---|---|---|---|---|---|
| STORET | 122 2186 | 47 9833 | LPAH,Cd | 3 | 3 |
| STORET | 122 2188 | 47 9846 | LPAH,Zn | 3 | 3 |
| STORET | 122 2209 | 47 9882 | Cd | 2 | 2 |
| SFTB | 122 2472 | 37 7864 | TDIELD,Hg | 10 | 10 |
| SFTB | 122 2620 | 37 7939 | Hg | 11 | 11 |
| SFTB | 122 2933 | 37 8019 | TPCB,Hg | 11 | 13 |
| SFTB | 122 2933 | 37 8042 | Hg | 11 | 13 |
| SFTB | 122 2944 | 37 8018 | TPCB,Hg | 11 | 13 |
| SFTB | 122 2944 | 37 8043 | TPCB | 11 | 13 |
| SFTB | 122 2945 | 37 8043 | HPAH,Hg | 11 | 13 |
| STORET | 122 3025 | 47 5192 | Sn | 37 | 37 |
| STORET | 122 3094 | 47 5267 | Sn | 37 | 37 |
| NS&T/BS | 122 3100 | 38 0483 | Hg,Cr | 0 | 0 |
| STORET | 122 3178 | 47 5364 | HPAH,LPAH,Pb,Cd | 38 | 39 |
| STORET | 122 3186 | 47 5353 | HPAH,Sn | 39 | 40 |
| STORET | 122 3294 | 47 5431 | HPAH,LPAH,As | 40 | 44 |
| STORET | 122 3353 | 47 5461 | Sn | 40 | 44 |
| SFTB | 122 3360 | 37 7914 | Sb | 12 | 14 |
| SFTB | 122 3360 | 37 7931 | Sb | 12 | 14 |
| SFTB | 122 3360 | 37 7946 | Sb | 12 | 14 |
| STORET | 122 3364 | 47 5456 | Sn | 40 | 44 |
| NS&T/BS | 122 3367 | 37 7833 | Hg | 15 | 16 |
| STORET | 122 3394 | 47 5567 | HPAH,LPAH,Zn,Cd | 40 | 44 |
| STORET | 122 3397 | 47 5906 | Sn | 43 | 44 |
| STORET | 122 3408 | 47 5569 | HPAH,Sn | 41 | 43 |
| STORET | 122 3422 | 47 5569 | Sn | 41 | 43 |
| STORET | 122 3433 | 47 5736 | HPAH,Sn | 42 | 44 |
| STORET | 122 3433 | 47 5853 | HPAH,Sn | 42 | 43 |
| STORET | 122 3464 | 47 5683 | Sn,Pb | 43 | 44 |
| STORET | 122 3469 | 47 5678 | Sn | 43 | 44 |
| STORET | 122 3483 | 47 5675 | HPAH | 43 | 44 |
| NS&T/BS | 122 3500 | 47 5917 | TPCB | 42 | 43 |
