4.0 Sediment Quality Investigations

Concerns were expressed during the Feasibility Study regarding the chemical quality of sediments that would be disturbed during project construction, and the potential adverse effects on aquatic resources. In the riverine section of the project area, from Philadelphia to Artificial Island, channel sediments would be dredged and placed in several confined, upland dredged material disposal sites. Sediment quality concerns in this portion of the project regard turbidity generated at the point of dredging, and the turbidity associated with the discharge of effluent from the disposal areas. In Delaware Bay, channel sediments comprised primarily of sand would be used for various beneficial uses that involve placement of sediments in open water. Sediment quality concerns in this area include turbidity generated at the point of dredging and impacts associated with open water placement.

Two types of chemical quality concerns can be raised with regard to dredging and dredged material disposal activities. The first is potential short-term water quality degradation arising from disturbance of bottom sediments, and ensuing impacts to aquatic biota. Aquatic ecosystems concentrate biological and chemical substances such as organic matter, nutrients, heavy metals and toxic chemical compounds in bottom sediments. When introduced to the water column, these substances tend to bind with suspended particulate matter and eventually settle to the bottom. Dredging operations typically elevate levels of suspended particulates in the water column through agitation of the sediment. Suspension of sediment exposes associated biological and chemical constituents to dissolved oxygen, which can result in a variety of chemical reactions. Adverse impacts to water quality may include oxygen depletion and the release of chemical substances, making them biologically available to aquatic organisms through ingestion or respiration. It is generally believed that carefully designed and conducted dredging operations do not pose a significant adverse environmental threat, primarily because dredging is a temporary localized phenomenon that does not supply a persistent load of suspended sediment (USACE, 1983; Allen and Hardy, 1980). The turbidity associated with temporary dredging activities is usually less than the turbidity associated with natural flooding. In addition, most rivers that are used for navigation, including the Delaware River, are naturally turbid.

The second type of concern is long-term contamination problems associated with the dredged material disposal site. Generally, the greatest potential for environmental effects from dredged material discharge to open water lies in the benthic environment (USEPA/ACE, 1994). Deposited dredged material is not mixed and dispersed as rapidly or as greatly as the portion of the material that may remain in the water column. Bottom dwelling animals living and feeding on deposited material for extended periods

represent the most likely pathways by which adverse effects to aquatic biota can occur. Placement of contaminated sediment at upland disposal sites can also result in long-term impacts such as groundwater contamination and direct uptake of contaminants by plants and animals.

To address these concerns the Corps has conducted various sediment quality studies as outlined in the national comprehensive testing strategy, developed jointly by the Corps and the U.S. Environmental Protection Agency (USEPA/ACE, 1994). This tiered testing approach provides for successive levels of investigation to be implemented on a "reason to believe" that there is potential for unacceptable adverse effects. The following provides a summary of the work efforts and findings.

4.1 Bulk Sediment Analyses

If there is reason to believe that contaminants are present, which was the case with the main channel deepening project, the first level of evaluation consists of bulk sediment analysis. This is essentially an inventory of contaminants to identify those that could potentially have an impact on the environment during dredging and dredged material disposal activities. To date, a series of 86 sediment cores have been collected within channel and bend widening locations that would be dredged during project construction. Bend widening locations provide a "worst case" picture of contaminant concentrations that would potentially be in the dredged material. These areas are not currently dredged, as such contaminants could accumulate over a long period of time. Within the channel, accumulated sediment is quickly removed to maintain project dimensions, thus precluding contaminant accumulation over time. Sample locations were determined with the assistance of the U.S. Environmental Protection Agency and the U.S. Fish and Wildlife Service. Plates 5 and 6 depict locations where sediment cores were collected.

Sediment cores were collected with vibracoring equipment that employed a collection tube approximately three inches in diameter. Sediment cores were collected to proposed project depths and divided into 153 distinct sediment strata. Each sediment strata greater than six inches constituted a separate sample. Strata were then individually evaluated through grain size and chemical analyses. Sediment was removed from the interior portion of the core to minimize chemical contamination associated with the core tube. If a core consisted of a single, homogenous unit, the interior portion of the core was removed over the entire length of the core, thoroughly homogenized, and sub-sampled. Sediment from the exterior portion of the core was used for grain size analyses. Bulk chemical analyses were conducted on each strata to determine the range of contaminants and their total concentrations. The chemical parameter list included a host of heavy metals, pesticides, PCBs, PAHs and a variety of volatile and semi-volatile organics (Table 4-1). All results were reported on a dry weight basis.

Table 4-1. Chemical Parameter List for Bulk Sediment Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

METALS		
antimony		
arsenic		
beryllium		
cadmium		
chromium		
copper		
lead		
mercury		
nickel		
selenium		
silver		
thallium		
zinc		
PESTICIDES		
aldrin		
dieldrin		
chlordane		
DDT, DDE & DDD		
endosulfan		
endrin		
endrin aldehyde		
heptachlor		
heptachlor epoxide		
alpha-hexachlorocyclohexane		
beta-hexachlorocyclohexane		
delta-hexachlorocyclohexane		
gamma-hexachlorocyclohexane		
toxaphene		
mirex		
methoxychlor		
parathion		
malathion		
guthion		
demeton		
POLYCHLORINATED BIPHENYLS (PCB) AS AROCHLORS		
PCB-1242		
PCB-1254		
PCB-1221		
PCB-1232		
PCB-1248		
PCB-1260		
PCB-1016		
	VOLATILE ORGANICS	
	VOLATILE HALOGENATED ALKANES	carbon tetrachloride
		1,2-dichloroethane
		1,1,1-trichloroethane
		1,1-dichloroethane
		1,1,2-trichloroethane
		1,1,2,2-tetrachloroethane
		chloroethane
		chloroform
		1,2-dichloropropane
		methylene chloride
		chloromethane
		bromomethane
		bromoform
		dichlorobromoethane
		chlorodibromomethane
	VOLATILE HALOGENATED ALKENES	1,1-dichlorethene
		1,2-trans-dichlorethene
		trans-1,3-dichloropropene
		cis-1,3-dichloropropene
		tetrachlorethene
		trichlorethene
		vinyl chloride
	VOLATILE AROMATIC HYDROCARBONS	benzene
		ethylbenzene
		toluene
	VOLATILE CHLORINATED AROMATIC HYDROCARBONS	chlorobenzene
	VOLATILE UNSATURATED CARBONYL COMPOUNDS	acrolein
		acrylonitrile
	VOLATILE ETHERS	2-chlorethylvinylether
	ACID EXTRACTABLE ORGANICS	
	PHENOLS	phenol
		2,4-dimethylphenol
	SUBSTITUTED PHENOLS	2,4,6-trichlorophenol
		para-chloro-meta-cresol
		2-chlorophenol
		2,4-dichlorophenol
		4-chloro-3-methylphenol
		pentachlorophenol
		4,6-dinitro-2-methylphenol
		2-nitrophenol
		4-nitrophenol
		2,4-dinitrophenol

