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DISTRIBUTION OF METALS IN BALTIMORE HARBOR SEDIMENTS

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Annapolis Field Office
Region III
Environmental Protection Agency

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ABSTRACT

In order to develop a current inventory of metals contamination of Baltimore Harbor, sediment samples were collected at 176 stations and analyzed for Pb, Cu, Cr, Cd, Zn, Ni, Mn and Hg using atomic absorption spectrophotometry. Concentration levels were compared with levels found in another highly industrialized harbor complex, other estuarine systems and in Chesapeake Bay sediments geographically removed from the Harbor. Distribution patterns of various metals were related to industrial/municipal inputs.

INTRODUCTION

Baltimore Harbor (the Patapsco River Estuary) is a large industrial port which transfers 50 million short tons of cargo per year and supports numerous industries located on or near the waterfront. The Harbor receives wastewater effluents from the municipal and industrial facilities surrounding this complex, the most critical problem emanating from large quantities of toxic industrial wastes. Any geographical area subjected to such a high concentration of commercial facilities would be expected to show the effects of such stress in terms of environmental degradation. This survey attempts to show the results of this stress in the accumulation of heavy metals in sediments of the Harbor.

Sampling programs spanning several years have been carried out by various private and public institutions. Each study usually selected one geographical area of the Harbor to be investigated for a particular project. Knowledge of heavy metals content in sediments is necessary for future bridge or tunnel excavations, utility crossings, pier expansions and especially dredging projects. All of these various programs provided data that fulfilled immediate needs but did little to present an overview of the metals accumulation in the Harbor. This study is an effort to provide a synoptic picture of the heavy metals contamination of Baltimore Harbor as it presently exists.

It is not the purpose of this effort to examine toxicological effects in any detail. The toxicity of various heavy metals has been well documented (1, 2, 3) and the occurrence of large scale outbreaks of metal poisoning (4, 5, 6, 7, 8) have illustrated the potential health hazard of these substances. However, it would be simplistic to directly correlate a given, measured concentration of a metal to a specific toxic level. Considerations such as chemical bonding of the metallic species (9), particle size of the substrate (10), valence state, humic acid availability (11, 12), synergistic and antagonistic mechanisms all relate to the reactivity of a given metal.

Effects of long term exposure to low levels of trace metals, in whatever form, are not well defined. The toxicity of some heavy metals is presented in Appendix III.

Appendix II contains information pertinent to the programs of the U.S. Army Corps of Engineers.

SUMMARY AND CONCLUSIONS

1) This report presents an inventory of present conditions relating to metals contamination of Baltimore Harbor sediments.

2) Concentrations of all metals analyzed from the Harbor were about three (3) to fifty (50) times greater in value than their counterparts from the Chesapeake Bay.

3) Distribution of metals generally reflected the inputs from the large industrial complex which Baltimore Harbor supports.

4) Heavy metals accumulations in bottom deposits and the disrupted benthic community show similar distribution patterns indicating a possible correlation in the study area.

5) Solubilities of divalent sulfide compounds indicate that in black colored sediments mercury, copper, lead and cadmium probably exist as sulfides.

6) Particle size can play a significant role in adsorption reactions of metallic species. Baltimore Harbor and the Chesapeake Bay have generally similar sand, silt and clay ranges, with both averaging about 84% silt and clay. Differences in concentration between the 2 systems were therefore not attributed to variations in particle size.

7) Comparison of Baltimore Harbor data with other estuaries revealed the following:

a) The James River showed little accumulation of heavy metals with most levels being about equal to Chesapeake Bay values;

b) The Potomac Estuary showed some metallic deposition with most levels being about twice those found in the James River and the Bay;

c) The Delaware Estuary showed considerable build-up of metals in sediments but still less than the levels found in Baltimore Harbor.

8) Examination of the seven major Harbor divisions revealed the following:

a) The Northwest Branch contained very high concentrations of chromium, copper and zinc with slightly lesser amounts of mercury and lead present;

b) The Middle Branch sediments showed considerably lower metals levels than other harbor areas. A few isolated high lead and zinc levels were found;

c) Curtis Bay had some high zinc, copper and mercury levels with lesser amounts of cadmium, chromium and lead;

d) Colgate Creek was found to be contaminated in specific, isolated areas with lead, copper, mercury, cadmium, zinc and chromium;

e) Bear Creek was found contaminated with chromium and zinc, and with some lesser, but still high, amounts of lead, mercury, copper and cadmium;

f) Old Road Bay was grossly contamined with lead and zinc and also contained high chromium and mercury levels;

g) The Outer Harbor contained high levels of chromium between Hawkins Point and Sollers Point and generally contained high zinc levels.

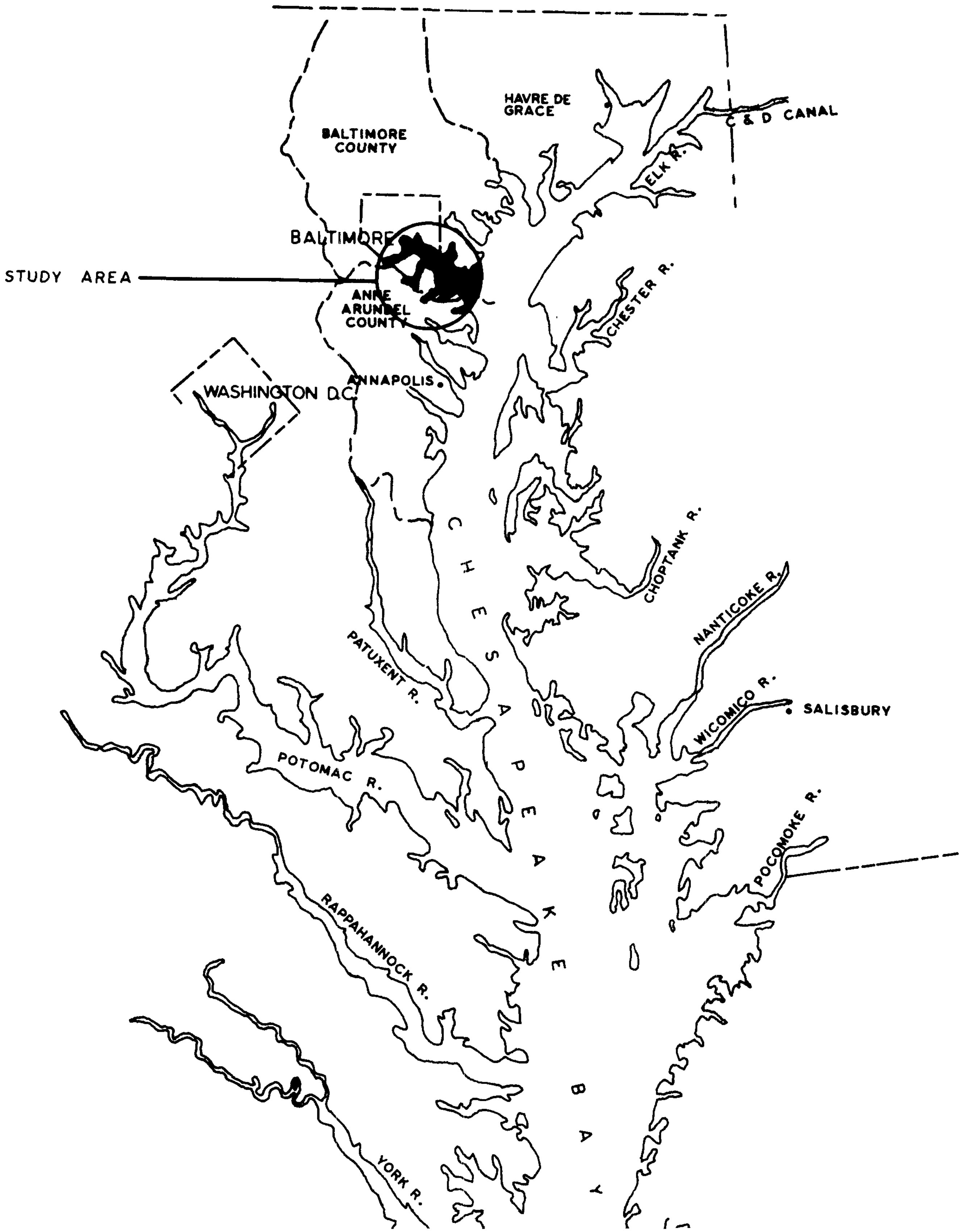
GEOGRAPHICAL DESCRIPTION

Baltimore Harbor, or the tidal Patapsco River, is a tributary embayment to the Chesapeake Bay and is located on the upper west side of the Bay about 160 miles from the Virginia Capes. It is bounded on the north by Baltimore County, Anne Arundel County on the south and Baltimore City at its western end (see Figure 1). The Harbor is the fourth largest port in the nation for ocean and coastal traffic and a major industrial center.

The Harbor is a shallow embayment consisting of approximately 34 square miles of the lower portion of the Patapsco River and measures 10 nautical miles along the channel from a line between North Point and Rock Point to the extremity of the Northwest Branch (see Figure 2). Most of the shoreline, except for the lower south shore, upper Bear Creek, eastern Old Road Bay and upper Curtis Creek is occupied by manufacturing industry or marine or commercial establishments. Heavily industrialized tributaries are lower Bear Creek, Colgate Creek, Curtis Bay and Curtis Creek. Two non-tidal tributaries - Jones Falls and Gwynns Falls - and the Patapsco River drain many heavy industrial or commercial districts in their lower urban reaches. The Harbor, bordered to a great extent by concentrated development, has received heavy loads of polluting material.

Figure 1

BALTIMORE HARBOR AND VICINITY



Three natural streams flow into the Harbor: Patapsco River (drainage area 367 sq. mi.) and Gwynns Falls (drainage area 69 sq. mi.) enter the Middle Branch and Jones Falls (drainage area 64 sq. mi.) enters the Northwest Branch. Minor coastal plain tributaries have an aggregate drainage area of 111 sq. mi. The width of the Harbor increases from about one to four miles between Fort McHenry and the mouth of the Harbor. Except in the dredged areas, water depths in the Harbor are generally less than 20 feet. The main channel in the Outer Harbor is 42 feet deep and approximately 800 feet wide. In addition to the main channel, there are also maintained channels in the Northwest Branch, lower Middle Branch and Curtis Bay. The mean water depth (below mean low water) for the Outer Harbor is 18.7 feet, and the mean depth for the Inner Harbor is 16.1 feet, with a volume of 15 billion cubic feet. The surface area, mean depth and volumes for the major Harbor divisions are tabulated in Table I.

Some ambiguity exists as to the nomenclature of the areas of the Harbor. For the purposes of this study the Harbor was subdivided into six divisions (see Figure 2). These divisions are Northwest Branch (to the north and west of a line extended directly east of Ft. McHenry) and the Middle Branch (west of a line extended directly south from Ft. McHenry), Patapsco River, Curtis Bay, Colgate Creek, Bear Creek and Old Road Bay. The "Inner Harbor" includes the Northwest and Middle Branches.

TABLE I

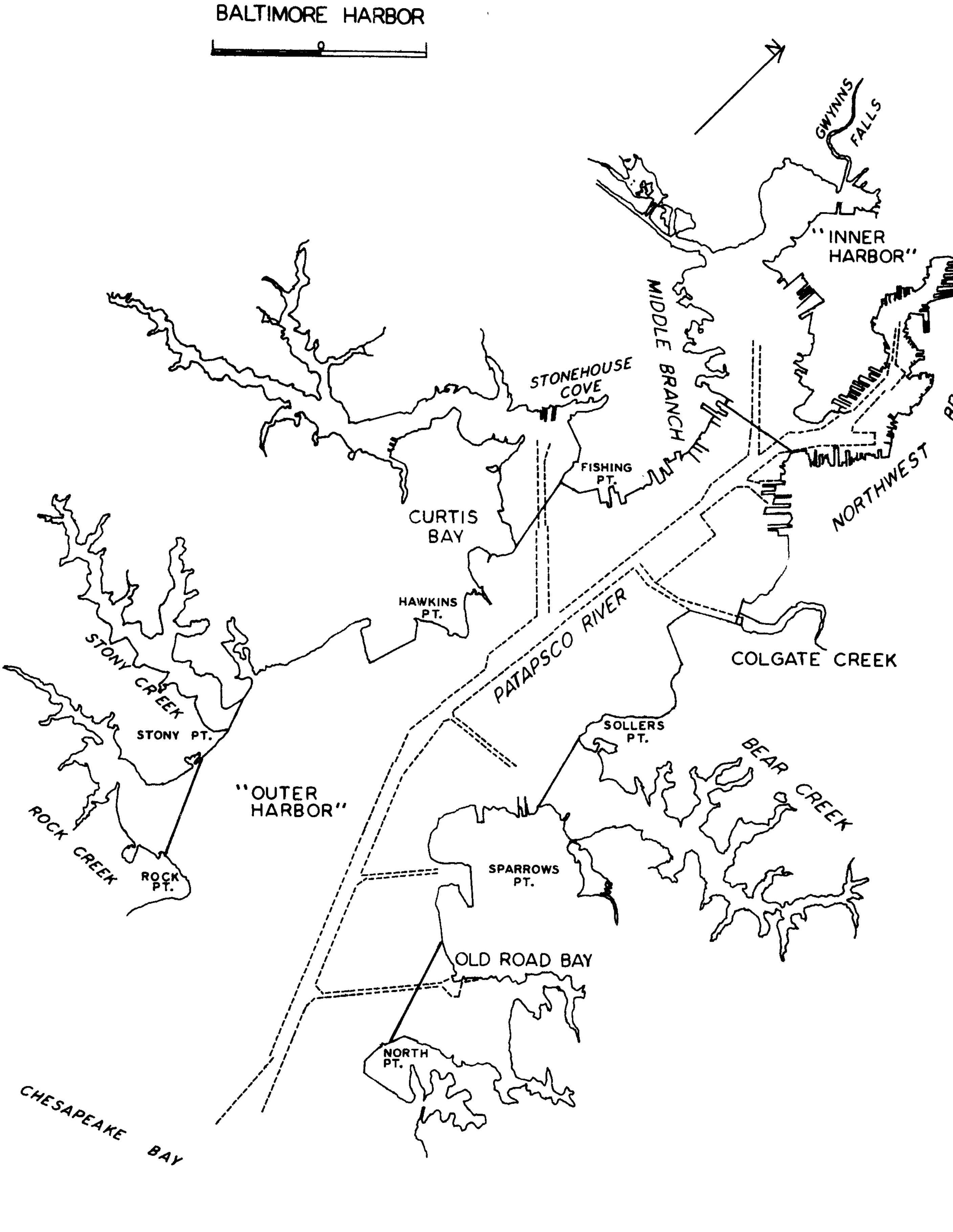
PHYSICAL CHARACTERISTICS OF BALTIMORE HARBOR[20]

Major Harbor Division	Surface Area 10^6 sq. ft.	Mean Depth Feet	Volume 10^6 cu. ft.
Northwest Branch	38.4	24.6	941
Middle Branch	74.4	11.9	992
Curtis Bay	79.2	14.2	1,121
Colgate Creek	5.3	13.4	71
Bear Creek	75.1	10.9	820
Old Road Bay	34.1	6.5	221
Outer Harbor	580.0	18.7	10,282
TOTAL	886.5	14.7	14,448

NOTE:
1. All values are based on mean low water
2. Soundings shown on U.S. and C+GS Charts 545 and 549 were used to compute the values for the Outer Harbor
3. The values for the other divisions were taken from Garland's study(1)

[20] Table from Quirk, Lawler and Matusky Engineers, Environmental Science and Engineering Consultants (Tappan, N.Y.) "Water Quality of Baltimore Harbor", QLM Project No. 224-1, March, 1973