| STORET | 122 3511 | 47 5883 | HPAH,LPAH | 43 | 44 |
| NS&T/BS | 122 3517 | 47 5950 | TPCB | 42 | 43 |
| STORET | 122 3528 | 47 5881 | HPAH,LPAH,Pb | 43 | 44 |
| ODES | 122 3531 | 47 5958 | Zn,Ag | 43 | 44 |
| NS&T/BS | 122 3533 | 47 5900 | TPCB,HPAH | 42 | 43 |
| STORET | 122 3547 | 47 5878 | HPAH,LPAH,Zn,Sn,As | 42 | 43 |
| STORET | 122 3561 | 47 5886 | HPAH,LPAH,Sn,Pb | 44 | 45 |
| NS&T/BS | 122 3567 | 47 5917 | TPCB | 43 | 44 |
| STORET | 122 3575 | 47 5811 | HPAH,LPAH,Pb | 42 | 44 |
| STORET | 122 3578 | 47 5756 | HPAH,LPAH,Sn | 42 | 45 |
| STORET | 122 3578 | 47 5878 | HPAH,LPAH | 42 | 43 |
| STORET | 122 3586 | 47 5811 | HPAH | 42 | 44 |
| STORET | 122 3589 | 47 5753 | HPAH,Sn,Pb | 42 | 45 |
| STORET | 122 3589 | 47 5872 | HPAH | 43 | 44 |
| ODES | 122 3597 | 47 2613 | Cd,As | 64 | 65 |
| STORET | 122 3597 | 47 5747 | HPAH | 43 | 46 |
| STORET | 122 3600 | 47 5811 | HPAH | 41 | 43 |
| STORET | 122 3600 | 47 5864 | HPAH,LPAH,Zn,Sn,Pb,As,Sb | 43 | 44 |
| ODES | 122 3601 | 47 2627 | Cd | 63 | 64 |
| SFTB | 122 3606 | 37 8218 | Hg | 14 | 16 |
| ODES | 122 3628 | 47 2636 | HPAH,Cd | 65 | 66 |
| NS&T/BS | 122 3633 | 47 5900 | TPCB | 43 | 44 |
| ODES | 122 3641 | 47 2643 | HPAH | 65 | 66 |
| SFTB | 122 3643 | 37 9125 | Hg | 3 | 7 |
| STORET | 122 3658 | 47 5858 | HPAH,LPAH | 44 | 45 |
| ODES | 122 3665 | 47 2663 | HPAH,LPAH,Cu,Cd,As | 67 | 67 |
| ODES | 122 3667 | 47 2658 | HPAH,Cd,As | 66 | 66 |
| STORET | 122 3667 | 47 5950 | TPCB | 44 | 44 |
| NS&T/BS | 122 3670 | 37 7000 | HPAH | 4 | 7 |
| ODES | 122 3673 | 47 2655 | HPAH,LPAH,Cu,Cd,As,Sb | 66 | 67 |
| SFTB | 122 3688 | 37 9215 | TDIELD,TDDT,Hg | 3 | 7 |