BASE NEUTRAL ORGANICS

ORGANONITROGEN COMPOUNDS	benzidine
	3,3'-dichlorobenzidine
	2,4-dinitrotoluene
	2,6-dinitrotoluene
	nitrobenzene
	N-nitrosodimethylamine
	N-nitrosodiphenylamine
	N-nitrosodi-n-propylamine
LOW MOLECULAR WEIGHT POLYNUCLEAR AROMATIC HYDROCARBONS (PAH)	acenaphthene
	naphthalene
	acenaphthylene
	anthracene
	phenanthrene
	fluorene
HIGH MOLECULAR WEIGHT (PAH)	fluoranthene
	benzo(a)anthracene
	benzo(a)pyrene
	benzo(b)fluoranthene
	benzo(k)fluoranthene
	chrysene
	benzo(ghi)perylene
	dibenzo(a,h)anthracene
	ideno(1,2,3-cd)pyrene
	pyrene
CHLORINATED AROMATIC HYDROCARBONS	1,2,4-trichlorobenzene
	hexachlorobenzene
	2-chloronaphthalene
	1,2-dichlorobenzene
	1,3-dichlorobenzene
	1,4-dichlorobenzene
CHLORINATED ALIPHATIC HYDROCARBONS	hexachlorobutadiene
	hexachloroethane
	hexachlorocyclopentadiene
HALOGENATED ETHERS	bis(2-chloroethyl)ether
	4-chlorophenyl-phenylether
	4-bromophenyl-phenylether
	bis(2-chloroisopropyl)ether
	bis(2-chlorethoxy)methane
PHTHALATES	bis(2-ethylhexy)phthalate
	butyl benzyl phthalate
	di-n-butyl phthalate
	di-n-octyl phthalate
	diethyl phthalate
	dimethyl phthalate
MISCELLANEOUS OXYGENATED COMPOUNDS	isophorone

Tables 4-2 through 4-8 provide a summary of the bulk sediment data. To facilitate this evaluation, the main channel project area was divided into five reaches (Reaches A through E), which correspond to disposal area locations. Material from Reaches A through D would be placed in several upland disposal sites. Reach A extends from the upstream project limit in Philadelphia Harbor to the Billingsport Range. Reach B extends from the Tinicum Range to the Cherry Island Range. Reach C extends from Deepwater Point Range to the New Castle Range. Reach D extends from Reedy Island Range to Ship John Light (Liston Range). Reach E is located in Delaware Bay, this material would be used for beneficial uses, such as sand stockpiling for beach nourishment and wetland creation.

To summarize the large volume of data, samples collected within each reach were grouped and the mean concentration of each chemical parameter was calculated. In many cases a chemical parameter was not detected in the sediment sample, and the laboratory reported the lowest quantifiable concentration that could be achieved with the test procedure. To include these data points in the analysis, the reported quantification limit was calculated into the mean, as if the chemical parameter had actually been present in the sediment at that concentration. This made the evaluation very conservative, because it is unlikely that the contaminant was present at that concentration. Actually, laboratories are able to detect and estimate the concentrations of many contaminants (excluding heavy metals) that are present below the quantification limits. The tables denote this with a "J", and the number of samples where this occurred. Tables 4-2 through 4-8 provide the mean concentration of each contaminant in Reaches A through E, the number of actual detections, and the detection range. Tables 4-7 and 4-8 summarize data for a variety of volatile and semi-volatile organic contaminants. Since the majority of these were not detected (60 of 64), mean concentrations are not provided by reach. The majority of contaminant parameters evaluated (88 of 130) were not detected in channel sediments. The presented mean concentration of a contaminant that was not detected in a particular reach, which is denoted in the tables by "ND" for number of detections, was calculated solely on the laboratory quantification limits. Keep in mind that this concentration is provided to indicate the mean of laboratory quantification limits, and does not actually represent the concentration of the contaminant in channel sediments.

Bulk analysis of sediments did not identify high concentrations of organic contaminants within the channel or bend widening locations. PCBs were detected in two samples. One sample was collected in the Bellevue Range, and the other was collected in the upper portion of Liston Range. The Bellevue sample contained PCB arochlors 1248 and 1254 at concentrations of 0.53 and 1.19 parts per million (ppm), respectively. The Liston sample contained PCB arochlors 1248 and 1260 at concentrations of 0.12 and 0.19 ppm, respectively. DDE, DDD, endosulfan and heptachlor

Table 4-2. Heavy Metal Data Summary of Bulk Sediment Sample Analyses Conducted With the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	33	49	29	19	23
Antimony					
Mean Concentration	3.19	9.93	10.00	10.70	2.35
# of Detections	3	24	23	11	ND
Detection Range	2.33-24.0	1.7-32.0	1.5-32.4	1.1-35.4	-
Arsenic					
Mean Concentration	5.97	6.41	8.37	8.97	2.35
# of Detections	20	38	29	19	23
Detection Range	0.24-26.6	1.22-18.4	0.8-52.8	1.29-17.5	0.25-6.5
Beryllium					
Mean Concentration	0.91	0.82	0.64	0.69	0.28
# of Detections	15	38	24	18	13
Detection Range	0.23-0.82	0.31-1.5	0.10-1.5	0.14-1.5	0.06-0.84
Cadmium					
Mean Concentration	1.66	0.94	1.00	0.96	0.70
# of Detections	16	19	15	10	14
Detection Range	0.50-5.24	0.11-4.0	0.09-4.8	0.35-5.2	0.32-2.8
Chromium					
Mean Concentration	15.95	26.28	28.73	37.18	12.7
# of Detections	20	41	23	13	10
Detection Range	1.45-83.2	4.5-63.7	3.49-145	10.5-60.8	2.9-39.6
Copper					
Mean Concentration	9.97	11.72	14.74	10.33	5.08
# of Detections	30	49	28	19	22
Detection Range	1.17-107	1.0-51.0	1.25-131	2.3-15.3	0.7-19.7
Lead					
Mean Concentration	18.94	19.09	24.80	19.53	7.11
# of Detections	27	44	26	19	17
Detection Range	2.96-146	4.7-120	2.9-173	3.5-102	0.20-25.2