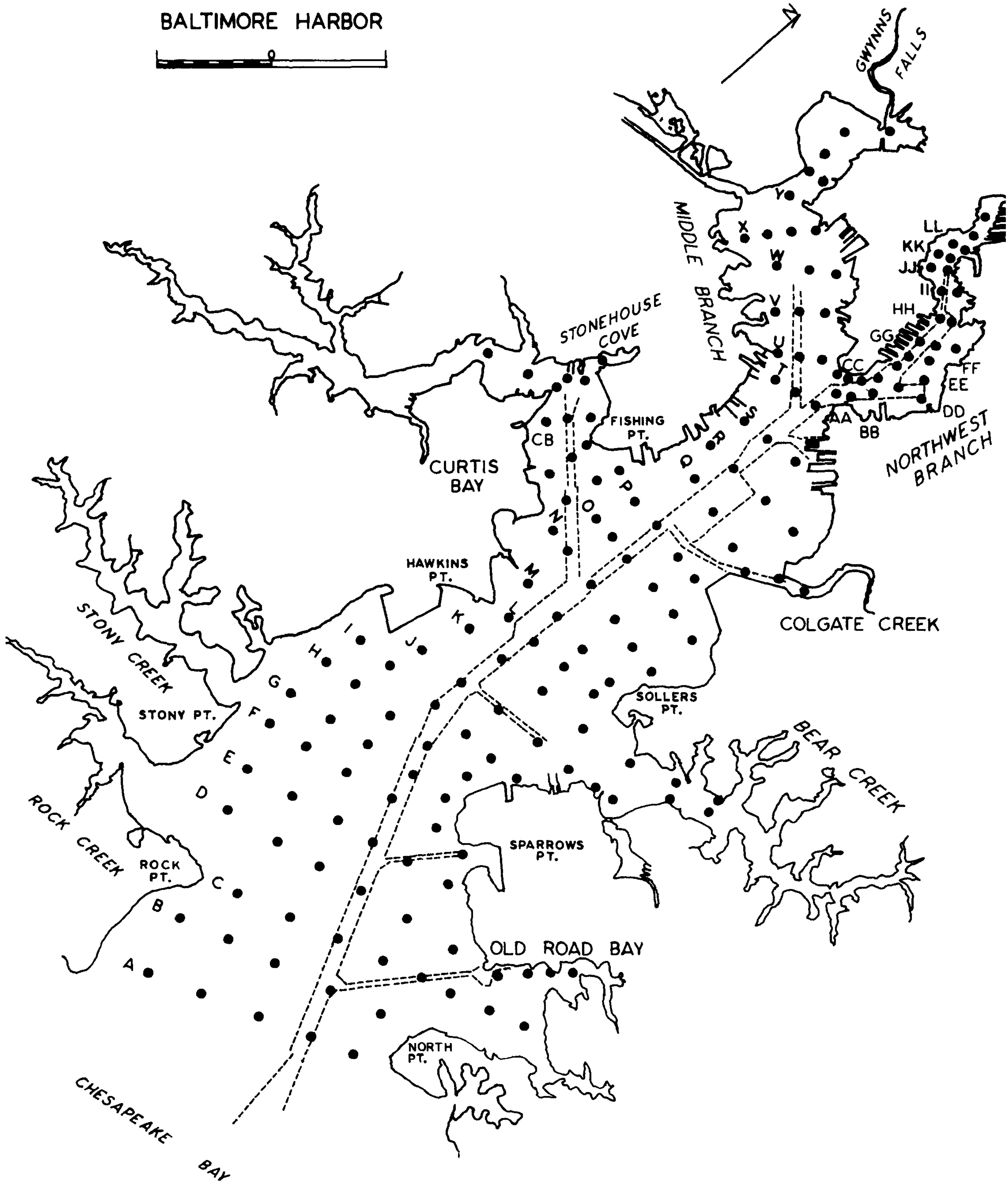
Figure 2


BALTIMORE HARBOR
0
GWYNNS FALLS
"INNER HARBOR"
MIDDLE BRANCH
STONEHOUSE COVE
NORTHWEST BRANCH
FISHING PT.
CURTIS BAY
HAWKINS PT.
STONY CREEK
STONY PT.
PATAPSCO RIVER
COLGATE CREEK
SOLLERS PT.
BEAR CREEK
"OUTER HARBOR"
ROCK CREEK
ROCK PT.
SPARROWS PT.
OLD ROAD BAY
NORTH PT.
CHESAPEAKE BAY

The "Outer Harbor" refers to the Patapsco River from the Inner Harbor to North Point exclusive of the tributary creeks and bay.

The sampling stations used in this study are shown in Figure 3.

Figure 3


BALTIMORE HARBOR
GWYNNS FALLS
MIDDLE BRANCH
STONEHOUSE COVE
FISHING PT.
CURTIS BAY
CB
HAWKINS PT.
NORTHWEST BRANCH
COLGATE CREEK
SOLLERS PT.
BEAR CREEK
STONY CREEK
STONY PT.
ROCK CREEK
ROCK PT.
SPARROWS PT.
OLD ROAD BAY
NORTH PT.
CHESAPEAKE BAY
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
AA
BB
CC
DD
EE
FF
GG
HH
II
JJ
KK
LL

EXPERIMENTAL

Samples were taken with a Phleger core. The top five cm representing substantial sediment-water interface were discarded and the sediment between five and fifteen cm was taken as the sample to be analyzed. Twenty-four samples were also taken at a thirty to forty cm depth.

A known volume of well-mixed wet sediment was put in a 125 ml glass-stoppered flask. Distilled water washings were made in the transfer so that the addition of 25 mls of concentrated HNO_3 would result in a 50-75 ml digestion solution. (Determinations of wet and dry weights were made concurrently for conversion of analytical results to desired units.) This solution was heated at 48-50°C (29) for 4-6 hours in a shaking hot water bath. After digestion, the samples were cooled and filtered through a .45 micron millipore filter and the volume adjusted to 100 mls. Blank solutions were run throughout the same extraction procedure. (30, 31)

Filtered acid extracts were analyzed for Pb, Cd, Cr, Cu, Zn, Mn and Ni using a Perkin Elmer 303 atomic absorption spectrophotometer equipped with a standard pre-mix burner. Air and acetylene were used for all flame techniques. Cr and Cd were analyzed using a graphite atomizer attachment which provided greater stability and sensitivity for these elements. Standard operating parameters are shown in Table II.

TABLE II

OPERATING PARAMETERS

Metal	Wavelength mμ or nm	Current	Slit Width
Pb	217	10 ma	7A
Cu	324.75	15 ma	7A
Cr	357.87	20 ma	2A
Cd	228.80	6 ma	7A
Zn	214	15 ma	7A
Ni	232	25 ma	2A
Mn	279	15 ma	7A

Mercury was analyzed using an automated flameless atomic absorption technique (13, 14, 15). Mercury analysis was performed by a cold vapor technique employing the Coleman Mercury Analyzer MAS-50 and a Technicon Autoanalyzer. Concentrated sulfuric acid and potassium permanganate were added to oxidize the sample. Further oxidation of organomercury compounds was assured through the addition of potassium persulfate. Samples were then heated to 105°C. Hydroxylamine sulfate-sodium chloride was used to reduce the excess permanganate. The mercury in the sample was then reduced to the elemental state through the addition of excess stannous sulfate and a large amount of air. The gaseous phase was then analyzed in the MAS-50.

DISCUSSION

The purpose of this study was to assemble an up-to-date inventory of metals accumulations in Baltimore Harbor. One hundred and seventy-six stations were sampled between January and March of 1973 and the surface (5-15 cm) analyzed for Pb, Cd, Cr, Cu, Mn, Ni, Zn and Hg. Twenty-four cores were sampled at 30-40 cm as well as 5-15 cm.

In general the concentrations in surface samples were equal to or greater than the values at 30-40 cm, although the opposite was true in the Northwest Branch. Lead distribution, however, was atypical with the 30-40 cm samples being 2-3 times the surface values throughout the entire Harbor area including the Northwest Branch. It should be noted that many of the stations involved in this dual sampling were located in or near a channel and are subject to physical changes other than those which would be naturally occurring.

The distribution of metals by geographical areas is presented in Table III. The Northwest Branch, Colgate Creek and Bear Creek are the most severely polluted areas. Old Road Bay sediments are also seriously contaminated but not to the degree of the aforementioned areas.

Additional investigations should be made in some of the Harbor tributaries, particularly Bear Creek and Colgate Creek. The degree of metals contamination in these two areas suggests

TABLE III

GEOGRAPHICAL DISTRIBUTION OF METALS IN BALTIMORE HARBOR

Division		Cd	Cr	Cu	Pb	Mn	Hg	Ni	Zn
Northwest Branch	High	15	4756	2926	13890	543	11.34	58	1608
	Average	3.13-3.37	1031	894	791	340	2.73	34	733
	Low	<1	39	13	5	121	<.01	14	38
Middle Branch	High	3	573	469	457	1527	1.91	59	1195
	Average	1-1.3	174	222	158	469	.56	34	440
	Low	<1	42	26	9	190	.13	22	106
Curtis Bay	High	1	524	590	376	812	1.57	54	1084
	Average	.6-1.0	186	255	165	412	.73	30	487
	Low	<1	28	<1	<1	125	<.01	13	49
Colgate Creek	High	654	1336	1532	2282	421	12.20	94	4020
	Average	337	936	966	1270	341	6.32	67	2404
	Low	20	537	401	259	261	.43	40	789
Bear Creek	High	26	5745	946	981	437	3.87	71	5874
	Average	16	1993	408	560	311	1.66	40	3315
	Low	5	876	204	248	200	.75	30	1690
Old Road Bay	High	8	980	216	1310	1187	1.81	47	6040
	Average	4.2-4.3	340	167	826	937	1.37	33	3416
	Low	<1	103	124	292	698	.50	26	910
Outer Harbor	High	10	1538	644	504	2721	2.83	62	2858
	Average	1.5-1.89	323	196	187	1012	.69	38	710
	Low	<1	10	10	7	209	<.01	12	31

a need for further studies to determine the effect of these high levels on the biological lifeforms inhabiting these tributaries.

The effects of the Sparrows Point industrial complex is evident in the Bear Creek and Old Road Bay areas. High mercury, cadmium, zinc and lead levels were found in these sediments.

Figures IV through XIX graphically depict the distribution patterns of heavy metals in the Harbor.

Abrupt changes in color from black to grey were noted in many of the core samples. No attempt was made at systematically correlating metallic content to color. Aside from the organic contribution to sediment color, Biggs (28) has determined that the black color is due to FeS_nH_2O, while the grey color is indicative of the absence of FeS_nH_2O. Since the order of solubilities for divalent sulfides is $Hg<Cu<Pb<Cd<Ni<Zn$, Biggs postulated that in black sediment the least soluble sulfides would show the highest ratio in Harbor sediments relative to their abundance in the Chesapeake Bay. If there is a greater concentration of the element in the Harbor and if the sulfide is the least soluble chemical form which that element can be present as, then the elements should be present in the following order of decreasing ratio:

$$Hg > Cu > Pb > Cd > Ni > Zn$$

Several stations were selected which were predominantly black and the order of divalent sulfide solubilities were investigated. The results are shown in Table IV.

The actual results compare favorably with the expected order except for zinc which is apparently present in forms other than the sulfide.

Metallic concentration is also affected by sediment particle size. High surface area and adsorption capacity make clays a perfect scavenger for metallic substances. Sediment grain size can be a significant factor in evaluating the distribution of heavy metals in bottom deposits. Given the absence of other contributing causes, particle size is indicative of the adsorption capacity and thus the metallic concentration of sediments (10). Two stations in the survey located in areas with an unusually high percentage of sand (90%) showed very low concentrations of metals. However, sand, silt and clay ratios for 24 Harbor stations (26) showed a generally similar overall percentage breakdown as was earlier reported for the Chesapeake Bay proper (27) indicating that particle size is not the primary influence on metallic distribution patterns when comparing the Harbor with the Bay.

The biological effects of the contaminated bottom deposits of Baltimore Harbor are discussed in a report by the Chesapeake Biological Laboratory (26). The benthic community of the Inner Harbor area was adversely affected with conditions improving

TABLE IV

SULFIDE RATIOS IN
BALTIMORE HARBOR SEDIMENTS

Station	Order of Decreasing Ratio
J6	Hg > Cr > Cu > Zn > Cd > Pb > Ni
J7	Hg > Cr > Cu > Zn > Pb > Cd > Ni
GG3	Cu > Hg > Cr > Pb > Zn > Cd > Ni
HH2	Cu > Hg > Cr > Pb > Zn > Cd > Ni
II1	Hg > Cu > Cr > Pb > Zn > Cd > Ni
JJ1	Hg > Cu > Cr > Pb > Zn > Cd > Ni
JJ2	Hg > Cu > Cr > Pb > Zn > Cd > Ni
LL4	Hg > Cr > Cu > Pb > Zn > Cd > Ni

gradually towards the Harbor mouth. Scarcity of some common benthic species and the deteriorated condition of bottom feeders found in this area show the affects of a stressed environment.

The distribution of eggs, larvae and juvenile fish suggests that the mouth of the Harbor is in a relatively healthy state. This same study reported large fish populations, especially of white perch, but the absence of bottom fish was noted.

Heavy metals contamination of bottom deposits may be a major contributing factor to the biological deterioration of the Baltimore Harbor benthic community.

For a given area it is difficult to objectively state what concentration levels of a metal are, in fact, above the "normal" background level. However, a realistic attempt to define metallic pollution must be made if the observed data are to have any meaning. In attempting to evaluate the degree of heavy metals contamination in Baltimore Harbor, comparisons of the concentrations found in the Harbor were made with those found in:

1) Another highly industrialized harbor area, namely the South Branch of the Elizabeth River in Norfolk, Virginia (Table V);

2) The open regions of the Chesapeake Bay (Table VI);

3) Other estuarine environments, in this case the Delaware, Potomac and James River estuaries (Table VII); and

4) The earth's crust (average values at best) (Table VIII).

Appendix I, Tables IX through XVI, contains the results for all the metals analyzed in this survey. A map showing sampling stations is at the end of Appendix I (Figure 3).

The South Branch of the Elizabeth River is similar to the Baltimore Harbor area in that it, too, supports a highly industrialized port facility. Table V provides a comparison of Cu, Pb, Zn and Hg levels in these two harbors.

Average lead and zinc concentrations in Baltimore Harbor are two to three times the levels found in the South Branch of the Elizabeth River. Copper, on the other hand, is more concentrated in the Elizabeth River sediments by a factor of three times.

For all metals compared, Baltimore Harbor had higher "high" values than the Elizabeth River.

Table VI is a comparison of the Harbor values with those found in the open Chesapeake Bay (approximately 5 miles from the Magothy River in mid-Bay to Cove Point). For all metals analyzed the average and high Harbor values exceeded the open Bay values. Ignoring for the time being the low and high values as being extreme, the average chromium, copper and lead Harbor values are 20, 50 and 13 times their Bay values. The average manganese values in the Bay and Harbor are approximately equal. The average cadmium value for the Harbor is 6.3-6.6 and at least six times the value in the Bay.

All Harbor metals investigated but manganese were 3 to 50

TABLE V

METALS IN BALTIMORE HARBOR AND ELIZABETH RIVER SEDIMENTS

Metal	Baltimore Harbor[22]	Elizabeth River[16]
Copper, mg/kg		
Low	<1	20
Average	342	900
High	2926	1500
Lead, mg/kg		
Low	<1	10
Average	341	100
High	13890	500
Zinc, mg/kg		
Low	31	80
Average	888	350
High	6040	1300
Mercury, mg/kg		
Low	<.01	.30
Average	1.17	.90
High	12.20	3.00

times greater than their Bay counterparts. These factors should be carefully weighed when considering the disposal of dredged spoil in any open bay areas.

The Delaware, Potomac and James Estuaries provide another opportunity to evaluate Baltimore Harbor data. While none of these three estuaries have the concentrated industrial complex to the extent Baltimore Harbor does, they do provide for comparisons primarily with an industrialized tidal system (Delaware River), an estuary with mainly municipal inputs (Potomac River) and a third, more remote, system with a lesser degree of both municipal and industrial inputs (James River). The James River sediments contain the least amounts of zinc and lead, and in fact, the average values of the James (Table VII) are remarkably similar to the open Bay (Table VI). Potomac Estuary sediments exhibit greater ranges of values than the James but are no more than two times greater than Bay concentrations.

The Delaware Estuary shows consistently higher levels than the James or Potomac but still considerably less than levels found in Baltimore Harbor. The chromium and copper averages are about 5-6 times greater in the Harbor than in the Delaware while lead and zinc values are twice as great in the Harbor.