"5xHigh"sites in COSED

| ORIGIN | LONGITUDE | LATITUDE | 5xHIGH | NE 10 | NE 20 |
|---|---|---|---|---|---|
| STORET | 122 3692 | 47 5836 | HPAH,LPAH | 44 | 45 |
| ODES | 122 3696 | 47 2672 | HPAH,Cd,As | 67 | 67 |
| ODES | 122 3707 | 47 2683 | HPAH,Cd | 67 | 67 |
| ODES | 122 3722 | 47 2691 | HPAH,Cd,As | 67 | 67 |
| ODES | 122 3724 | 47 2702 | Cd,As | 67 | 67 |
| ODES | 122 3726 | 47 2696 | HPAH,LPAH,Cd,As | 67 | 67 |
| ODES | 122 3732 | 47 2692 | HPAH,LPAH,Cu,Cd,As | 67 | 67 |
| ODES | 122 3737 | 47 2703 | LPAH | 67 | 67 |
| SFTB | 122 3749 | 37 9253 | TDIELD,TDDT,Hg | 3 | 6 |
| ODES | 122 3750 | 47 2707 | HPAH | 67 | 67 |
| ODES | 122 3774 | 47 2561 | Cd | 66 | 67 |
| ODES | 122 3841 | 47 2619 | HPAH,LPAH,Cd | 65 | 66 |
| ODES | 122 3847 | 47 2616 | Cd | 66 | 67 |
| ODES | 122 3851 | 47 2613 | Cd | 66 | 67 |
| SFTB | 122 3867 | 37 7472 | HPAH,LPAH,Ag,Hg,As,Sb | 7 | 12 |
| ODES | 122 3868 | 47 2629 | Cd | 67 | 67 |
| ODES | 122 3886 | 47 2647 | Cd | 67 | 67 |
| SFTB | 122 3888 | 37 7472 | HPAH,LPAH,Ag,Sb | 7 | 12 |
| ODES | 122 3890 | 47 2767 | LPAH | 67 | 67 |
| ODES | 122 3891 | 47 2643 | Cd | 67 | 67 |
| ODES | 122 3895 | 47 2640 | Cd | 67 | 67 |
| ODES | 122 3903 | 47 2651 | Cd | 67 | 67 |
| ODES | 122 3905 | 47 2658 | Cd | 66 | 66 |
| ODES | 122 3909 | 47 2654 | Cd | 67 | 67 |
| ODES | 122 3915 | 47 2650 | Cd | 67 | 67 |
| ODES | 122 3929 | 47 2666 | Cd | 67 | 67 |
| ODES | 122 3948 | 47 2684 | LPAH,Cd | 67 | 67 |
| ODES | 122 3952 | 47 2676 | Cd | 67 | 67 |
| ODES | 122 3953 | 47 2778 | LPAH | 67 | 67 |
| ODES | 122 3958 | 47 8300 | Sb | 1 | 1 |
| ODES | 122 3961 | 47 2671 | Cd | 68 | 68 |
| ODES | 122 3968 | 47 2786 | LPAH | 68 | 68 |
| ODES | 122 3983 | 47 2788 | Hg,Cu | 68 | 68 |
| SFTB | 122 3994 | 37 7479 | Ag,As,Sb | 8 | 8 |
| NS&T/BS | 122 4000 | 37 8833 | TDDT | 4 | 8 |
| ODES | 122 4009 | 47 2727 | LPAH,Cd | 70 | 70 |
| ODES | 122 4025 | 47 2812 | LPAH | 70 | 70 |
| NS&T/MW | 122 4060 | 47 6278 | TCDANE | 42 | 48 |
| ODES | 122 4120 | 47 2875 | Cd | 73 | 73 |
| ODES | 122 4121 | 47 2663 | LPAH,Pb,Cu,Cd,As | 73 | 73 |
| ODES | 122 4139 | 47 4819 | Ag | 8 | 20 |
| ODES | 122 4146 | 47 2680 | Pb,Cd | 73 | 73 |
| ODES | 122 4152 | 47 2627 | LPAH | 72 | 72 |
| ODES | 122 4153 | 47 3494 | Ag | 51 | 69 |
| SFTB | 122 4156 | 38 0119 | Sb | 2 | 5 |
| ODES | 122 4161 | 47 2693 | Pb | 73 | 73 |
| ODES | 122 4161 | 47 2884 | Cd | 73 | 73 |
| ODES | 122 4167 | 47 2643 | LPAH | 74 | 74 |
| NS&T/MW | 122 4180 | 47 5758 | TCDANE | 46 | 48 |
| SFTB | 122 4181 | 38 0114 | Sb | 2 | 5 |
| ODES | 122 4183 | 47 2701 | LPAH | 74 | 74 |
| ODES | 122 4193 | 47 2669 | LPAH | 74 | 74 |
| SFTB | 122 4197 | 38 0100 | As,Sb | 2 | 5 |
| ODES | 122 4197 | 47 6369 | Sb | 39 | 45 |
| ODES | 122 4211 | 47 5297 | Ag | 36 | 44 |
| ODES | 122 4261 | 47 7486 | As,Sb | 2 | 2 |
| ODES | 122 4264 | 47 2560 | HPAH,LPAH,Cd | 74 | 75 |
| STORET | 122 4277 | 47 6243 | HPAH,LPAH,Zn,Pb | 41 | 46 |
| ODES | 122 4285 | 47 2681 | LPAH,Cu,Cd | 75 | 75 |
| ODES | 122 4291 | 47 2518 | LPAH,Pb,Cd | 74 | 75 |
| STORET | 122 4292 | 47 6281 | Pb | 39 | 46 |
| ODES | 122 4302 | 47 2622 | LPAH,Pb,Cu,Cd | 75 | 75 |
| ODES | 122 4302 | 47 2662 | LPAH | 75 | 75 |