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-2. Heavy Metal Data Summary of Bulk Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	33	49	29	19	23
Mercury					
Mean Concentration	0.15	0.16	0.24	0.15	0.14
# of Detections	5	9	4	ND	ND
Detection Range	0.05-0.67	0.02-0.56	0.13-1.4	-	-
Nickel					
Mean Concentration	11.20	18.30	15.79	18.33	6.70
# of Detections	31	49	29	19	17
Detection Range	4.04-24.8	4.5-38.0	3.17-32.6	4.3-31.0	1.7-21.4
Selenium					
Mean Concentration	31.67	16.53	18.78	16.37	20.08
# of Detections	13	28	19	6	11
Detection Range	0.26-155	0.21-119	0.13-136	18.3-117	13.0-121
Silver					
Mean Concentration	1.04	0.87	0.67	0.64	0.81
# of Detections	7	10	12	2	3
Detection Range	0.63-1.30	0.50-1.14	0.50-1.4	1.22-1.30	0.50-0.50
Thallium					
Mean Concentration	3.76	2.48	0.66	1.46	0.47
# of Detections	1	13	3	2	ND
Detection Range	0.19	0.17-9.0	0.17-0.32	7.0-10.5	-
Zinc					
Mean Concentration	67.41	64.46	84.88	73.88	26.01
# of Detections	33	49	29	19	23
Detection Range	1.36-607	19-240	6.82-630	12.9-219	4.1-106

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-2. Heavy Metal Data Summary of Bulk Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Concluded.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	12	8	6	6	12
Barium					
Mean Concentration	49.68	61.96	49.84	27.14	11.37
# of Detections	12	8	6	6	12
Detection Range	12.6-96.3	35.0-92.9	8.2-99.2	9.5-56.3	2.4-42.8
Vanadium					
Mean Concentration	21.32	29.81	37.02	19.51	9.77
# of Detections	12	7	6	6	12
Detection Range	5.8-42.7	11.0-54.7	6.1-61.8	5.6-46.8	1.8-42.8