Table VIII shows average concentrations of heavy metals in the earth's crust. As can be seen these concentration ranges are far less than those found in Baltimore Harbor. Those values

TABLE VI

METALS IN BALTIMORE HARBOR AND CHESAPEAKE BAY SEDIMENTS

Metal	Baltimore Harbor[22]	Chesapeake Bay[22]
Chromium, mg/kg		
Low	10	18
Average	492	25
High	5745	42
Copper, mg/kg		
Low	<1	<1
Average	342	6.4-7.0
High	2926	22
Lead, mg/kg		
Low	<1	9
Average	346	27
High	13890	86
Zinc, mg/kg		
Low	31	33
Average	888	128
Hgih	6040	312
Cadmium, mg/kg		
Low	<1	<1
Average	6.3-6.6	<1
High	654	<1
Nickel, mg/kg		
Low	12	5
Average	36	12
High	94	27
Manganese, mg/kg		
Low	121	218
Average	739	690
High	2721	1608
Mercury, mg/kg		
Low	<.01	<.01
Average	1.17	.061-.067
High	12.20	.31

TABLE VII

METALS IN BALTIMORE HARBOR, DELAWARE RIVER, POTOMAC RIVER AND JAMES RIVER SEDIMENTS

Metal	Baltimore Harbor[22]	Delaware River[22]	Potomac River[17]	James River[16]
Chromium, mg/kg				
Low	10	8	20	NO
Average	492	58	--	
High	5745	172	80	DATA
Copper, mg/kg				
Low	<1	4	10	NO
Average	342	73	--	
High	2926	201	60	DATA
Lead, mg/kg				
Low	<1	26	20	4
Average	341	145	--	27
High	13890	805	100	55
Zinc, mg/kg				
Low	31	137	125	10
Average	888	523	--	131
High	6040	1364	1000	708
Cadmium, mg/kg				
Low	<1	<1	<1	NO
Average	6.3-6.6	2.9-3.1	--	
High	654	17	.60	DATA
Nickel, mg/kg				
Low	12	NO	20	NO
Average	36		--	
High	94	DATA	45	DATA
Manganese, mg/kg				
Low	121	NO	500	NO
Average	739		--	
High	2721	DATA	4800	DATA
Mercury, mg/kg				
Low	<.01	<.01	.01	.02
Average	1.17	1.99	--	.32
High	12.20	6.97	.03	1.00

-- Data taken from tables - ranges only

TABLE VIII[23, 24]

CONCENTRATION OF HEAVY METALS IN EARTH'S CRUST, AVG. RANGE

Metal	Range, mg/kg
Chromium	.10 - 100.00
Copper	4.00 - 55.00
Lead	7.00 - 20.00
Zinc	16.00 - 95.00
Cadmium	.05 - .30
Nickel	2.00 - 75.00
Manganese	50.00 - 1100.00
Mercury	.03 - .40

from Chesapeake Bay and the James River are just slightly higher than the values in Table VIII. For the Potomac sediments, Pb, Zn, Cd and Mn values are in excess of the averages while Cr, Cu, Ni and Hg are within the specified ranges.

APPENDIX I

Location	mg/kg	Location	mg/kg	Location	mg/kg	Location	mg/kg
A 1	<1	H 3	<1	O 4	1	AA 1	4
2	<1	4	<1	5	<1	2	<1
3	<1	4*	<1	6	<1	2*	<1
4	<1	5	7	P 1	1	3	15
5	<1	I 1	<1	2	1	BB 1	2
B 1	<1	2	2	2*	1	2	3
2	<1	3	<1	3	<1	CC 1	4
3	<1	4	3	4	2	2	1
4	<1	5	3	Q 1	3	DD 1	4
5	<1	6	2	2	<1	1*	4
C 1	NS	6*	<1	3	2	2	1
2	<1	J 1	1	3*	<1	3	<1
3	<1	2	<1	4	8	EE 1	<1
3*	<1	3	1	5	20	2	1
4	<1	4	5	6	654	FF 1	<1
5	<1	4*	5	R 1	2	2	<1
6	<1	5	10	2	1	3	4
7	3	6	24	2*	<1	GG 1	<1
8	8	7	26	3	5	2	5
D 1	NS	8	19	4	1	2*	9
2	1	9	15	S 1	6	3	7
3	<1	K 1	<1	2	<1	HH 1	1
4	<1	2	<1	3	2	2	5
5	1	3	2	T 1	3	II 1	4
6	2	4	4	2	2	2	4
7	<1	5	12	3	2	JJ 1	9
8	4	6	5	3*	<1	2	5
9	4	6*	5	U 1	3	KK 1	<1
10	6	7	8	2	<1	2	4
E 1	1	L 1	1	2*	2	LL 1	1
2	<1	2	1	3	2	2	2
3	1	2*	<1	V 1	<1	3	3
4	4	3	3	2	1	3*	9
5	<1	4	NS	3	1	4	5
6	4	M 1	1	W 1	<1	CB 1	1
6*	8	2	1	2	1	2	1
F 1	2	3	<1	2*	1	3	<1
2	1	4	<1	3	2	4	1
3	1	4*	3	X 1	NS	5	<1
4	<1	N1	1	2	<1	6	1
5	8	2	1	3	<1	7	1
5*	9	2*	1	4	<1	8	1
6	4	3	1	4*	1	8*	1
G 1	NS	4	2	Y 1	<1	9	<1
2	1	5	1	2	1	10	<1
3	1	6	NS	3	2	11	<1
4	<1	O 1	3	4	1	12	1
5	2	2	3	5	1	13	<1
H 1	1	2*	1	5*	2	14	1
2	1	3	<1	6	2	15	1

NS No sample taken

* Same sample 30-40 cm

Location	mg/kg	Location	mg/kg	Location	mg/kg	Location	mg/kg
A 1	41	H 3	42	O 4	215	AA 1	963
2	157	4	196	5	134	2	163
3	60	4*	34	6	284	2*	42
4	28	5	536	P 1	115	3	310
5	53	I 1	140	2	224	BB 1	534
B 1	29	2	457	2*	161	2	558
2	31	3	193	3	45	CC 1	969
3	64	4	652	4	460	2	60
4	160	5	299	Q 1	637	DD 1	940
5	84	6	444	2	97	1*	876
C 1	NS	6*	14	3	473	2	247
2	10	J 1	293	3*	139	3	39
3	86	2	190	4	578	EE 1	51
3*	88	3	624	5	537	2	181
4	141	4	1397	6	1336	FF 1	92
5	185	4*	950	R 1	404	2	180
6	103	5	1538	2	520	3	657
7	231	6	2401	2*	58	GG 1	46
8	208	7	5745	3	320	2	1656
D 1	NS	8	1044	4	193	2*	1564
2	89	9	1432	S 1	1124	3	2137
3	21	K 1	267	2	148	HH 1	486
4	161	2	75	3	285	2	2013
5	114	3	568	T 1	730	II 1	1745
6	220	4	1261	2	658	2	1682
7	15	5	1336	3	604	JJ 1	3184
8	206	6	1120	3*	239	2	3057
9	310	6*	560	U 1	573	KK 1	95
10	980	7	876	2	193	2	1755
E 1	112	L 1	599	2*	119	LL 1	340
2	72	2	274	3	477	2	746
3	85	2*	38	V 1	121	3	1292
4	161	3	860	2	79	3*	2102
5	195	4	NS	3	328	4	4756
6	402	M 1	432	W 1	64	CB 1	283
6*	282	2	372	2	155	2	200
F 1	547	3	162	2*	159	3	57
2	225	4	149	3	200	4	524
3	74	4*	965	X 1	NS	5	90
4	119	N 1	765	2	53	6	149
5	618	2	409	3	42	7	275
5*	183	2*	400	4	94	8	319
6	234	3	405	4*	157	8*	216
G 1	NS	4	378	Y 1	46	9	40
2	113	5	363	2	114	10	55
3	91	6	NS	3	211	11	32
4	36	O 1	664	4	109	12	296
5	159	2	569	5	128	13	28
H 1	229	2*	203	5*	98	14	208
2	116	3	141	6	140	15	242

NS No sample taken

* Same sample 30-40 cm

Location	mg/kg	Location	mg/kg	Location	mg/kg	Location	mg/kg
A 1	69	H 3	68	O 4	226	AA 1	1616
2	112	4	140	5	15	2	373
3	63	4*	57	6	58	2*	14
4	32	5	281	P 1	234	3	324
5	68	I 1	142	2	252	BB 1	1665
B 1	62	2	334	2*	276	2	731
2	32	3	123	3	10	CC 1	910
3	68	4	153	4	247	2	143
4	123	5	230	Q 1	345	DD 1	1389
5	79	6	242	2	65	1*	1315
C 1	NS	6*	10	3	358	2	881
2	14	J 1	177	3*	121	3	16
3	97	2	109	4	277	EE 1	24
3*	95	3	372	5	401	2	278
4	145	4	390	6	1532	FF 1	99
5	216	4*	412	R 1	352	2	243
6	124	5	541	2	291	3	2926
7	168	6	544	2*	12	GG 1	57
8	173	7	946	3	281	2	1415
D 1	NS	8	333	4	185	2*	2000
2	55	9	329	S 1	557	3	2220
3	29	K 1	102	2	123	HH 1	682
4	135	2	25	3	229	2	2178
5	120	3	164	T 1	412	II 1	1057
6	231	4	218	2	644	2	1526
7	36	5	218	3	619	JJ 1	1136
8	177	6	283	3*	197	2	1542
9	142	6*	305	U 1	375	KK 1	13
10	216	7	204	2	174	2	1426
E 1	94	L 1	311	2*	93	LL 1	247
2	56	2	217	3	368	2	433
3	65	2*	2	V 1	134	3	354
4	122	3	338	2	68	3*	882
5	134	4	NS	3	306	4	933
6	375	M 1	272	W 1	104	CB 1	330
6*	209	2	66	2	218	2	281
F 1	229	3	35	2*	330	3	44
2	134	4	67	3	362	4	427
3	73	4*	393	X 1	NS	5	88
4	78	N 1	347	2	95	6	288
5	389	2	331	3	34	7	304
5*	133	2*	92	4	278	8	501
6	323	3	288	4*	263	8*	139
G 1	NS	4	271	Y 1	26	9	<1
2	110	5	198	2	164	10	189
3	72	6	NS	3	469	11	28
4	91	O 1	534	4	142	12	590
5	182	2	405	5	198	13	12
H 1	142	2*	229	5*	161	14	265
2	90	3	140	6	209	15	472

NS No sample taken * Same sample 30-40 cm

Location	mg/kg	Location	mg/kg	Location	mg/kg	Location	mg/kg
A 1	90	H 3	20	O 4	161	AA 1	351
2	163	4	176	5	7	2	341
3	138	4*	16	6	14	2*	6
4	16	5	475	P 1	119	3	13890
5	111	I 1	174	2	169	BB 1	844
B 1	34	2	454	2*	240	2	365
2	23	3	191	3	7	CC 1	448
3	128	4	379	4	124	2	320
4	174	5	504	Q 1	209	DD 1	384
5	178	6	393	2	26	1*	636
C 1	NS	6*	9	3	234	2	166
2	33	J 1	179	3*	109	3	6
3	161	2	179	4	216	EE 1	13
3*	180	3	262	5	259	2	36
4	323	4	410	6	2282	FF 1	22
5	301	4*	453	R 1	191	2	176
6	292	5	489	2	228	3	729
7	642	6	501	2*	<1	GG 1	5
8	1310	7	981	3	168	2	466
D 1	NS	8	581	4	139	2*	1170
2	138	9	636	S 1	363	3	511
3	20	K 1	109	2	61	HH 1	336
4	146	2	28	3	193	2	466
5	156	3	233	T 1	347	II 1	518
6	317	4	448	2	269	2	477
7	13	5	291	3	386	JJ 1	383
8	1026	6	548	3*	197	2	529
9	682	6*	2218	U 1	457	KK 1	10
10	1006	7	682	2	129	2	584
E 1	137	L 1	180	2*	104	LL 1	254
2	93	2	55	3	188	2	426
3	132	2*	4	V 1	93	3	347
4	147	3	301	2	77	3*	889
5	152	4	NS	3	169	4	336
6	380	M 1	139	W 1	42	CB 1	376
6*	1008	2	132	2	129	2	360
F 1	248	3	36	2*	318	3	14
2	180	4	36	3	35	4	164
3	128	4*	298	X 1	NS	5	30
4	113	N 1	81	2	30	6	284
5	475	2	71	3	23	7	164
5*	564	2*	159	4	74	8	231
6	356	3	120	4*	158	8*	57
G 1	NS	4	255	Y 1	9	9	<1
2	177	5	105	2	252	10	36
3	122	6	NS	3	319	11	3
4	19	O 1	393	4	134	12	367
5	190	2	348	5	328	13	6
H 1	130	2*	270	5*	238	14	237
2	161	3	144	6	364	15	202

NS No sample taken * Same sample 30-40 cm

Location	mg/kg	Location	mg/kg	Location	mg/kg	Location	mg/kg
A 1	1301	H 3	1431	O 4	1207	AA 1	263
2	1287	4	1222	5	209	2	516
3	2076	4*	1157	6	363	2*	578
4	1166	5	461	P 1	989	3	292
5	1059	I 1	1588	2	782	BB 1	333
B 1	1186	2	405	2*	875	2	438
2	1173	3	2309	3	1287	CC 1	385
3	1729	4	353	4	374	2	489
4	1261	5	643	Q 1	523	DD 1	443
5	1007	6	410	2	1050	1*	508
C 1	NS	6*	1129	3	532	2	418
2	590	J 1	964	3*	267	3	421
3	2286	2	1448	4	334	EE 1	300
3*	3317	3	740	5	421	2	543
4	711	4	447	6	261	FF 1	199
5	1544	4*	494	R 1	497	2	185
6	698	5	515	2	804	3	399
7	1112	6	290	2*	635	GG 1	121
8	1187	7	437	3	539	2	330
D 1	NS	8	327	4	361	2*	278
2	1254	9	367	S 1	460	3	467
3	1227	K 1	841	2	535	HH 1	302
4	2721	2	2097	3	552	2	360
5	936	3	214	T 1	540	II 1	259
6	589	4	266	2	698	2	389
7	587	5	200	3	685	JJ 1	276
8	1129	6	274	3*	1134	2	264
9	775	6*	245	U 1	445	KK 1	185
10	722	7	285	2	467	2	297
E 1	494	L 1	662	2*	395	LL 1	384
2	1518	2	1118	3	435	2	395
3	1441	2*	1432	V 1	454	3	324
4	2433	3	396	2	516	3*	212
5	1772	4	NS	3	383	4	222
6	741	M 1	984	W 1	344	CB 1	348
6*	1026	2	1402	2	296	2	422
F 1	365	3	1399	2*	289	3	266
2	1220	4	1487	3	427	4	507
3	1505	4*	389	X 1	NS	5	598
4	1740	N 1	530	2	190	6	180
5	714	2	1176	3	350	7	541
5*	609	2*	1128	4	513	8	574
6	1327	3	969	4*	308	8*	392
G 1	NS	4	530	Y 1	477	9	231
2	1657	5	1291	2	460	10	224
3	1622	6	NS	3	195	11	125
4	1247	O 1	367	4	389	12	512
5	873	2	412	5	1527	13	528
H 1	259	2*	397	5*	325	14	313
2	1987	3	1253	6	580	15	812