"5xHigh"sites in COSED

| ORIGIN | LONGITUDE | LATITUDE | 5xHIGH | NE 10 | NE 20 |
|---|---|---|---|---|---|
| ODES | 122 4305 | 47 2426 | HPAH,LPAH,Pb,Cd | 73 | 74 |
| ODES | 122 4308 | 47 2475 | LPAH,Pb,Cd | 74 | 74 |
| ODES | 122 4309 | 47 2462 | LPAH,Hg,Pb,Cd | 74 | 74 |
| ODES | 122 4310 | 47 2448 | HPAH,LPAH,Pb,Cd | 74 | 74 |
| ODES | 122 4313 | 47 2638 | LPAH,Hg,Cu,Cd,As | 75 | 75 |
| ODES | 122 4315 | 47 2508 | HPAH,LPAH,Pb,Cd | 74 | 75 |
| ODES | 122 4317 | 47 2520 | LPAH,Pb,Cd | 74 | 75 |
| ODES | 122 4323 | 47 2531 | LPAH,Pb,Cd | 74 | 75 |
| ODES | 122 4324 | 47 2553 | Cd | 74 | 75 |
| ODES | 122 4328 | 47 2562 | LPAH,Cd | 74 | 75 |
| ODES | 122 4339 | 47 2583 | HPAH,LPAH,Cd | 74 | 75 |
| ODES | 122 4355 | 47 2604 | LPAH | 74 | 75 |
| ODES | 122 4356 | 47 6697 | Zn | 12 | 37 |
| ODES | 122 4358 | 47 2619 | HPAH,LPAH | 74 | 74 |
| ODES | 122 4398 | 47 2636 | LPAH | 75 | 75 |
| ODES | 122 4561 | 47 6417 | Ag | 23 | 26 |
| ODES | 122 4619 | 47 2837 | LPAH,Cd | 73 | 73 |
| ODES | 122 4651 | 47 2770 | LPAH | 71 | 71 |
| STORET | 122 4942 | 47 6114 | HPAH | 11 | 12 |
| STORET | 122 4944 | 47 6131 | HPAH | 11 | 12 |
| ODES | 122 4955 | 47 2950 | LPAH,Cu,Cd,As | 44 | 44 |
| STORET | 122 4956 | 47 6194 | Cd | 11 | 12 |
| STORET | 122 4967 | 47 6164 | HPAH | 11 | 12 |
| STORET | 122 4978 | 47 6181 | HPAH | 11 | 12 |
| ODES | 122 4995 | 47 2983 | Zn,Se,Hg,Pb,Cu,Cd,As,Sb | 41 | 41 |
| ODES | 122 5008 | 47 3022 | Cd,As | 41 | 41 |
| ODES | 122 5034 | 47 3011 | HPAH,LPAH,Zn,Se,Hg,Pb,Cu,Cd,As,Sb | 38 | 38 |
| ODES | 122 5034 | 47 3014 | Zn,Hg,Pb,Cu,Cd,As,Sb | 38 | 38 |
| ODES | 122 5042 | 47 3017 | HPAH,LPAH,Zn,Se,Ni,Hg,Pb,Cu,Cd,As,Sb | 39 | 39 |
| ODES | 122 5158 | 47 3089 | Zn,Pb,Cu,Cd,As,Sb | 34 | 34 |
| ODES | 122 5207 | 47 3106 | As | 28 | 29 |
| ODES | 122 5836 | 47 3356 | HPAH,LPAH | 8 | 8 |
| STORET | 122 6300 | 47 5596 | Pb | 2 | 2 |
| STORET | 122 6592 | 47 5514 | Pb | 2 | 2 |
| STORET | 122 6658 | 47 5486 | Zn,Cd | 2 | 2 |
| NS&T/BS | 123 0300 | 38 3050 | Cr | 0 | 0 |
| NS&T/BS | 123 0580 | 37 6567 | Cd | 0 | 0 |
| ODES | 123 4572 | 48 1353 | Cd | 0 | 0 |
| NS&T/BS | 124 1233 | 40 8350 | Cr | 1 | 1 |
| NS&T/MW | 124 1680 | 40 8220 | TCDANE | 1 | 1 |
| STORET | 124 2014 | 43 3633 | Cu | 2 | 2 |
| STORET | 124 2100 | 43 3733 | Cu,Cr | 2 | 2 |
| NS&T/BS | 124 2170 | 43 4000 | Ag,Cd | 2 | 2 |
| NS&T/MW | 124 2320 | 41 7212 | Ni,Cr | 0 | 0 |
| STORET | 124 3106 | 43 2964 | Cr | 0 | 0 |

# APPENDIX III

## Spatial Distribution of Sediment Contaminants from EMAP Data.

EMAP data from randomly selected sites were used to calculate cumulative areal coverage of copper concentrations for the total estuarine area in Virginian and Louisianian Provinces (Figure **8**). That calculation has been extended here, and cumulative areal coverages have been calculated for each metal and each aggregate organic group. EMAP statistical design calls for four years of sampling to achieve complete coverage of the provinces and estuarine classes (small, large, and tidal rivers). With only two years of sampling data, there is some uncertainty associated with the results, however, it is expected that these results are representative of the remaining two years. These distribution plots would represent the average extent of contamination along the Northeast and Gulf of Mexico coast of the United States, as discussed in page 26. It is observed that in all cases in Figures **15-18**, that concentrations in excess of "5xHigh" are found over only a very small percentage of the total area and that over 90% of the total area has contaminant concentrations below the "High".