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-3. Pesticide Data Summary of Bulk Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	33	49	29	19	23
Aldrin					
Mean Concentration	0.03	0.02	0.02	0.02	0.02
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Dieldrin					
Mean Concentration	0.03	0.03	0.03	0.04	0.03
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Chlordane					
Mean Concentration	0.32	0.24	0.23	0.35	0.17
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Toxaphene					
Mean Concentration	0.56	0.34	0.29	0.41	0.26
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Endrin					
Mean Concentration	0.03	0.03	0.03	0.04	0.03
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Endrin Aldehyde					
Mean Concentration	0.03	0.03	0.03	0.04	0.03
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Heptachlor					
Mean Concentration	0.03	0.02	0.02	0.02	0.02
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Heptachlor Epoxide					
Mean Concentration	0.03	0.02	0.02	0.02	0.02
Number of Detections	1	ND	ND	ND	ND
Detection Range	0.06	-	-	-	-
Endosulfan					
Mean Concentration	0.03	0.03	0.03	0.04	0.03
Number of Detections	ND	1	ND	ND	ND
Detection Range	-	0.06	-	-	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-3. Pesticide Data Summary of Bulk Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
DDT					
Number of Samples	33	49	29	19	23
Mean Concentration	0.04	0.04	0.03	0.05	0.03
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
DDD					
Number of Samples	31	42	27	17	19
Mean Concentration	0.03	0.03	0.03	0.04	0.02
Number of Detections	ND	ND	ND	1	ND
Detection Range	-	-	-	0.026	-
DDE					
Number of Samples	31	42	27	17	19
Mean Concentration	0.03	0.03	0.03	0.04	0.02
Number of Detections	ND	ND	ND	1	ND
Detection Range	-	-	-	0.045	-
Mirex					
Number of Samples	20	22	10	7	11
Mean Conmcentration	0.35	0.11	0.03	0.04	0.03
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Methoxychlor					
Number of Samples	29	30	16	13	23
Mean Concentration	0.07	0.09	0.12	0.11	0.10
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Parathion					
Number of Samples	20	22	10	7	11
Mean Concentration	3.64	12.08	6.61	9.44	12.01
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Malathion					
Number of Samples	20	22	10	7	11
Mean Concentration	3.64	12.08	6.60	9.43	12.00
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-3. Pesticide Data Summary of Bulk Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Concluded.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Hexachlorocyclohexane Alpha					
Number of Samples	33	49	29	19	23
Mean Concentration	0.03	0.02	0.02	0.02	0.02
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Hexachlorocyclohexane Beta					
Number of Samples	33	49	29	19	23
Mean Concentration	0.03	0.02	0.02	0.02	0.02
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Hexachlorocyclohexane Delta					
Number of Samples	33	49	29	19	23
Mean Concentration	0.03	0.02	0.02	0.02	0.02
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Hexachlorocyclohexane Gamma (Lindane)					
Number of Samples	33	49	29	19	23
Mean Concentration	0.03	0.02	0.02	0.02	0.02
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Guthion					
Number of Samples	20	22	10	7	11
Mean Concentration	3.64	12.10	6.64	9.47	12.03
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Demeton					
Number of Samples	20	22	10	7	11
Mean Concentration	3.99	12.16	6.61	9.44	12.01
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-4. PCB Data Summary of Bulk Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	33	49	29	19	23
PCB-1242					
Mean Concentration	0.30	0.21	0.15	0.23	0.17
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
PCB-1254					
Mean Concentration	0.34	0.32	0.29	0.41	0.26
Number of Detections	ND	1	ND	ND	ND
Detection Range	-	1.19	-	-	-
PCB-1221					
Mean Concentration	0.30	0.21	0.15	0.23	0.17
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
PCB-1232					
Mean Concentration	0.30	0.21	0.15	0.23	0.17
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
PCB-1248					
Mean Concentration	0.30	0.21	0.15	0.23	0.17
Number of Detections	ND	1	ND	1	ND
Detection Range	-	0.53	-	0.12	-
PCB-1260					
Mean Concentration	0.34	0.31	0.29	0.41	0.26
Number of Detections	ND	ND	ND	1	ND
Detection Range	-	-	-	0.19	-
PCB-1016					
Mean Concentration	0.30	0.21	0.15	0.23	0.17
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-5. PAH Data Summary of Bulk Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	33	49	29	19	23
Acenapthene					
Mean Concentration	0.53	0.47	0.51	0.52	0.35
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Naphthalene					
Mean Concentration	0.53	0.46	0.46	0.52	0.35
Number of Detections	ND	1(1J)	1(1J)	ND	ND
Detection Range	-	0.18	0.42	-	-
Acenaphthylene					
Mean Concentration	0.53	0.47	0.51	0.52	0.35
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Anthracene					
Mean Concentration	0.53	0.47	0.51	0.51	0.35
Number of Detections	ND	2(1J)	ND	1(1J)	ND
Detection Range	-	0.20-0.51	-	0.05	-
Benzo(a)pyrene					
Mean Concentration	0.53	0.48	0.46	0.51	0.35
Number of Detections	ND	2(1J)	6(5J)	3(2J)	ND
Detection Range	-	0.53-1.12	0.06-0.49	0.07-0.37	-
Benzo(b)fluoranthene					
Mean Concentration	0.54	0.47	0.48	0.50	0.35
Number of Detections	1	2(1J)	1(1J)	2(2J)	ND
Detection Range	0.67	0.49-1.02	0.82	0.07-0.08	-
Benzo(k)fluoranthene					
Mean Concentration	0.53	0.47	0.48	0.50	0.35
Number of Detections	ND	2(1J)	1(1J)	2(2J)	ND
Detection Range	-	0.49-0.83	0.82	0.06-0.09	-
Chrysene					
Mean Concentration	0.53	0.49	0.46	0.50	0.35
Number of Detections	ND	2(1J)	2(2J)	2(2J)	ND
Detection Range	-	0.71-1.27	0.05-0.62	0.09-0.10	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-5. PAH Data Summary of Bulk Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Concluded.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	33	49	29	19	23
Phenanthrene					
Mean Concentration	0.53	0.48	0.47	0.51	0.35
Number of Detections	ND	2(1J)	1(1J)	1(1J)	ND
Detection Range	-	0.49-0.95	0.65	0.05	-
Fluorene					
Mean Concentration	0.53	0.47	0.51	0.52	0.35
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Fluoranthene					
Mean Concentration	0.53	0.52	0.48	0.50	0.35
Number of Detections	2	2(1J)	1(1J)	2(2J)	ND
Detection Range	0.52-0.56	0.86-2.25	0.85	0.09-0.11	-
Benzo(a)anthracene					
Mean Concentration	0.53	0.49	0.51	0.50	0.35
Number of Detections	ND	2(1J)	ND	2(2J)	ND
Detection Range	-	0.59-1.52	-	0.10-0.11	-
Benzo(ghi)perylene					
Mean Concentration	0.53	0.47	0.47	0.51	0.35
Number of Detections	ND	2(1J)	1(1J)	1(1J)	ND
Detection Range	-	0.32-0.47	0.53	0.06	-
Dibenzo(ah)anthracene					
Mean Concentration	0.53	0.47	0.51	0.51	0.35
Number of Detections	ND	ND	ND	1(1J)	ND
Detection Range	-	-	-	0.06	-
Ideno(123-cd)pyrene					
Mean Concentration	0.53	0.47	0.47	0.51	0.35
Number of Detections	ND	2(1J)	1(1J)	1(1J)	ND
Detection Range	-	0.33-0.53	0.47	0.06	-
Pyrene					
Mean Concentration	0.54	0.50	0.48	0.50	0.35
Number of Detections	1	2(1J)	2(2J)	2(2J)	ND
Detection Range	0.62	0.81-1.76	0.05-0.87	0.10-0.12	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-6. Phthalate Data Summary of Bulk sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	18	28	19	12	12
Bis(2-ethylhexyl) phthalate					
Mean Concentration	0.62	0.51	0.53	0.51	0.42
Number of Detections	1(1J)	3(2J)	1(1J)	ND	ND
Detection Range	0.50	0.05-0.13	0.10	-	-
Butyl benzyl phthalate					
Mean Concentration	0.62	0.51	0.55	0.47	0.42
Number of Detections	ND	2(2J)	ND	ND	ND
Detection Range	-	0.05-0.18	-	-	-
Di-n-butyl phthalate					
Mean Concentration	0.73	0.29	0.30	0.31	0.55
Number of Detections	3(1J)	20(19J)	13(13J)	5(5J)	8
Detection Range	0.11-2.67	0.06-1.51	0.08-0.19	0.11-0.17	0.41-0.88
Di-n-octyl phthalate					
Mean Concentration	0.62	0.54	0.55	0.51	0.42
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Diethyl phthalate					
Mean Concentration	0.62	0.54	0.55	0.51	0.42
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Dimethyl phthalate					
Mean Concentration	0.62	0.54	0.55	0.51	0.42
Number of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-7. Volatile Organic Data Summary of Bulk Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	No. of Samples	Mean Conc.	No. of Detections	Detection Range
Volatile Halogenated Alkanes				
carbon tetrachloride	45	0.11	ND	-
1,2-dichloroethane	45	0.11	ND	-
1,1,1-trichloroethane	45	0.11	ND	-
1,1-dichloroethane	45	0.11	ND	-
1,1,2-trichloroethane	45	0.11	ND	-
1,1,2,2-tetrachloroethane	45	0.11	ND	-
chloroethane	45	0.11	ND	-
chloroform	45	0.11	ND	-
1,2-dichloropropane	45	0.11	ND	-
methylene chloride	45	0.11	41(38J)	0.003-0.875
chloromethane	39	0.02	ND	-
bromomethane	39	0.02	ND	-
bromoform	45	0.11	ND	-
dichlorobromoethane	45	0.11	ND	-
chlorodibromomethane	45	0.11	ND	-
Volatile Halogenated Alkenes				
1,1-dichlorethene	39	0.01	ND	-
1,2-trans-dichlorethene	39	0.01	ND	-
trans-1,3-dichloropropene	39	0.01	ND	-
cis-1,3-dichloropropene	39	0.01	ND	-
tetrachlorethene	39	0.01	ND	-
trichloroethene	39	0.01	ND	-
vinyl chloride	45	0.11	ND	-
Volatile Aromatic Hydrocarbons				
benzene	45	0.11	ND	-
ethylbenzene	45	0.11	3(3J)	0.001-0.009
toluene	45	0.11	6(6J)	0.002-0.007
Volatile Chlorinated Aromatic Hydrocarbons				
chlorobenzene	45	0.11	ND	-
Volatile Unsaturated Carbonyl Compounds				
acrolein	45	0.52	ND	-
acrylonitrile	45	0.28	ND	-
Volatile Ethers				
2-chlorethylvinylether	45	0.11	ND	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-8. Semi-Volatile Organic Data Summary of Bulk Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	No. of Samples	Mean Conc.	No. of Detections	Detection Range
Phenols				
phenol	45	0.59	ND	-
2,4-dimethylphenol	45	0.59	ND	-
Substituted Phenols				
2,4,6-trichlorophenol	45	0.59	ND	-
para-chloro-meta-cresol	6	0.87	ND	-
2-chlorophenol	45	0.59	ND	-
2,4-dichlorophenol	45	0.59	ND	-
4-chloro-3-methylphenol	39	0.54	ND	-
pentachlorophenol	45	2.47	ND	-
4,6-dinitro-2-methylphenol	39	2.72	ND	-
2-nitrophenol	45	0.59	ND	-
4-nitrophenol	45	2.94	ND	-
2,4-dinitrophenol	45	2.94	ND	-
Organonitrogen Compounds				
benzidine	45	2.29	ND	-
3,3'-dichlorobenzidine	45	1.02	1(1J)	0.140
2,4-dinitrotoluene	45	0.59	ND	-
2,6-dinitrotoluene	45	0.59	ND	-
nitrobenzene	45	0.59	ND	-
N-nitrosodimethylamine	45	0.59	ND	-
N-nitrosodiphenylamine	45	0.59	ND	-
N-nitrosodi-n-propylamine	45	0.59	ND	-
Chlorinated Aromatic Hydrocarbons				
1,2,4-trichlorobenzene	45	0.59	ND	-
hexachlorobenzene	45	0.59	ND	-
2-chloronaphthalene	45	0.59	ND	-
1,2-dichlorobenzene	45	0.59	ND	-
1,3-dichlorobenzene	45	0.59	ND	-
1,4-dichlorobenzene	45	0.59	ND	-
Chlorinated Aliphatic Hydrocarbons				
hexachlorobutadiene	45	0.59	ND	-
hexachloroethane	45	0.59	ND	-
hexachlorocyclopentadiene	45	0.59	ND	-
Halogenated Ethers				
bis(2-chloroethyl)ether	45	0.59	ND	-
4-chlorophenyl-phenylether	45	0.59	ND	-
4-bromophenyl-phenylether	45	0.59	ND	-
bis(2-chloroisopropyl)ether	45	0.59	ND	-
bis(2-chlorethoxy)methane	45	0.59	ND	-
Miscellaneous Oxygenated Compounds				
isophorone	45	0.59	ND	-