NS No sample taken * Same sample 30-40 cm

Location	mg/kg	Location	mg/kg	Location	mg/kg	Location	mg/kg
A 1	.14	H 3	.51	O 4	.66	AA 1	2.72
2	.70	4	1.17	5	<.01	2	.92
3	.19	4*	.45	6	<.01	2*	<.01
4	<.01	5	2.83	P 1	.51	3	10.35
5	.32	I 1	.60	2	.45	BB 1	4.84
B 1	<.01	2	LA	2*	1.15	2	1.01
2	<.01	3	.38	3	<.01	CC 1	1.86
3	.56	4	1.22	4	.39	2	.26
4	.72	5	1.27	Q 1	.84	DD 1	1.85
5	.26	6	2.54	2	.53	1*	1.49
C 1	NS	6*	<.01	3	.81	2	.49
2	.03	J 1	.39	3*	.62	3	<.01
3	.67	2	.32	4	.77	EE 1	<.01
3*	.43	3	.85	5	.43	2	.05
4	.57	4	1.00	6	12.20	FF 1	.23
5	.09	4*	1.39	R 1	1.21	2	1.69
6	.50	5	1.09	2	.61	3	3.58
7	1.81	6	2.43	2*	.06	GG 1	.51
8	1.81	7	3.87	3	.75	2	2.88
D 1	NS	8	1.28	4	.64	2*	3.70
2	<.01	9	1.13	S 1	1.42	3	3.06
3	<.01	K 1	.30	2	.50	HH 1	2.74
4	<.01	2	.22	3	.61	2	2.60
5	.15	3	.86	T 1	1.31	II 1	3.89
6	1.26	4	1.24	2	.95	2	2.31
7	<.01	5	1.20	3	.73	JJ 1	6.66
8	1.54	6	.95	3*	1.76	2	9.98
9	.99	6*	2.00	U 1	1.91	KK 1	.28
10	1.55	7	.75	2	.35	2	2.84
E 1	.36	L 1	.61	2*	.31	LL 1	.81
2	<.01	2	.65	3	.62	2	1.40
3	<.01	2*	<.01	V 1	.33	3	.69
4	.30	3	1.17	2	.22	3*	10.98
5	<.01	4	NS	3	.69	4	11.34
6	.39	M 1	2.10	W 1	.29	CB 1	1.28
6*	1.21	2	.54	2	.40	2	1.45
F 1	1.75	3	.41	2*	.81	3	.25
2	.67	4	.17	3	.39	4	.61
3	.66	4*	1.58	X 1	NS	5	.33
4	1.27	N 1	.98	2	.23	6	1.36
5	2.23	2	.61	3	.17	7	.77
5*	1.28	2*	.66	4	.22	8	.52
6	1.62	3	.69	4*	.61	8*	.35
G 1	NS	4	1.27	Y 1	.13	9	<.01
2	.97	5	.48	2	.63	10	.18
3	.54	6	NS	3	1.36	11	<.01
4	.51	O 1	.90	4	.64	12	1.57
5	.86	2	1.05	5	.86	13	<.01
H 1	.81	2*	1.64	5*	.77	14	1.55
2	.85	3	1.40	6	.69	15	1.07

NS No sample taken * Same sample 30-40 cm
LA Laboratory Accident

Location	mg/kg	Location	mg/kg	Location	mg/kg	Location	mg/kg
A 1	25	H 3	25	O 4	34	AA 1	38
2	48	4	41	5	12	2	26
3	45	4*	25	6	16	2*	22
4	27	5	47	P 1	44	3	22
5	62	I 1	46	2	42	BB 1	36
B 1	26	2	48	2*	35	2	35
2	30	3	44	3	26	CC 1	37
3	36	4	33	4	30	2	25
4	18	5	30	Q 1	47	DD 1	36
5	52	6	38	2	30	1*	38
C 1	NS	6*	20	3	42	2	31
2	12	J 1	32	3*	29	3	24
3	48	2	30	4	31	EE 1	24
3*	57	3	40	5	40	2	28
4	62	4	60	6	94	FF 1	18
5	54	4*	38	R 1	37	2	14
6	31	5	46	2	39	3	46
7	47	6	31	2*	26	GG 1	21
8	37	7	71	3	41	2	46
D 1	NS	8	35	4	25	2*	36
2	38	9	36	S 1	51	3	58
3	22	K 1	52	2	28	HH 1	20
4	51	2	33	3	31	2	44
5	33	3	29	T 1	44	II 1	37
6	52	4	30	2	40	2	42
7	16	5	30	3	31	JJ 1	36
8	26	6	40	3*	30	2	48
9	26	6*	39	U 1	59	KK 1	20
10	32	7	40	2	32	2	47
E 1	45	L 1	42	2*	26	LL 1	35
2	31	2	39	3	30	2	34
3	34	2*	22	V 1	29	3	37
4	44	3	48	2	31	3*	41
5	51	4	NS	3	37	4	40
6	44	M 1	44	W 1	23	CB 1	28
6*	48	2	42	2	22	2	26
F 1	45	3	30	2*	27	3	13
2	42	4	32	3	35	4	48
3	24	4*	37	X 1	NS	5	30
4	36	N 1	48	2	27	6	20
5	49	2	40	3	32	7	31
5*	25	2*	38	4	29	8	43
6	34	3	47	4*	27	8*	34
G 1	NS	4	34	Y 1	27	9	19
2	38	5	36	2	46	10	17
3	33	6	NS	3	38	11	18
4	26	O 1	43	4	29	12	48
5	37	2	35	5	40	13	24
H 1	34	2*	38	5*	37	14	29
2	37	3	32	6	46	15	54

NS No sample taken * Same sample 30-40 cm

Location	mg/kg	Location	mg/kg	Location	mg/kg	Location	mg/kg
A 1	91	H 3	125	O 4	560	AA 1	937
2	757	4	744	5	192	2	461
3	494	4*	103	6	263	2*	69
4	84	5	2858	P 1	636	3	639
5	620	I 1	405	2	943	BB 1	773
B 1	74	2	1331	2*	833	2	804
2	112	3	635	3	68	CC 1	1050
3	353	4	1363	4	556	2	103
4	667	5	1301	Q 1	1010	DD 1	1034
5	515	6	1307	2	228	1*	1011
C 1	NS	6*	48	3	767	2	406
2	69	J 1	635	3*	189	3	68
3	572	2	590	4	786	EE 1	59
3*	655	3	1025	5	789	2	189
4	946	4	1530	6	4020	FF 1	83
5	859	4*	1719	R 1	588	2	243
6	910	5	2099	2	646	3	1028
7	2954	6	3370	2*	51	GG 1	42
8	4749	7	5874	3	121	2	1215
D 1	NS	8	4616	4	257	2*	1092
2	477	9	3021	S 1	1124	3	1608
3	92	K 1	412	2	204	HH 1	358
4	520	2	154	3	405	2	1211
5	554	3	748	T 1	862	II 1	1200
6	1409	4	1556	2	704	2	994
7	50	5	2857	3	31	JJ 1	1408
8	3540	6	1776	3*	271	2	1344
9	2300	6*	3730	U 1	1195	KK 1	38
10	6040	7	1690	2	268	2	1308
E 1	397	L 1	1213	2*	150	LL 1	610
2	280	2	816	3	399	2	587
3	370	2*	56	V 1	294	3	732
4	670	3	1571	2	245	3*	1066
5	610	4	NS	3	403	4	1453
6	1330	M 1	962	W 1	158	CB 1	674
6*	1880	2	669	2	388	2	490
F 1	1409	3	390	2*	320	3	177
2	808	4	422	3	470	4	1084
3	382	4*	1402	X 1	NS	5	299
4	506	N 1	1113	2	215	6	484
5	1684	2	850	3	178	7	743
5*	1090	2*	714	4	228	8	848
6	1119	3	920	4*	451	8*	488
G 1	NS	4	830	Y 1	106	9	49
2	930	5	592	2	574	10	210
3	743	6	NS	3	930	11	49
4	72	O 1	975	4	655	12	849
5	662	2	1220	5	519	13	60
H 1	687	2*	420	5*	458	14	509
2	668	3	385	6	698	15	779