Concentrations below the detection limit are reflected in these graphs. Many of the curves do not begin at the 0% cumulative area, owing to a number of sites below the detection limit. This is particularly noticeable for the organics for example, only 32% of the area analyzed by EMAP had concentrations above the DL for total dieldrin. As analytical methods improve the percentage of area below DL will decrease as well. The concentrations in these areas, however, will be lower than the current lowest concentrations, and should not affect the upper end of the distribution relative to "High" and "5xHigh".

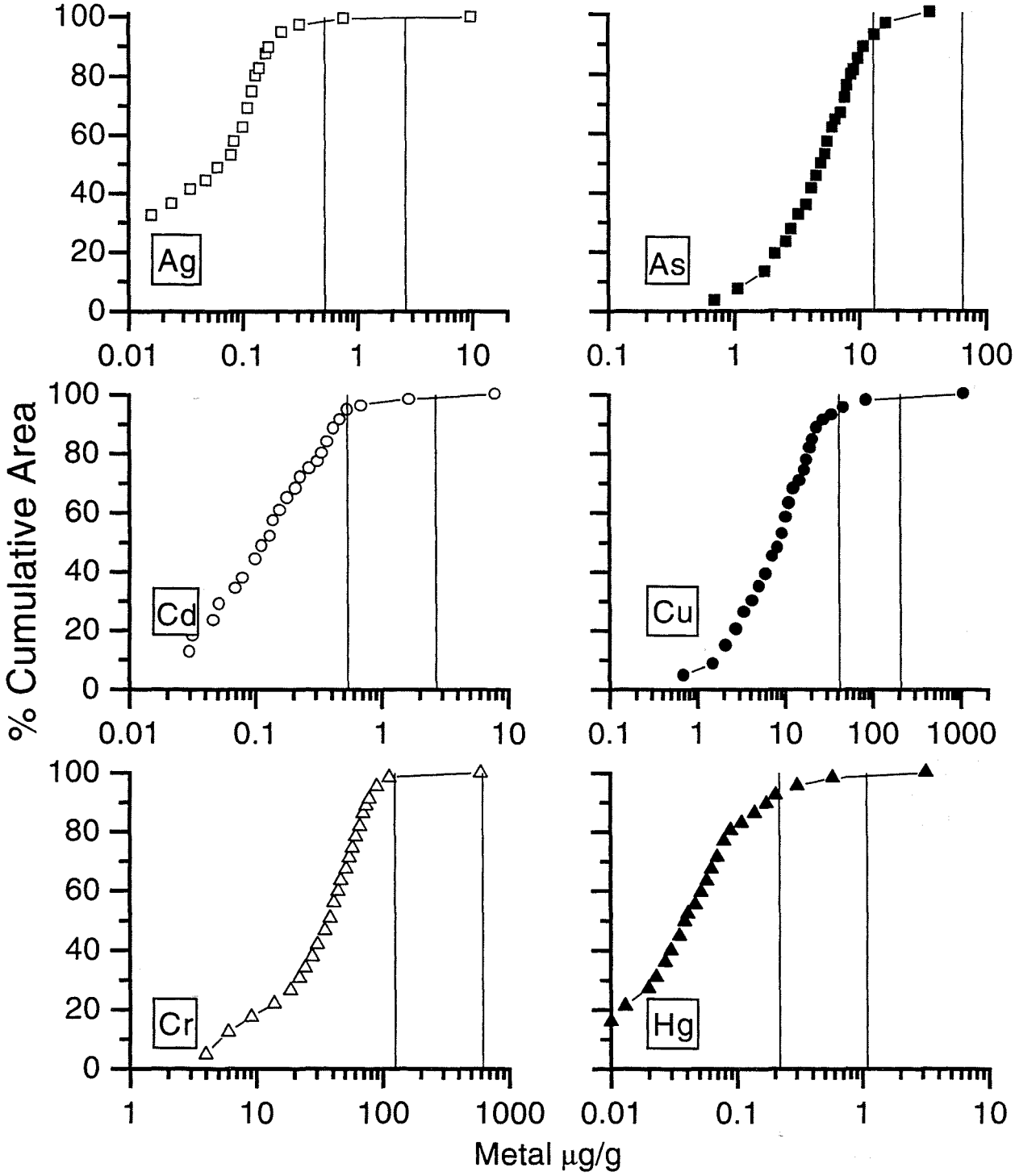


Figure **15**. Cumulative areal plots calculated from EMAP data for the Virginian and Louisianian Provinces for Ag, As, Cd, Cu, Cr, and Hg The vertical lines correspond to the NS&T/MW "High" (lower concentration) and "5xHigh" (greater concentration)