epoxide were the only pesticides detected. Endosulfan was detected once in the Bellevue Range sample; DDE and DDD were detected once in the Liston Range sample; and heptachlor epoxide was detected once in a sample collected from Mifflin Range. Concentrations of these pesticides were below 0.1 ppm. Polynuclear aromatic hydrocarbons (PAHs) were detected in several channel bends between Philadelphia Harbor and Artificial Island. PAHs are primarily formed through combustion of fossil fuels, and are expected to be found in highly industrialized and populated regions. PAHs were not detected in the Delaware Bay portion of the project area. PAH concentrations were generally below 2 ppm. The only exception was fluoranthene, which was detected in one sample collected in the vicinity of Tinicum Island at a concentration of 2.25 ppm. The U.S. Environmental Protection Agency has proposed sediment quality criteria (SQC) for fluoranthene, which are intended to predict toxicological effects of fluoranthene on organisms living in sediment. The freshwater criteria include a median concentration of 620 ppm, with a lower level 95 percent confidence interval of 290 ppm. These concentrations are orders of magnitude above levels found in the Delaware River navigation channel.

Of the remaining volatile and semi-volatile organic contaminants evaluated, only methylene chloride, acetone, 2-butanone, styrene and phthalates were detected at quantifiable levels. Styrene was detected in one sample and 2-butanone was detected in two samples. Concentrations of these chemicals were below 0.1 ppm. Methylene chloride was detected in several samples. Methylene chloride is mainly used as a low-temperature extractant of substances which are adversely affected by high temperature. It is also used as a solvent and as a paint remover. Because of its utility as a chemical extractant, methylene chloride is commonly used in laboratory analyses. It is likely that detection of methylene chloride was a byproduct of laboratory testing. Acetone was also detected in several samples. Acetone is also a common laboratory solvent, which was used to clean glassware and sampling implements for sample collection. Detection of acetone is also attributed to laboratory procedures.

Phthalates were also detected at more than one location. Phthalates are used in large quantities as plasticizers to improve the quality of plastics. A plasticizer is a substance added to plastics to keep them pliable or soft. Phthalates may also be used as starting or intermediate materials for a variety of industrial processes. The highest concentration was 2.67 ppm, which was reported for di-n-butyl phthalate from one sample collected in the vicinity of the Philadelphia Naval Base.

Heavy metals were found to be widely distributed throughout the project area, which was to be expected. Concentrations of metals in the predominantly sandy Delaware Bay sediments were generally lower than up-river areas. Other than that, there were no apparent contamination trends. The presence of heavy metals in channel sediments is attributed to the urban and industrialized

nature of the river basin.