NS No sample taken * Same sample 30-40 cm

Figure 4

CADMIUM (mg/Kg)
BALTIMORE HARBOR
PATAPSCO RIVER

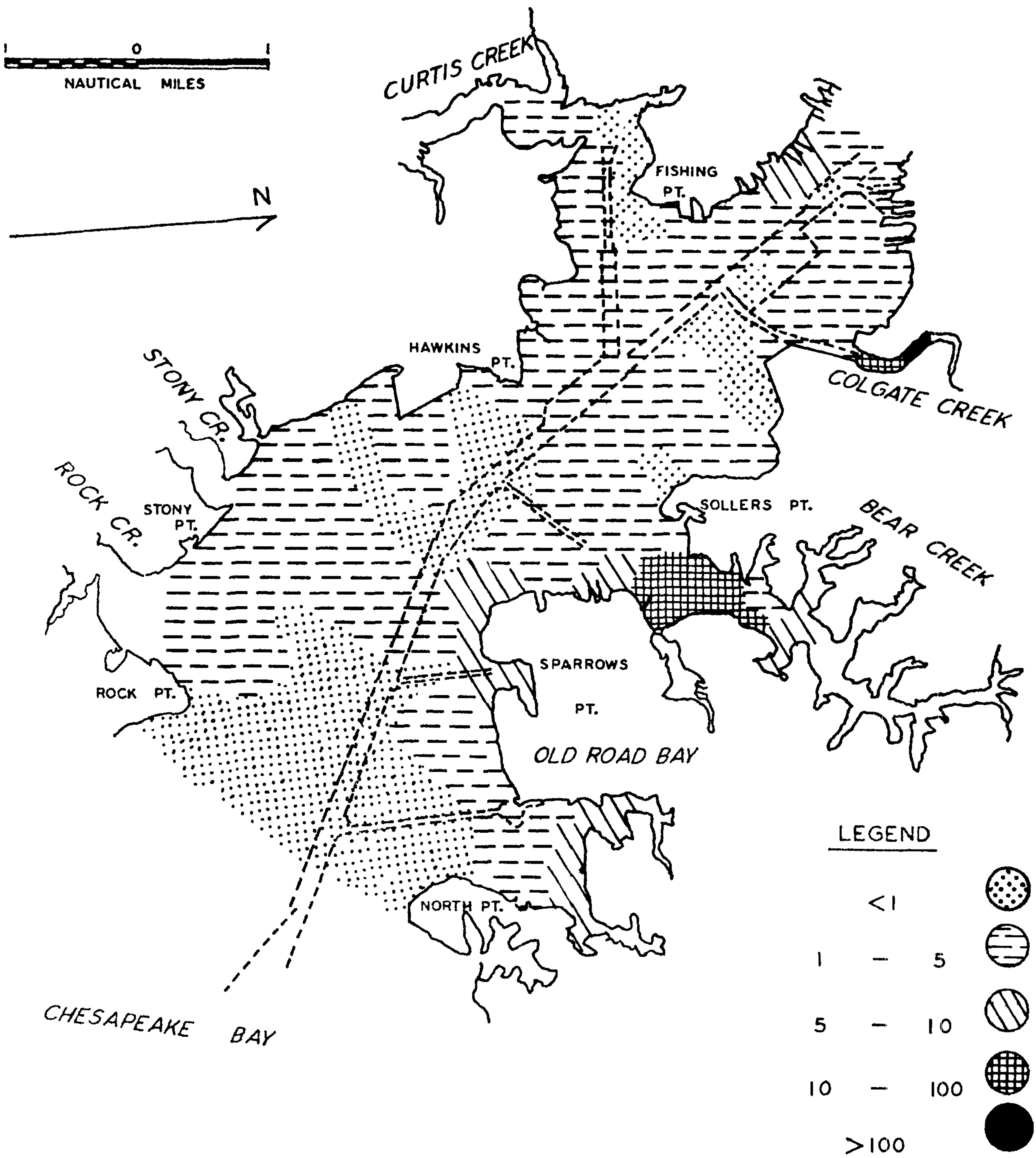


Figure 5

CADMIUM (mg/Kg)
BALTIMORE HARBOR
NORTHWEST & MIDDLE BRANCH

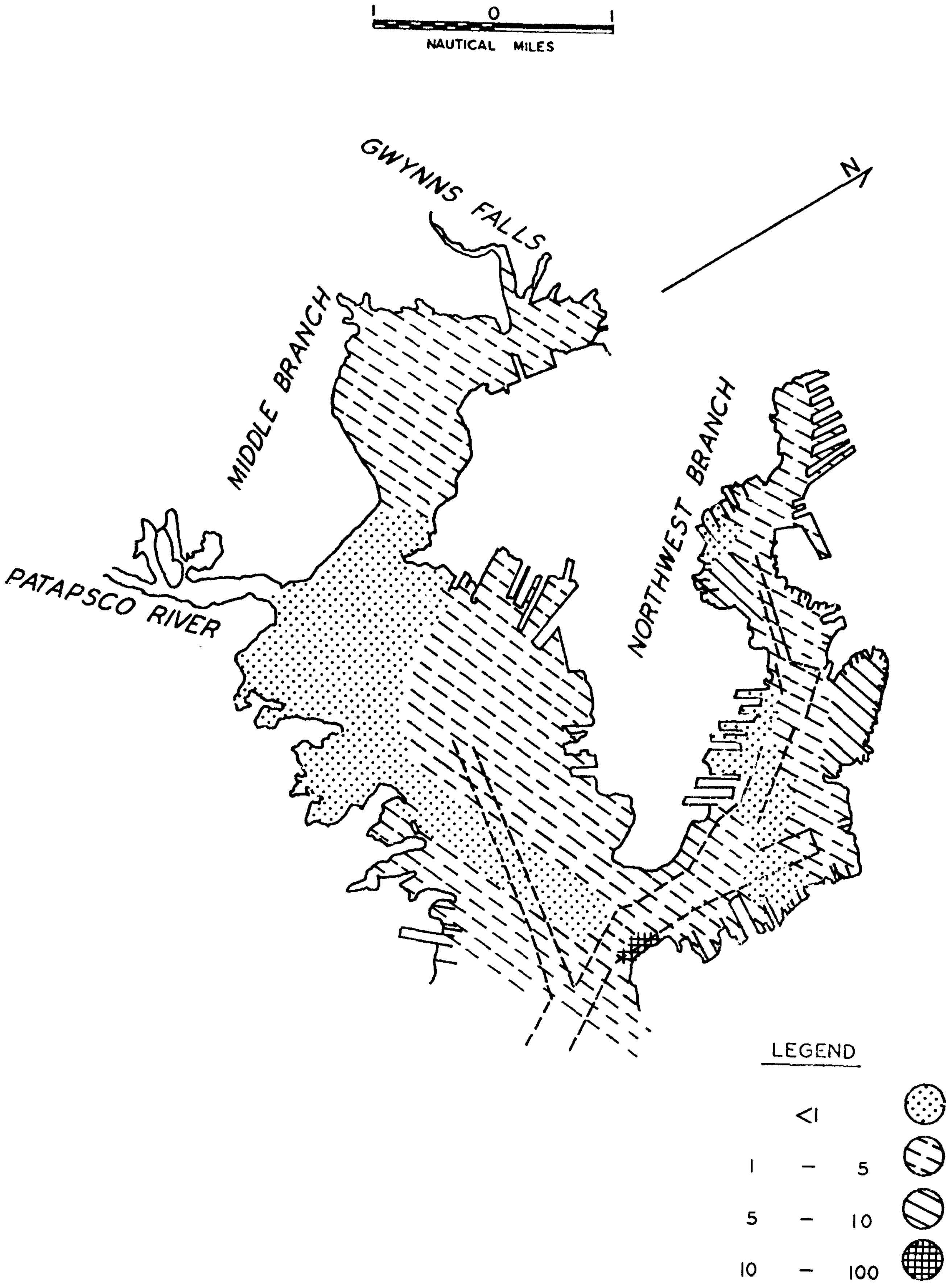


Figure 6

CHROMIUM (mg/Kg)
BALTIMORE HARBOR
PATAPSCO RIVER

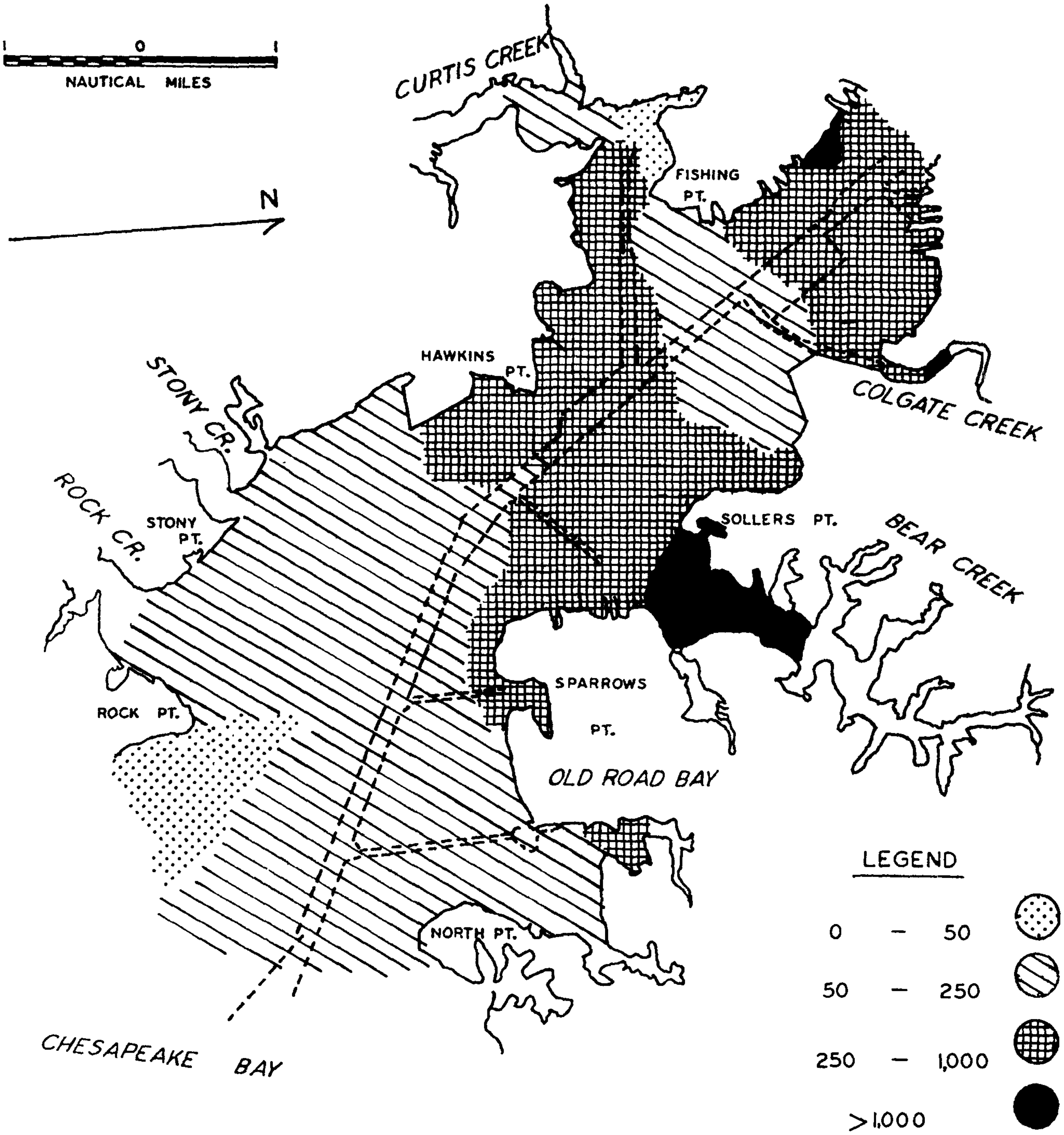


Figure 7

CHROMIUM (mg/Kg)
BALTIMORE HARBOR
NORTHWEST & MIDDLE BRANCH

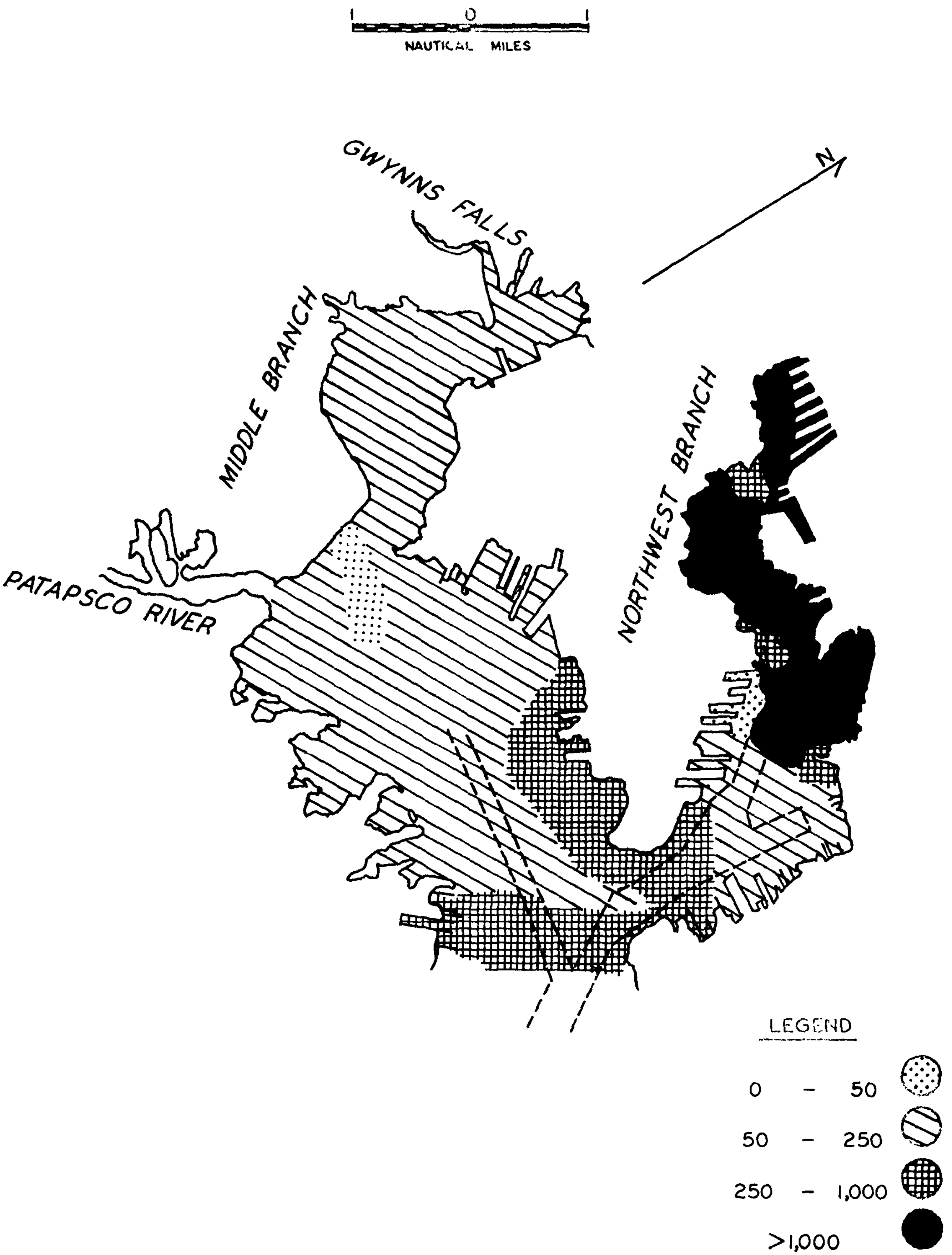


Figure 8

COPPER (mg/Kg)
BALTIMORE HARBOR