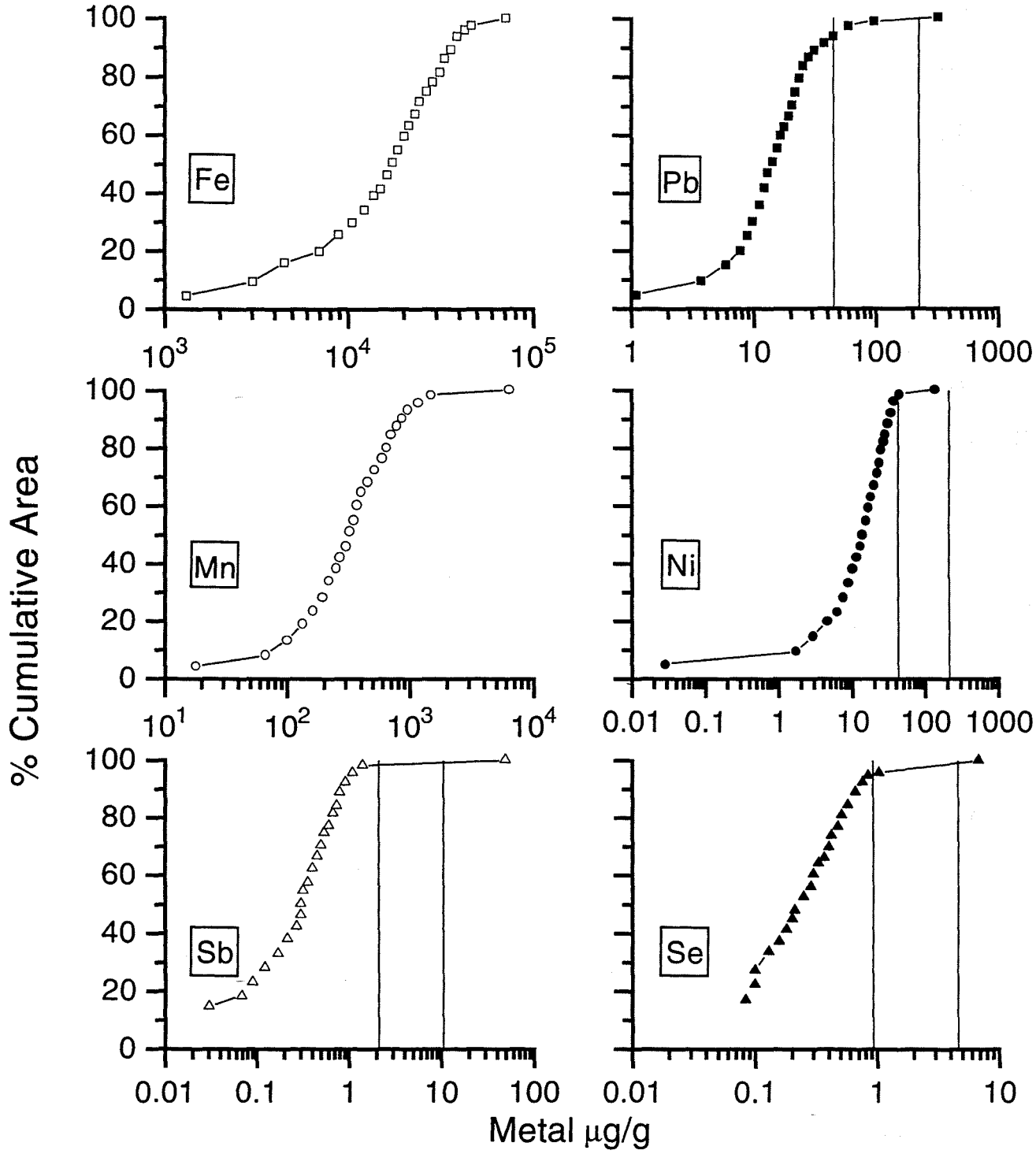


Figure **16** Cumulative areal plots calculated from EMAP data for the Virginian and Louisianian Provinces for Fe, Pb, Mn, Ni, Sb, and Se. The vertical lines correspond to the NS&T/MW "High" (lower concentration) and "5xHigh" (greater concentration).