To evaluate potential human health impacts associated with disposal of channel sediments, bulk data were compared to New Jersey Department of Environmental Protection (NJDEP) Residential, Non-Residential and Impact to Groundwater Soil Cleanup Criteria (NJAC 7:26D). These criteria were established to provide a technical basis for evaluating levels of chemical contamination, and the associated risks to human health. They are based on currently available information, and are periodically updated as scientific knowledge is refined. Compliance with the Residential Standards allows maximum unrestricted future use of property, including residential use. Compliance with Non-Residential Standards is also acceptable provided the property owner agrees to limit future uses to non-residential activities such as an industrial work site. The soil criteria are derived through risk assessment procedures that are based on a number of assumptions. These assumptions include:

a) the body weight of an adult male is 70 kg;

b) the body weight of a child is 11.3 or 16 kg, depending on the contaminant;

c) the length of a lifetime is 70 years;

d) the number of years spent at a residential property is 30;

e) the number of years spent at a non-residential property is 25;

f) an individual visits a residential property every day of the year;

g) an individual visits a non-residential property 5 out of 7 days, 49 out of 52 weeks a year;

h) a child ingests soil at a rate of 200 mg/day between the ages of 6 months and 6 years; and

i) an adult ingests soil at a rate of 100 mg/day.

Depending on the contaminant, the human health criteria are based on an additional lifetime cancer risk of 1 of 1,000,000 or 1 of 100,000.

Comparison of the bulk sediment data to these human health criteria is considered to be a conservative evaluation. Individuals would not be exposed to the dredged material at the assumed frequencies listed in d through g, above. The Non-Residential Standards are most applicable to material that would be placed in confined, upland dredged material disposal sites. These areas would remain undeveloped as a result of

disposal activities, and visitation would be minimal. Material dredged from Delaware Bay would be used for beneficial uses, primarily beach nourishment. The Residential Standards are more applicable here as people visiting the beaches would come in direct contact with the sand, and the more stringent standards provide the greatest level of safety.

A total of 91 chemical parameters were compared to the NJDEP criteria. Tables 4-9 through 4-19 provide this comparison. The mean concentrations calculated for Reaches A through E, with inclusion of laboratory quantification limits for samples where the parameter was not detected, are compared to the Residential and Impact to Groundwater Soil Cleanup Criteria. The Non-Residential standards are provided for parameters that exceeded the Residential standards. Again, since the majority of volatile and semi-volatile organic contaminants were not detected in channel sediments, mean concentrations are not presented by reach (Tables 4-18 and 4-19).

All 91 parameters in all five reaches met the NJDEP Impact to Ground Water Soil Cleanup Criteria, without exception. All 91 parameters in all five reaches met the NJDEP Residential and Non-Residential standards, with the exception of the pesticide toxaphene and the heavy metals thallium and cadmium. Toxaphene has Residential and Non-Residential standards of 0.10 and 0.20 ppm, respectively. While toxaphene was not detected in any of the 153 sediment samples tested, the laboratory quantification limits were consistently above NJDEP standards. As such, a definitive conclusion with regard to toxaphene is not possible. Worst case concentrations of toxaphene in channel sediments, calculated solely on laboratory detection levels, range from 0.26 ppm in Reach E to 0.56 ppm in Reach A. There is no reason to believe that toxaphene is a contaminant of concern in the Delaware Estuary. Therefore, the risk that actual concentrations of toxaphene in channel sediments are above NJDEP standards is considered low.

Both the Residential and Non-Residential standards for thallium are two ppm. Mean concentrations of thallium were above the standard in Reaches A and B. Mean concentrations were 3.76 and 2.48 ppm, respectively. Thallium and its compounds are used as rodenticides, fungicides, and insecticides; as catalysts in certain organic reactions; in the manufacture of optical lenses, plates and prisms; in photoelectric cells; in dyes and pigments; in fireworks; and imitation precious jewelry.

A total of 82 separate sediment samples were collected from Reaches A and B over three sampling events. All of these samples were analyzed for thallium. The initial event in 1991 collected 42 samples. Thirty of these samples had laboratory quantification limits greater than two ppm. Four samples had actual thallium detections greater than two ppm (5.5-9.0 ppm). Twenty additional sediment samples were collected in 1992, and

Table 4-9. Worst Case Mean Concentrations of Heavy Metals in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Residential Direct Contact Soil Cleanup Criteria.

Parameter	NJDEP Res. Standard	Mean Channel Sediment Concentrations				
		Reach A	Reach B	Reach C	Reach D	Reach E
Antimony	14	3.19	9.93	10.00	10.70	2.35
Arsenic	20	5.97	6.41	8.37	8.97	2.35
Barium	700	49.68	61.96	49.84	27.14	11.37
Beryllium	1	0.91	0.82	0.64	0.69	0.28
Cadmium	1	[1.66]	0.94	1.00	0.96	0.70
Chromium	NS	15.95	26.28	28.73	37.18	12.70
Copper	600	9.97	11.72	14.74	10.33	5.08
Lead	100	18.94	19.09	24.80	19.53	7.11
Mercury	14	0.15	0.16	0.24	0.15	0.14
Nickel	250	11.20	18.30	15.79	18.33	6.70
Selenium	63	31.67	16.53	18.78	16.37	20.08
Silver	110	1.04	0.87	0.67	0.64	0.81
Thallium	2	[3.76]	[2.48]	0.66	1.46	0.47
Vanadium	370	21.32	29.81	37.02	19.51	9.77
Zinc	1500	67.41	64.46	84.88	73.88	26.01

- All concentrations in parts per million (mg/kg), dry weight.
- [ ] - Sediment concentrations in brackets exceed NJDEP residential criteria.
- NS - No NJDEP standard for this parameter.
- NJDEP residential direct contact soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.
- NJDEP non-residential direct contact soil cleanup criteria for cadmium and thallium are 100 and 2 mg/kg, respectively.
- NJDEP impact to ground water soil cleanup criteria for heavy metals are not established. These values are based upon site specific chemical and physical parameters.

Table 4-10. Worst Case Mean Concentrations of Pesticides in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Residential Direct Contact Soil Cleanup Criteria.