PATAPSCO RIVER

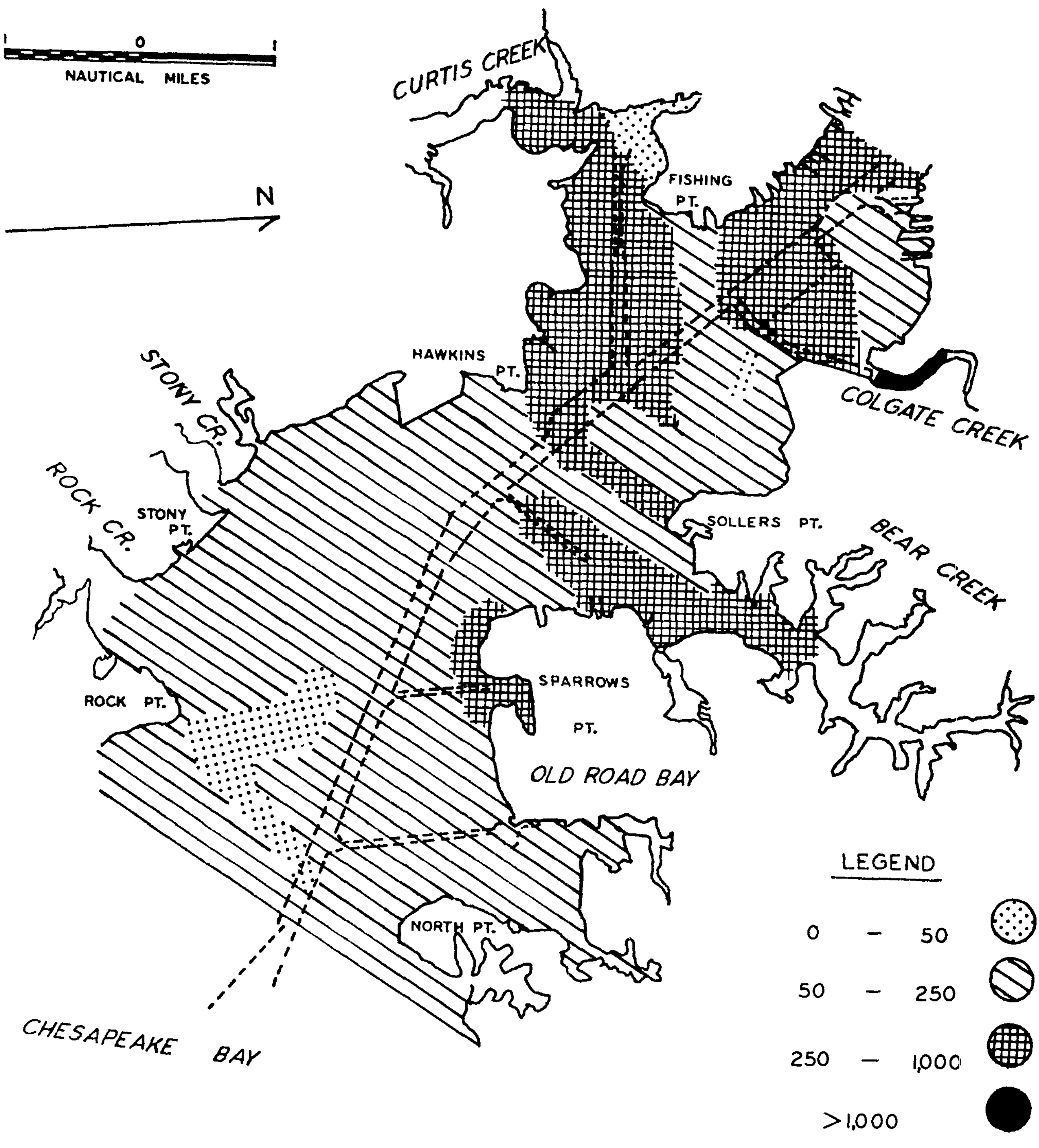


Figure 9

COPPER (mg/Kg)
BALTIMORE HARBOR
NORTHWEST & MIDDLE BRANCH

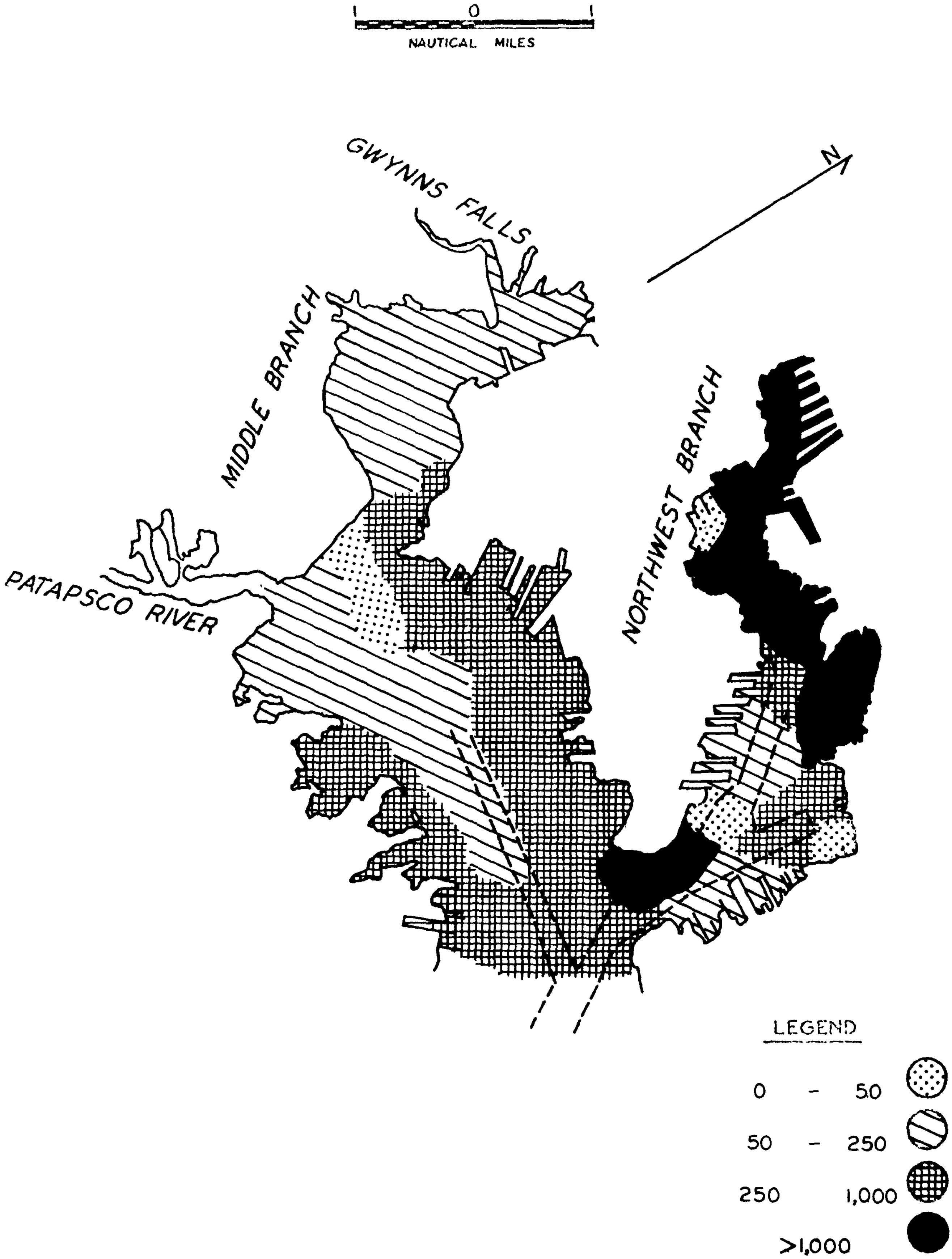


Figure 10

LEAD (mg/Kg)
BALTIMORE HARBOR
PATAPSCO RIVER

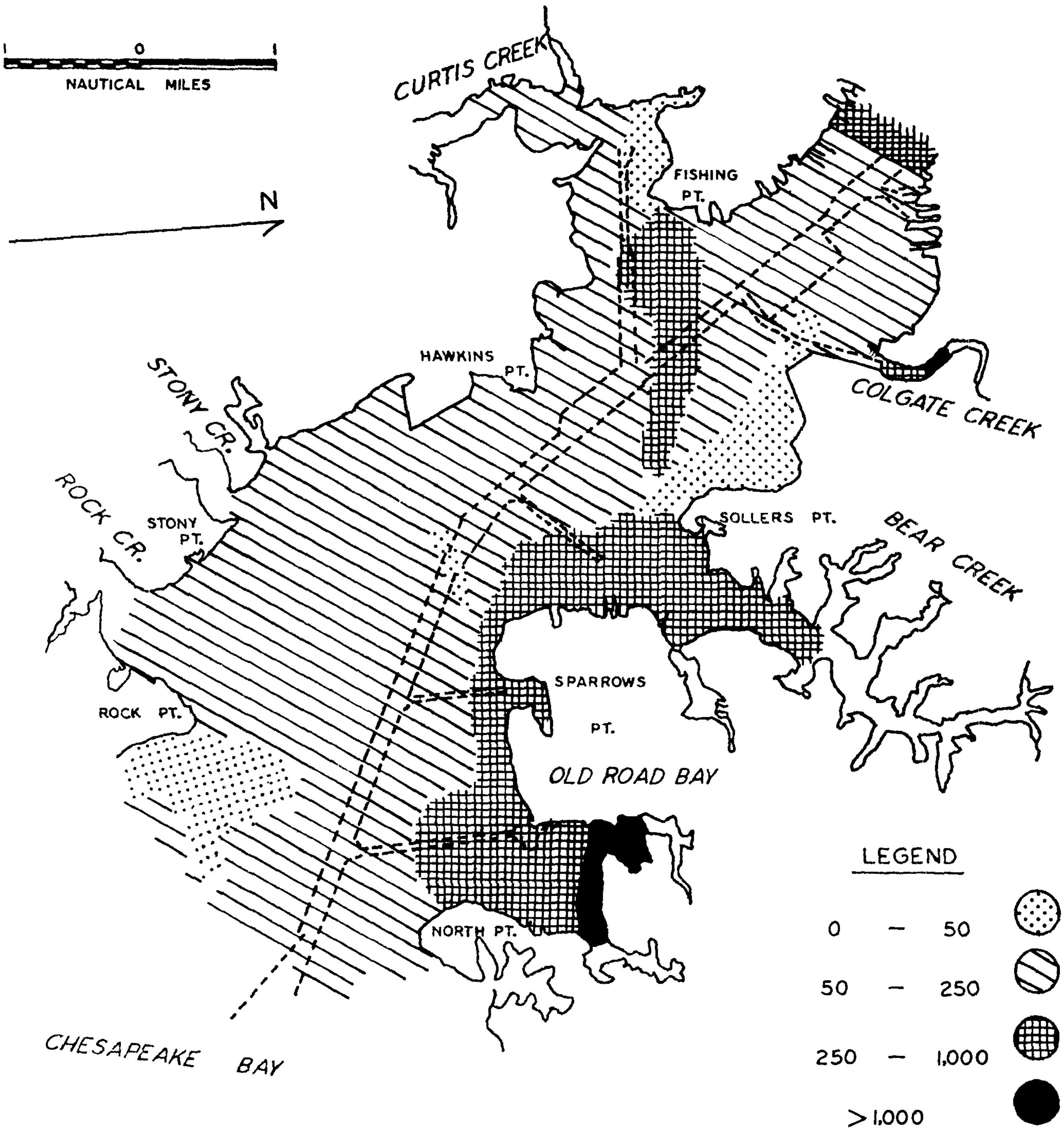


Figure 11

LEAD (mg/Kg)
BALTIMORE HARBOR
NORTHWEST & MIDDLE BRANCH

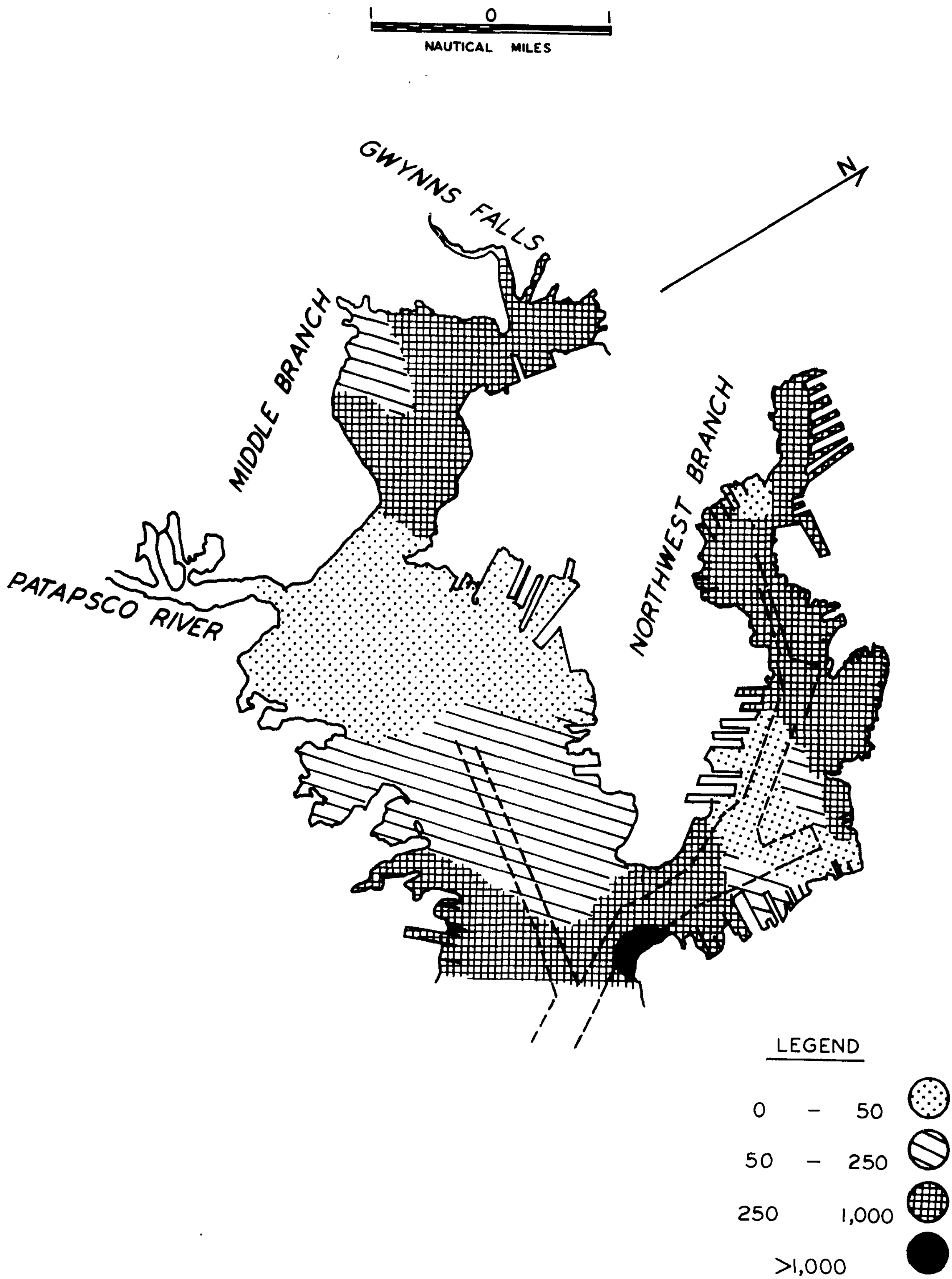


Figure 12

MANGANESE (mg/Kg)
BALTIMORE HARBOR
PATAPSCO RIVER

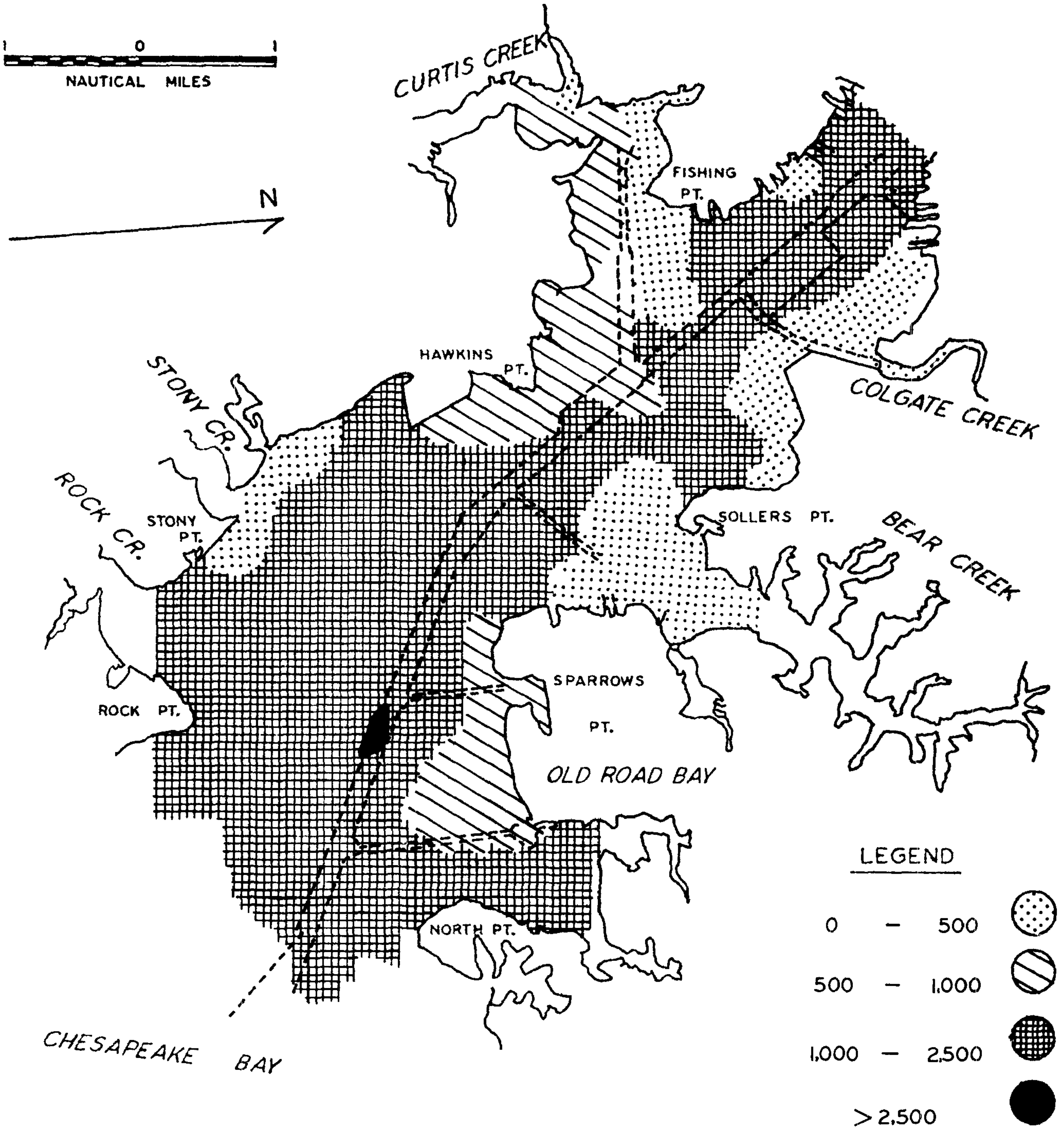


Figure 1[illegible]