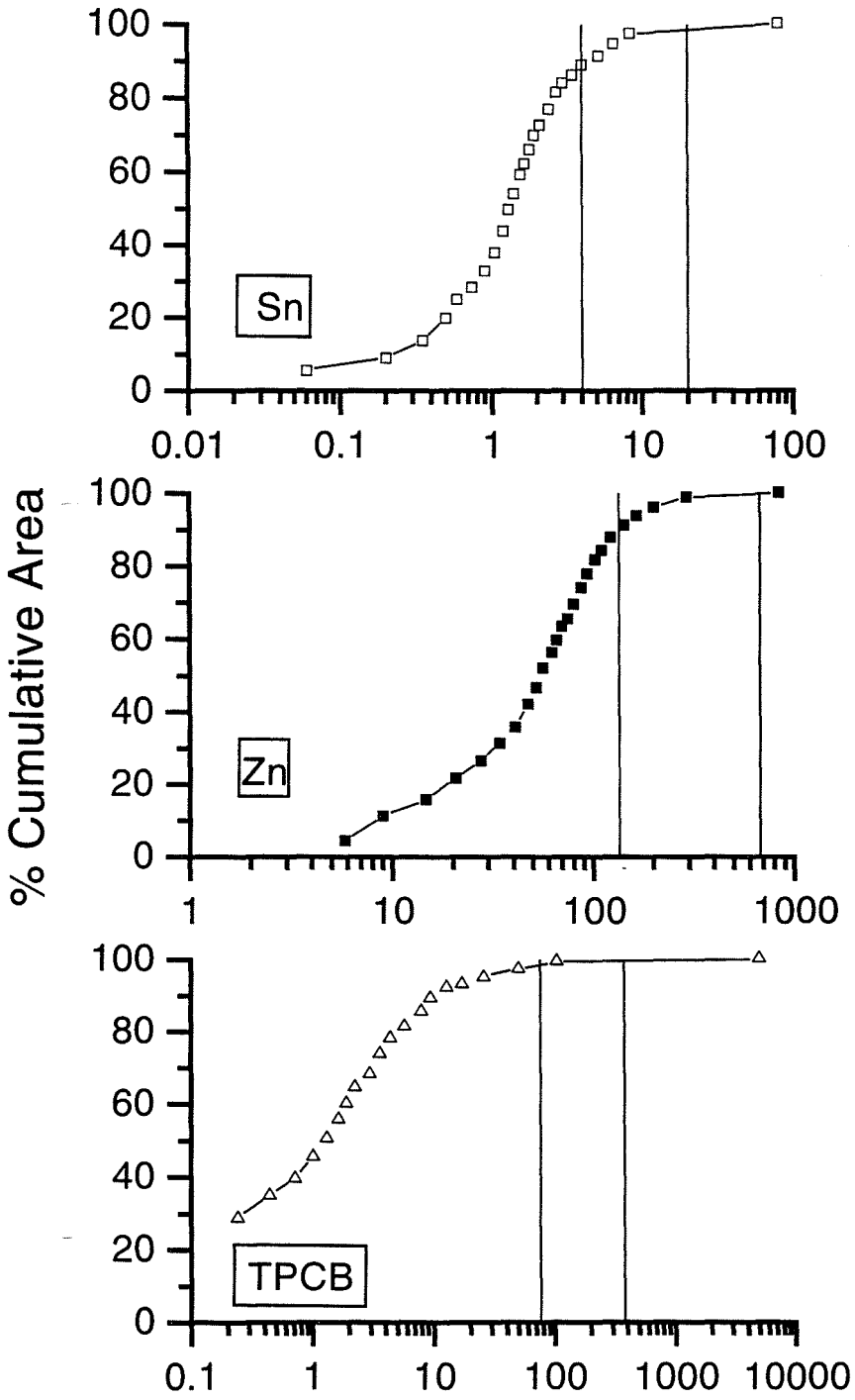


Figure **17**: Cumulative areal plots calculated from EMAP data for the Virginian and Louisianian Provinces for Sn, Zn and total PCB. The vertical lines correspond to the NS&T/MW "High" (lower concentration) and "5xHigh" (greater concentration) Concentrations are µg/g for Sn and Zn, and ng/g for Total PCB