	NJDEP Res.	Mean Channel Sediment Concentrations				
Parameter	Standard	Reach A	Reach B	Reach C	Reach D	Reach E
Aldrin	0.040	0.03	0.02	0.02	0.02	0.02
Dieldrin	0.042	0.03	0.03	0.03	0.04	0.03
Chlordane	NS	0.32	0.24	0.23	0.35	0.17
Toxaphene	0.10	[0.56]	[0.34]	[0.29]	[0.41]	[0.26]
Endrin	17	0.03	0.03	0.03	0.04	0.03
Endrin Aldehyde	NS	0.03	0.03	0.03	0.04	0.03
Heptachlor	0.15	0.03	0.02	0.02	0.02	0.02
Heptachlor Epoxide	NS	0.03	0.02	0.02	0.02	0.02
Endosulfan	340	0.03	0.03	0.03	0.04	0.03
DDT	2	0.04	0.04	0.03	0.05	0.03
DDD	3	0.03	0.03	0.03	0.04	0.02
DDE	2	0.03	0.03	0.03	0.04	0.02
Mirex	NS	0.35	0.11	0.03	0.04	0.03
Methoxychlor	280	0.07	0.09	0.12	0.11	0.10
Parathion	NS	3.64	12.08	6.61	9.44	12.01
Malathion	NS	3.64	12.08	6.60	9.43	12.00
Hexachlorocyclohexane						
Alpha	NS	0.03	0.02	0.02	0.02	0.02
Beta	NS	0.03	0.02	0.02	0.02	0.02
Delta	NS	0.03	0.02	0.02	0.02	0.02
Gamma (Lindane)	0.52	0.03	0.02	0.02	0.02	0.02
Guthion	NS	3.64	12.10	6.64	9.47	12.03
Demeton	NS	3.99	12.16	6.61	9.44	12.01

All concentrations in parts per million (mg/kg), dry weight.

[ ] - Sediment concentrations in brackets exceed NJDEP residential criteria.

NS - No NJDEP standard for this parameter.

NJDEP residential direct contact soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.

NJDEP non residential direct contact soil cleanup criteria for toxaphene is 0.2 mg/kg.

Table 4-11. Worst Case Mean Concentrations of Pesticides in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Impact to Ground Water Soil Cleanup Criteria.

Parameter	NJDEP Ground Water Standard	Mean Channel Sediment Concentrations				
		Reach A	Reach B	Reach C	Reach D	Reach E
Aldrin	50	0.03	0.02	0.02	0.02	0.02
Dieldrin	50	0.03	0.03	0.03	0.04	0.03
Chlordane	NS	0.32	0.24	0.23	0.35	0.17
Toxaphene	50	0.56	0.34	0.29	0.41	0.26
Endrin	50	0.03	0.03	0.03	0.04	0.03
Endrin Aldehyde	NS	0.03	0.03	0.03	0.04	0.03
Heptachlor	50	0.03	0.02	0.02	0.02	0.02
Heptachlor Epoxide	NS	0.03	0.02	0.02	0.02	0.02
Endosulfan	50	0.03	0.03	0.03	0.04	0.03
DDT	500	0.04	0.04	0.03	0.05	0.03
DDD	50	0.03	0.03	0.03	0.04	0.02
DDE	50	0.03	0.03	0.03	0.04	0.02
Mirex	NS	0.35	0.11	0.03	0.04	0.03
Methoxychlor	50	0.07	0.09	0.12	0.11	0.10
Parathion	NS	3.64	12.08	6.61	9.44	12.01
Malathion	NS	3.64	12.08	6.60	9.43	12.00
Hexachlorocyclohexane						
Alpha	NS	0.03	0.02	0.02	0.02	0.02
Beta	NS	0.03	0.02	0.02	0.02	0.02
Delta	NS	0.03	0.02	0.02	0.02	0.02
Gamma (Lindane)	50	0.03	0.02	0.02	0.02	0.02
Guthion	NS	3.64	12.10	6.64	9.47	12.03
Demeton	NS	3.99	12.16	6.61	9.44	12.01

All concentrations in parts per million (mg/kg), dry weight.

NS - No NJDEP standard for this parameter.

NJDEP impact to ground water soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.

Table 4-12. Worst Case Mean Concentrations of PCBs in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Residential Direct Contact Soil Cleanup Criteria.

Parameter	NJDEP Res. Standard	Mean Channel Sediment Concentrations				
		Reach A	Reach B	Reach C	Reach D	Reach E
PCB-1242	0.49	0.30	0.21	0.15	0.23	0.17
PCB-1254	0.49	0.34	0.32	0.29	0.41	0.26
PCB-1221	0.49	0.30	0.21	0.15	0.23	0.17
PCB-1232	0.49	0.30	0.21	0.15	0.23	0.17
PCB-1248	0.49	0.30	0.21	0.15	0.23	0.17
PCB-1260	0.49	0.34	0.31	0.29	0.41	0.26
PCB-1016	0.49	0.30	0.21	0.15	0.23	0.17

All concentrations in parts per million (mg/kg), dry weight.

NJDEP residential direct contact soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.

Table 4-13. Worst Case Mean Concentrations of PCBs in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Impact to Ground Water Soil Cleanup Criteria.

Parameter	NJDEP Res. Standard	Mean Channel Sediment Concentrations				
		Reach A	Reach B	Reach C	Reach D	Reach E
PCB-1242	50	0.30	0.21	0.15	0.23	0.17
PCB-1254	50	0.34	0.32	0.29	0.41	0.26
PCB-1221	50	0.30	0.21	0.15	0.23	0.17
PCB-1232	50	0.30	0.21	0.15	0.23	0.17
PCB-1248	50	0.30	0.21	0.15	0.23	0.17
PCB-1260	50	0.34	0.31	0.29	0.41	0.26
PCB-1016	50	0.30	0.21	0.15	0.23	0.17

All concentrations in parts per million (mg/kg), dry weight.

NJDEP impact to ground water soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.

Table 4-14. Worst Case Mean Concentrations of PAHs in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Residential Direct Contact Soil Cleanup Criteria.

Parameter	NJDEP Res. Standard	Mean Channel Sediment Concentrations				
		Reach A	Reach B	Reach C	Reach D	Reach E
Acenapthene	3400	0.53	0.47	0.51	0.52	0.35
Naphthalene	230	0.53	0.46	0.46	0.52	0.35
Acenaphthylene	NS	0.53	0.47	0.51	0.52	0.35
Anthracene	10000	0.53	0.47	0.51	0.51	0.35
Benzo(a)pyrene	0.66	0.53	0.48	0.46	0.51	0.35
Benzo(b)fluoranthene	0.9	0.54	0.47	0.48	0.50	0.35
Benzo(k)fluoranthene	0.9	0.53	0.47	0.48	0.50	0.35
Chrysene	9	0.53	0.49	0.46	0.50	0.35
Phenanthrene	NS	0.53	0.48	0.47	0.51	0.35
Fluorene	2300	0.53	0.47	0.51	0.52	0.35
Fluoranthene	2300	0.53	0.52	0.48	0.50	0.35
Benzo(a)anthracene	0.9	0.53	0.49	0.51	0.50	0.35
Benzo(ghi)perylene	NS	0.53	0.47	0.47	0.51	0.35
Dibenzo(ah)anthracene	0.66	0.53	0.47	0.51	0.51	0.35
Ideno(123-cd)pyrene	0.9	0.53	0.47	0.47	0.51	0.35
Pyrene	1700	0.54	0.50	0.48	0.50	0.35

All concentrations in parts per million (mg/kg), dry weight.