MANGANESE (mg/Kg)
BALTIMORE HARBOR
NORTHWEST & MIDDLE BRANCH

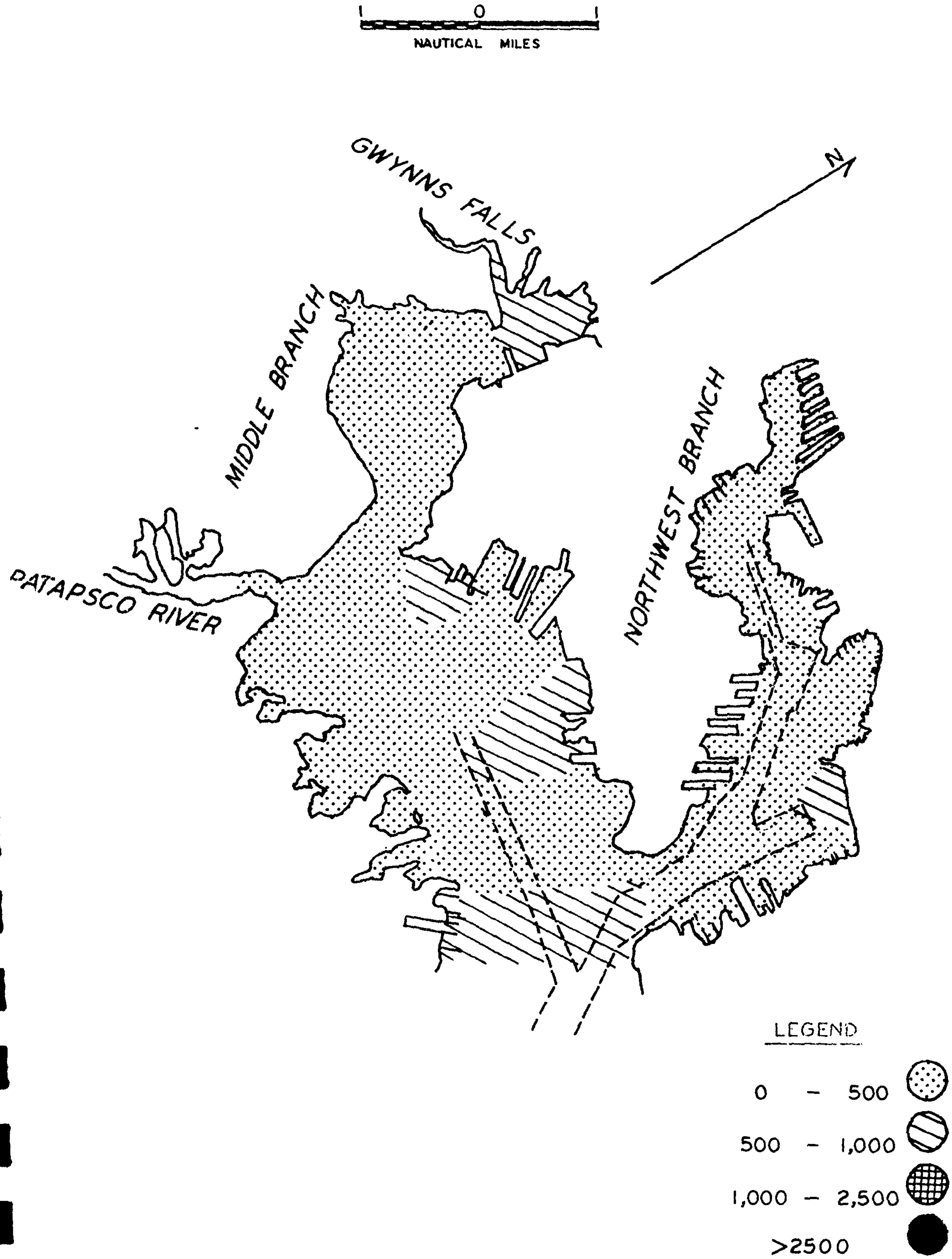


Figure 14

MERCURY (mg/Kg)
BALTIMORE HARBOR
PATAPSCO RIVER

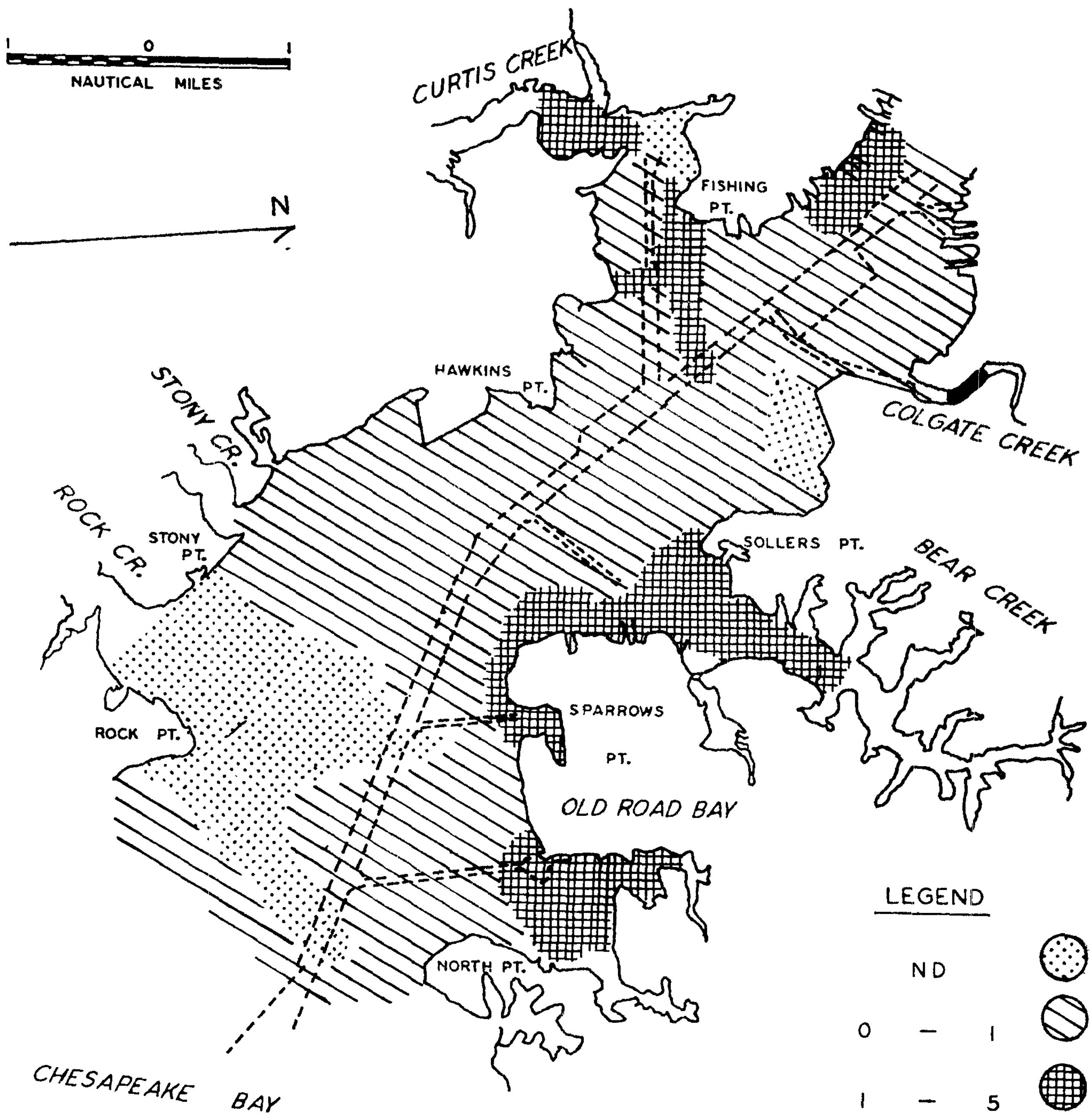


Figure 15

MERCURY (mg/Kg)
BALTIMORE HARBOR
NORTHWEST & MIDDLE BRANCH

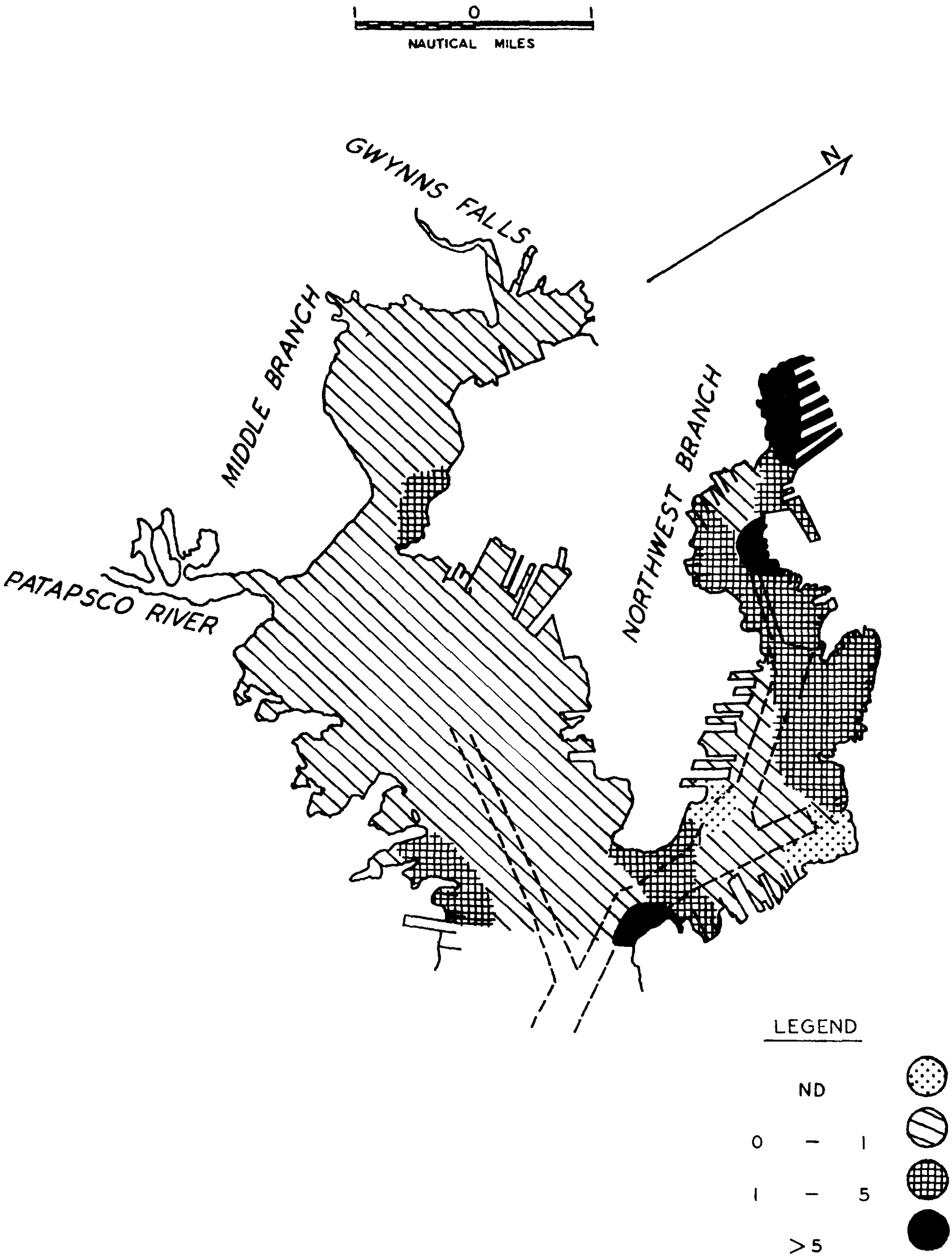


Figure 16

NICKEL (mg/Kg)
BALTIMORE HARBOR
PATAPSCO RIVER

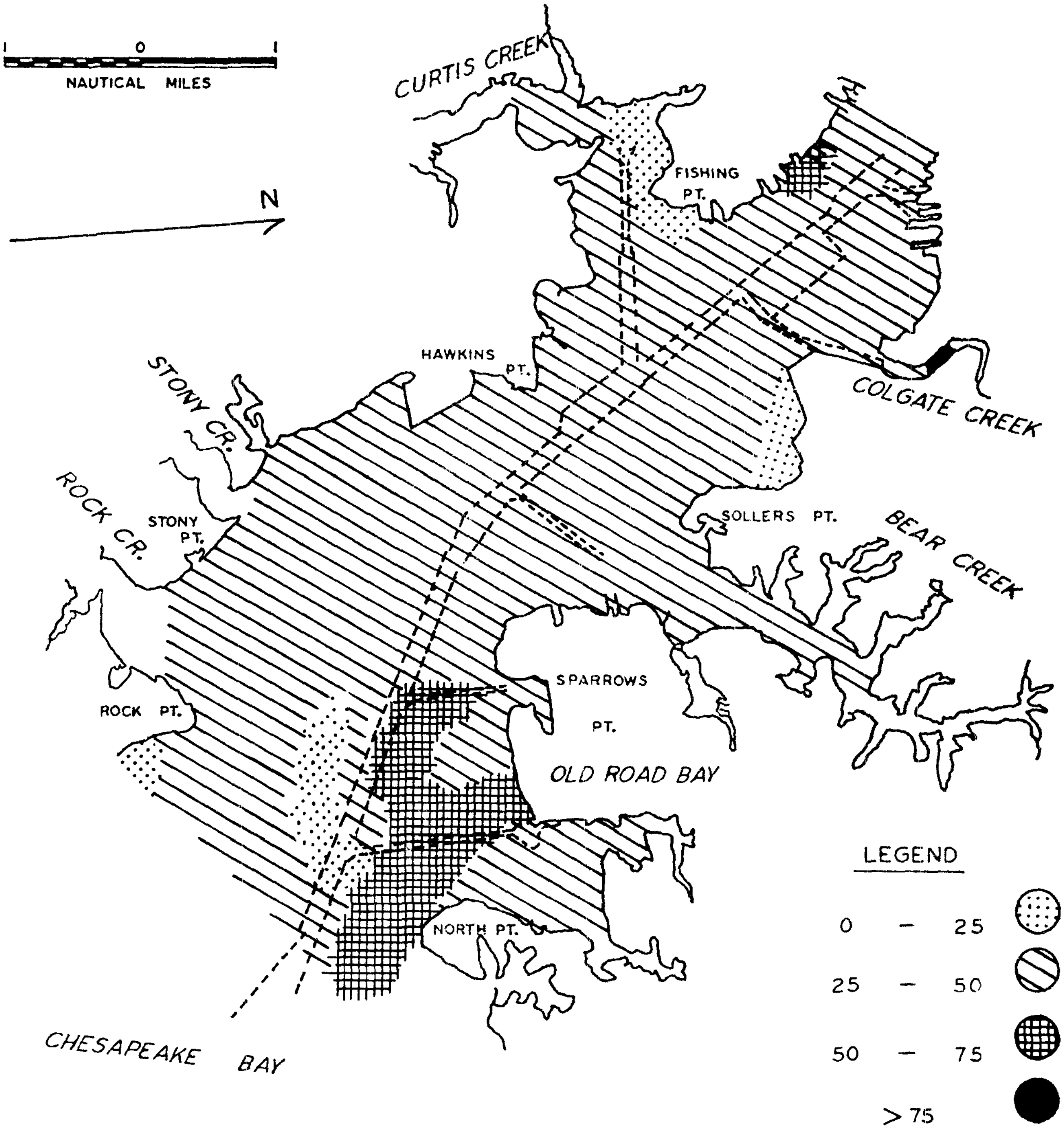


Figure 17

NICKEL (mg/Kg)
BALTIMORE HARBOR
NORTHWEST & MIDDLE BRANCH

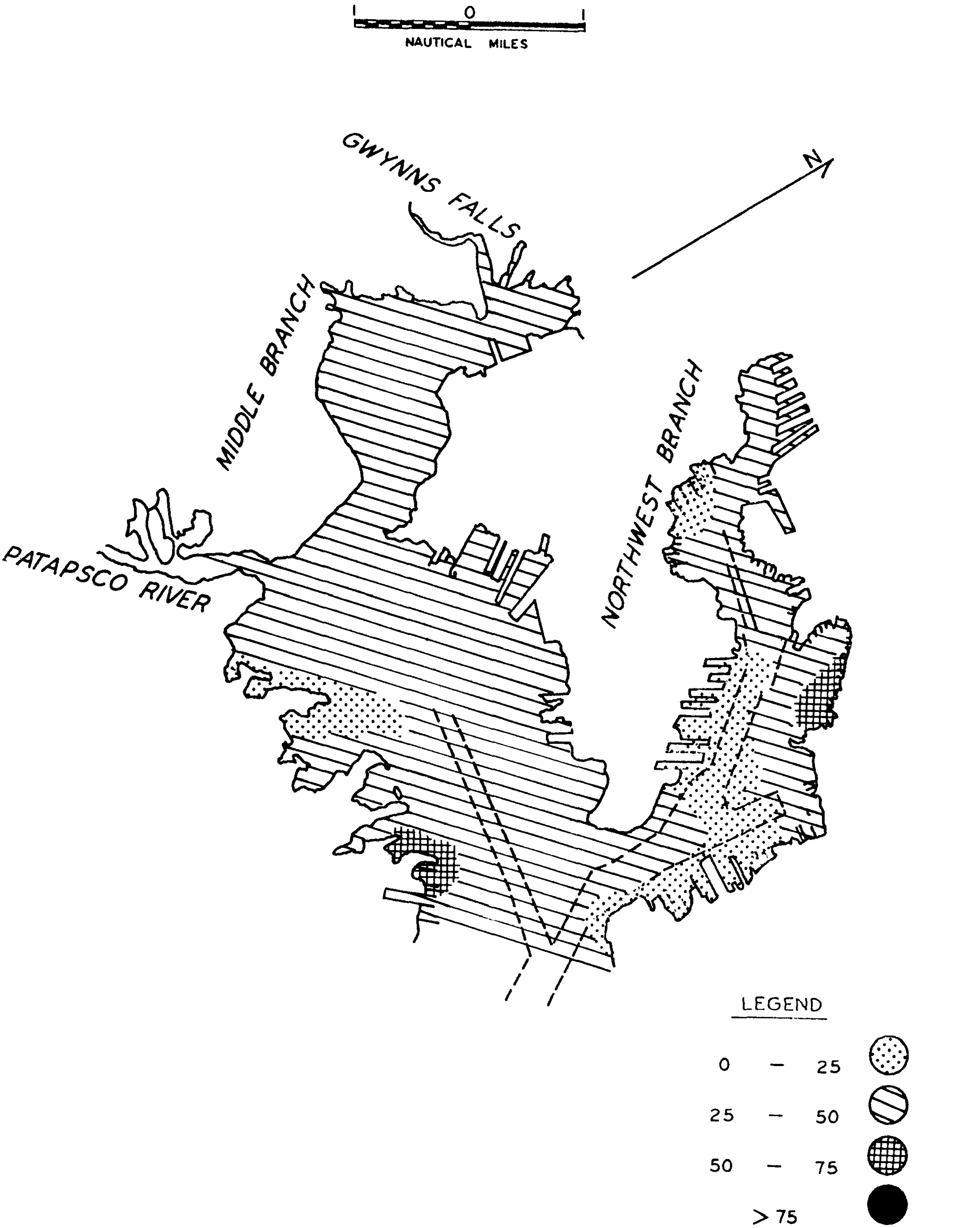


Figure 18

ZINC (mg/Kg)
BALTIMORE HARBOR
PATAPSCO RIVER

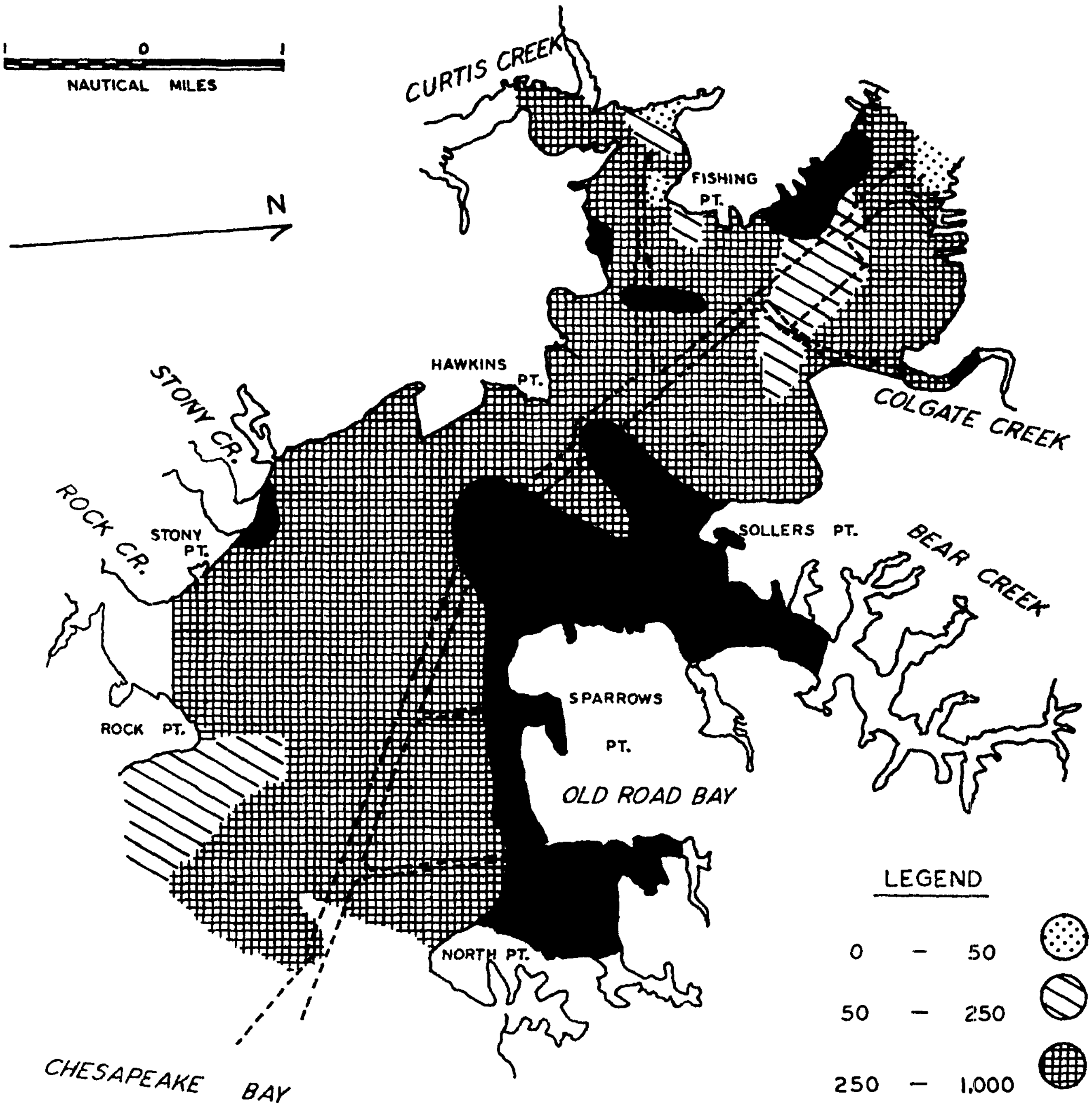


Figure 19

ZINC (mg/Kg)
BALTIMORE HARBOR
NORTHWEST & MIDDLE BRANCH

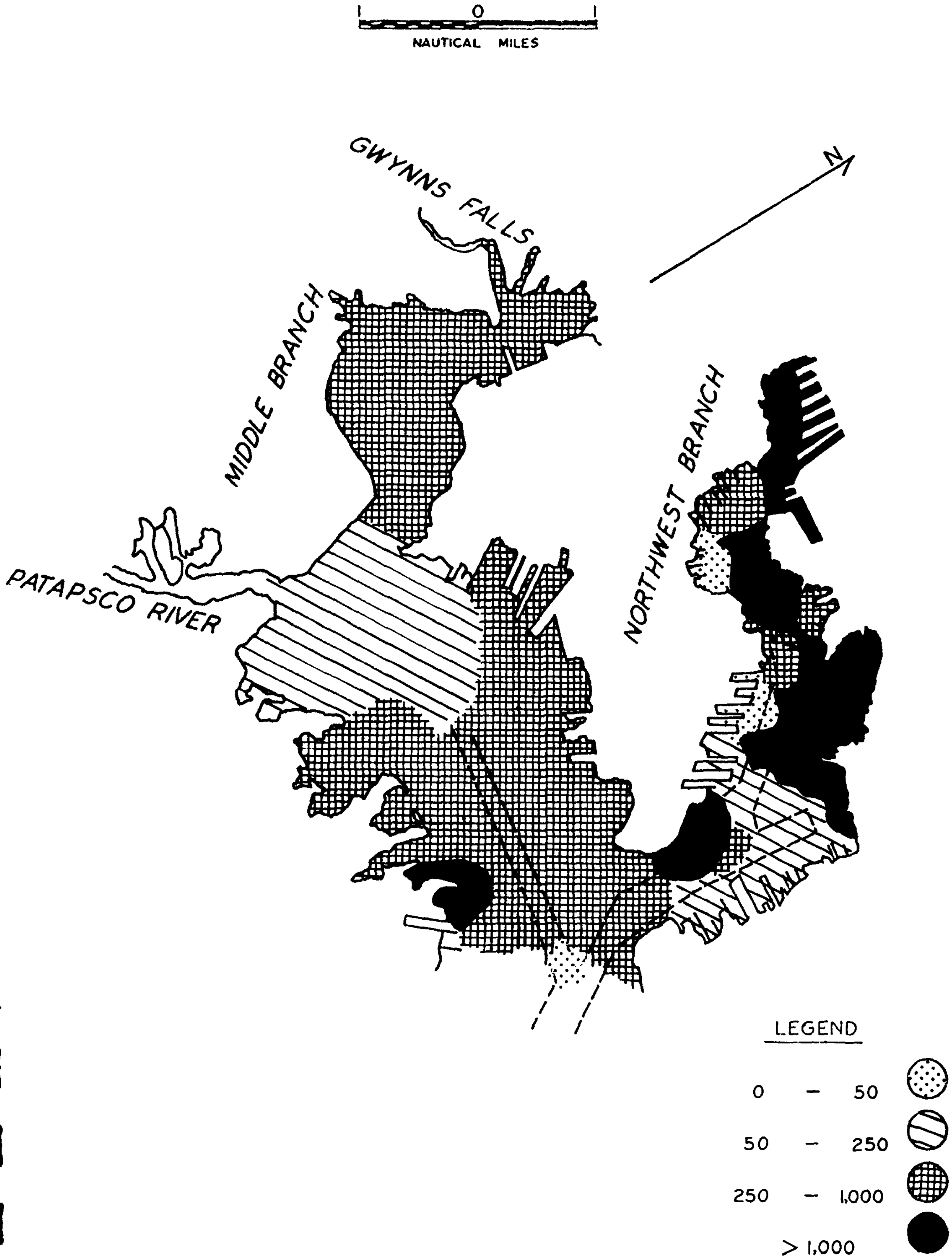
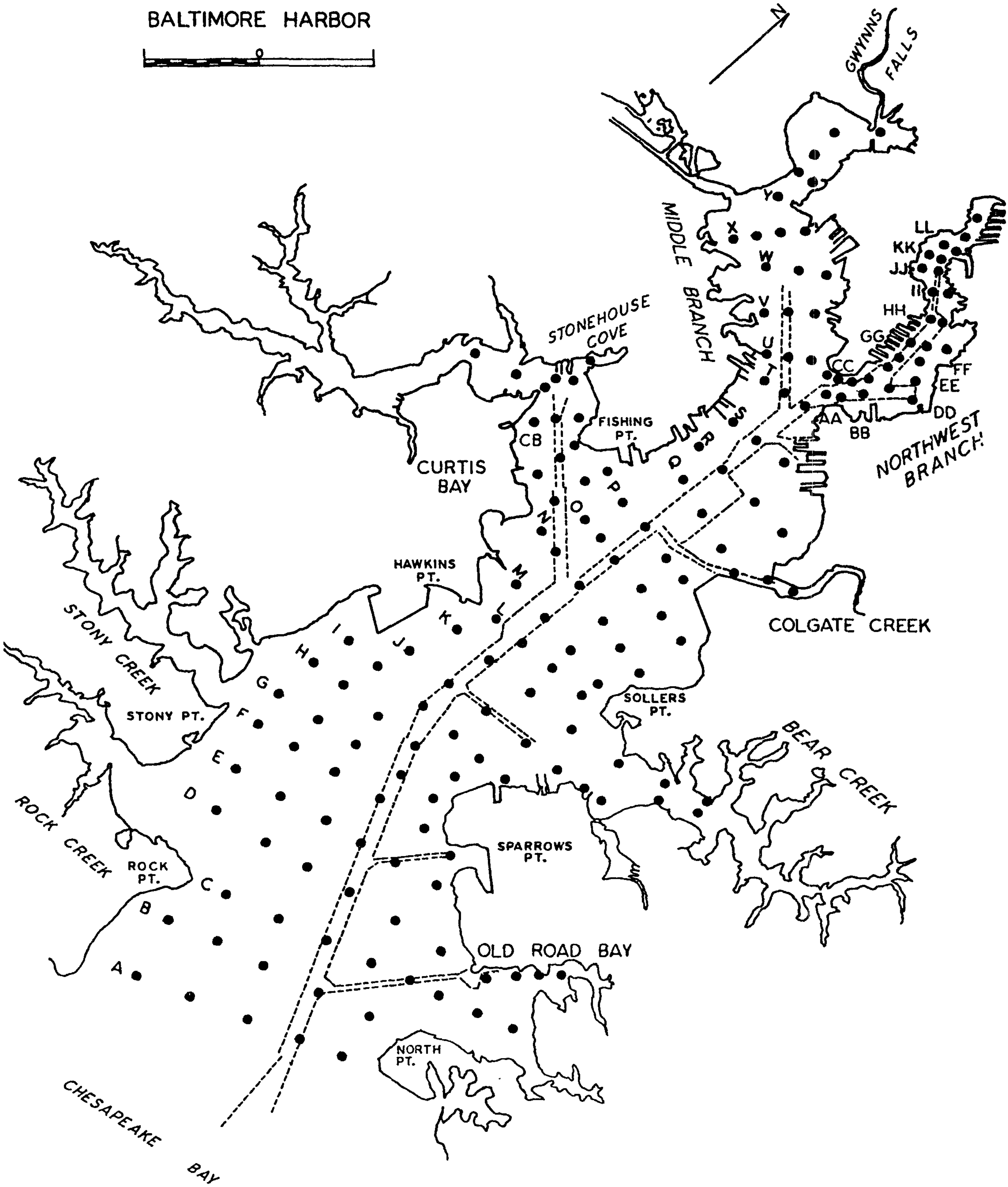


Figure 3


BALTIMORE HARBOR
N
GWYNNS FALLS
MIDDLE BRANCH
STONEHOUSE COVE
CURTIS BAY
FISHING PT.
CB
HAWKINS PT.
NORTHWEST BRANCH
COLGATE CREEK
STONY CREEK
STONY PT.
SOLLERS PT.
BEAR CREEK
ROCK CREEK
ROCK PT.
SPARROWS PT.
OLD ROAD BAY
NORTH PT.
CHESAPEAKE BAY
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
AA
BB
CC
DD
EE
FF
GG
HH
II
JJ
KK
LL

APPENDIX II

TABLE XVII

METALS CONCENTRATION IN MAIN CHANNEL OF BALTIMORE HARBOR

Transect/ Station	Cr	Cu	Pb	mg/kg Zn	Mn	Ni	Cd	Hg
A 4	28	32	16	84	1166	27	<1	<.01
B 4	160	123	174	667	1261	18	<1	.72
C 3	86	97	161	572	2286	48	<1	.67
C 3*	88	95	180	665	3317	57	<1	.43
D 4	161	135	146	520	2721	51	<1	<.01
D 4*	37	6	6	71	1345	19	2	<.01
E 4	161	122	147	670	2433	44	4	.30
F 4	119	78	113	506	1740	36	<1	1.27
F 4*	89	61	124	400	2171	21	<1	<.01
G 4	36	91	19	72	1247	26	<1	.51
H 4	196	140	176	744	1222	41	<1	1.17
H 4*	34	57	16	103	1157	25	<1	.45
I 3	193	123	191	635	2309	44	<1	.38
J 2	190	109	179	590	1448	30	<1	.32
J 2*	40	10	12	81	1288	21	<1	<.01
K 2	75	25	28	154	2097	33	<1	.22
L 2	274	217	55	816	1118	39	1	.65
L 2*	38	2	4	56	1432	22	<1	<.01
M 2	372	66	132	669	1402	42	1	.54
N 3	405	288	120	920	969	47	1	.69
N 3*	135	119	172	365	1380	22	<1	.07
O 3	141	140	144	385	1253	32	<1	1.40
P 2	224	252	169	943	782	42	1	.45
P 2*	161	276	240	833	875	35	1	1.15
R 2	520	291	228	646	804	39	1	.61
R 2*	58	12	<1	51	635	26	<1	.06
S 2	148	123	61	204	535	28	<1	.50
T 3	604	619	386	31	685	31	2	.73
T 3*	239	197	197	271	1134	30	<1	1.76