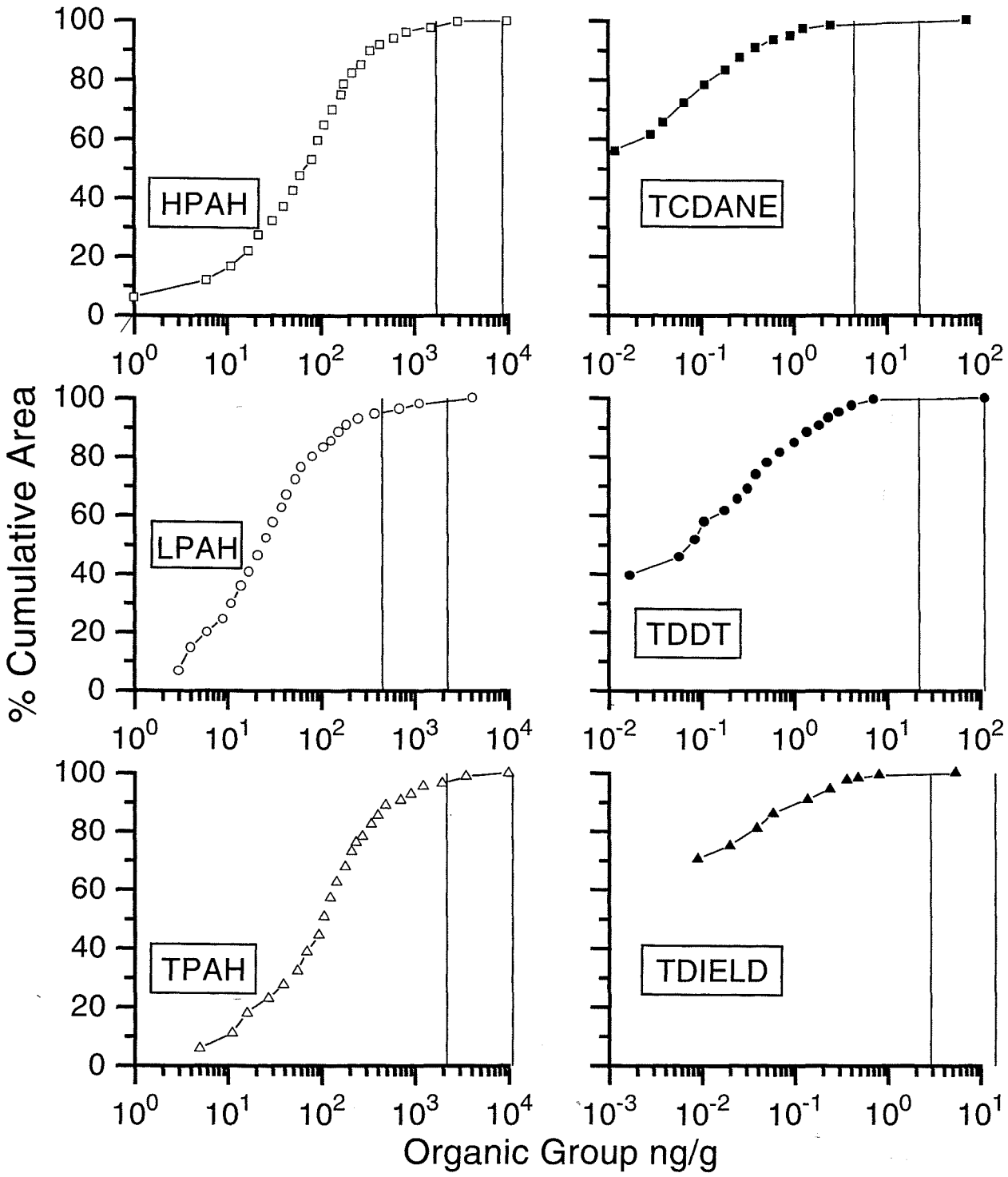


Figure **18** Cumulative areal plots calculated from EMAP data for the Virginian and Louisianian Provinces for organics The vertical lines correspond to the NS&T/MW "High" (lower concentration) and "5xHigh" (greater concentration)