AA 1	963	1616	351	937	263	38	4	2.72
BB 1	534	1665	844	773	333	36	2	4.84
BB 1*	1183	1060	615	710	376	32	4	1.59

* Same station at 30-40 cm

TABLE XVIII

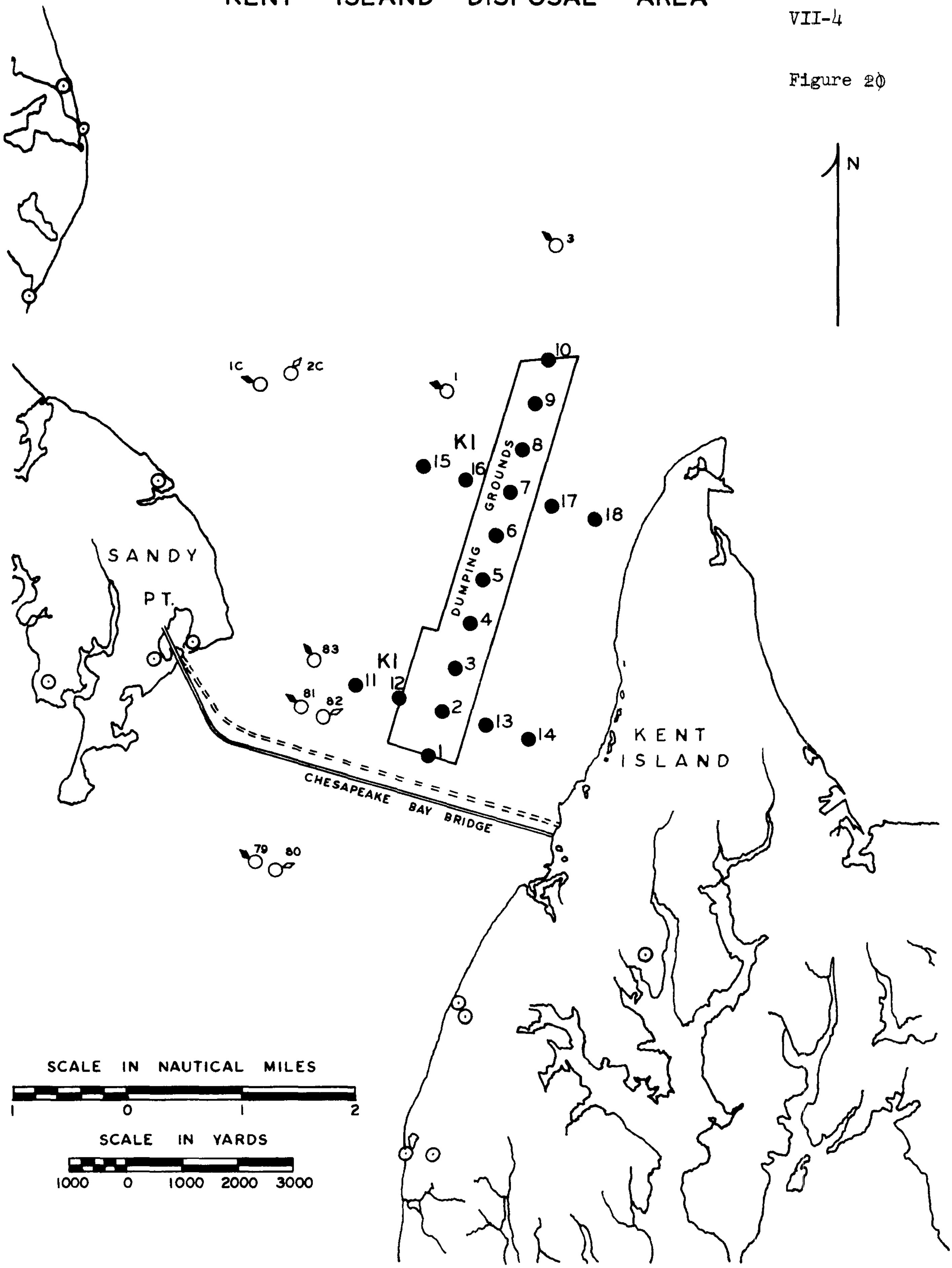
METALS CONCENTRATION IN KENT ISLAND DISPOSAL AREA

Station Number	mg/kg Cr	Cu	Pb	Zn	Mn	Ni	Cd	Hg
1	33	28	56	274	3142	62	< 1	.01
2	146	142	21	628	1460	38	1	.20
3	55	29	93	343	3594	51	< 1	.01
4	83	166	365	1180	1740	119	< 1	.12
5	41	114	315	175	1395	31	< 1	< .01
6	22	16	70	155	1419	27	< 1	< .01
7	63	26	135	509	2866	47	< 1	.01
8	42	29	156	353	1640	39	< 1	.07
9	23	47	24	144	1059	28	< 1	< .01
10	40	32	22	93	1219	28	< 1	< .01
11	17	11	48	146	750	42	< 1	< .01
12	26	10	13	122	2505	41	< 1	< .01
15	30	10	23	162	861	39	< 1	< .01
16	34	68	136	169	533	27	< 1	.20

NOTE: No cores were taken at stations 13, 14, 17 and 18 due to sandy bottom

KENT ISLAND DISPOSAL AREA

Figure 20



APPENDIX III

TABLE XIX [25]

TOXICITY OF METALS TO MARINE LIFE

Metal	Chemical Symbol	Range of Concentrations that have Toxic Effects on Marine Life (mg/l or ppm)
Arsenic	As	2.0
Cadmium	Cd	0.01 to 10
Chromium	Cr	1.0
Copper	Cu	0.1
Mercury	Hg	0.1
Lead	Pb	0.1
Nickel	Ni	0.1
Zinc	Zn	10.0

TABLE XX

TRACE METALS - USES AND HAZARDS

Metals	Industrial Use	Health Effects
Arsenic	coal, petroleum, detergents, pesticides, mine tailings	hazard disputed, may cause cancer
Barium	paints, linoleum, paper, drilling mud	muscular and cardiovascular disorders, kidney damage
Cadmium	batteries, paints, plastics, coal, zinc mining, water mains and pipes, tobacco smoke	high blood pressure, sterility, flu-like disorders, cardiovascular disease and hypertension in humans suspected, interferes with zinc and copper metabolism
Chromium	alloys, refractories, catalysts	skin disorders, lung cancer, liver damage
Lead	batteries, auto exhaust from gasoline, paints (prior to 1948)	colic, brain damage, convulsions, behavioral disorders, death
Mercury	coal, electrical batteries, fungicides, electrical instruments, paper and pulp, pharmaceuticals	birth defects, nerve damage, death
Nickel	diesel oil, residual oil, coal, tobacco smoke, chemicals and catalysts, steel and nonferrous alloys, plating	dermatitis, lung cancer (as carbonyl)

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