NS - No NJDEP standard for this parameter.

NJDEP residential direct contact soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.

Table 4-15. Worst Case Mean Concentrations of PAHs in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Impact to Ground Water Soil Cleanup Criteria.

Parameter	NJDEP Ground Water Standard	Mean Channel Sediment Concentrations				
		Reach A	Reach B	Reach C	Reach D	Reach E
Acenapthene	100	0.53	0.47	0.51	0.52	0.35
Naphthalene	100	0.53	0.46	0.46	0.52	0.35
Acenaphthylene	NS	0.53	0.47	0.51	0.52	0.35
Anthracene	100	0.53	0.47	0.51	0.51	0.35
Benzo(a)pyrene	100	0.53	0.48	0.46	0.51	0.35
Benzo(b)fluoranthene	50	0.54	0.47	0.48	0.50	0.35
Benzo(k)fluoranthene	500	0.53	0.47	0.48	0.50	0.35
Chrysene	500	0.53	0.49	0.46	0.50	0.35
Phenanthrene	NS	0.53	0.48	0.47	0.51	0.35
Fluorene	100	0.53	0.47	0.51	0.52	0.35
Fluoranthene	100	0.53	0.52	0.48	0.50	0.35
Benzo(a)anthracene	500	0.53	0.49	0.51	0.50	0.35
Benzo(ghi)perylene	NS	0.53	0.47	0.47	0.51	0.35
Dibenzo(ah)anthracene	100	0.53	0.47	0.51	0.51	0.35
Ideno(123-cd)pyrene	500	0.53	0.47	0.47	0.51	0.35
Pyrene	100	0.54	0.50	0.48	0.50	0.35

All concentrations in parts per million (mg/kg), dry weight.

NS - No NJDEP standard for this parameter.

NJDEP impact to ground water soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.

Table 4-16. Worst Case Mean Concentrations of Phthalates in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Residential Direct Contact Soil Cleanup Criteria.

Parameter	NJDEP Res. Standard	Mean Channel Sediment Concentrations				
		Reach A	Reach B	Reach C	Reach D	Reach E
Bis(2-ethylhexyl) phthalate	49	0.62	0.51	0.53	0.51	0.42
Butyl benzyl phthalate	1100	0.62	0.51	0.55	0.47	0.42
Di-n-butyl phthalate	5700	0.73	0.29	0.30	0.31	0.55
Di-n-octyl phthalate	1100	0.62	0.54	0.55	0.51	0.42
Diethyl phthalate	10000	0.62	0.54	0.55	0.51	0.42
Dimethyl phthalate	10000	0.62	0.54	0.55	0.51	0.42

All concentrations in parts per million (mg/kg), dry weight.

NJDEP residential direct contact soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.

Table 4-17. Worst Case Mean Concentrations of Phthalates in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Impact to Ground Water Soil Cleanup Criteria.

Parameter	NJDEP Ground Water Standard	Mean Channel Sediment Concentrations				
		Reach A	Reach B	Reach C	Reach D	Reach E
Bis(2-ethylhexyl) phthalate	100	0.62	0.51	0.53	0.51	0.42
Butyl benzyl phthalate	100	0.62	0.51	0.55	0.47	0.42
Di-n-butyl phthalate	100	0.73	0.29	0.30	0.31	0.55
Di-n-octyl phthalate	100	0.62	0.54	0.55	0.51	0.42
Diethyl phthalate	50	0.62	0.54	0.55	0.51	0.42
Dimethyl phthalate	50	0.62	0.54	0.55	0.51	0.42

All concentrations in parts per million (mg/kg), dry weight.

NJDEP impact to ground water soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.

Table 4-18. Worst Case Mean Concentrations of Volatile Organics in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Residential Direct Contact, and Impact to Ground Water Soil Cleanup Criteria.

Parameter	NJDEP Ground Water Standard	NJDEP Res. Standard	Mean Sed. Conc.
Volatile Halogenated Alkanes			
carbon tetrachloride	1	2	0.11
1,2-dichloroethane	1	6	0.11
1,1,1-trichloroethane	50	210	0.11
1,1-dichloroethane	10	8	0.11
1,1,2-trichloroethane	1	22	0.11
1,1,2,2-tetrachloroethane	1	34	0.11
chloroethane	NS	NS	0.11
chloroform	1	19	0.11
1,2-dichloropropane	NS	10	0.11
methylene chloride	1	49	0.11
chloromethane	10	520	0.02
bromomethane	1	79	0.02
bromoform	1	86	0.11
dichlorobromoethane	1	11	0.11
chlorodibromomethane	1	110	0.11
Volatile Halogenated Alkenes			
1,1-dichlorethene	10	8	0.01
1,2-trans-dichlorethene	50	1000	0.01
trans-1,3-dichloropropene	1	4	0.01
cis-1,3-dichloropropene	1	4	0.01
tetrachlorethene	NS	NS	0.01
trichloroethene	1	23	0.01
vinyl chloride	10	2	0.11
Volatile Aromatic Hydrocarbons			
benzene	1	3	0.11
ethylbenzene	100	1000	0.11
toluene	500	1000	0.11
Volatile Chlorinated Aromatic Hydrocarbons			
chlorobenzene	1	37	0.11
Volatile Unsaturated Carbonyl Compounds			
acrolein	NS	NS	0.52
acrylonitrile	1	1	0.28
Volatile Ethers			
2-chlorethylvinylether	NS	NS	0.11

All concentrations presented in parts per million (mg/kg), dry weight.
NS - No NJDEP standard for this parameter.
NJDEP soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.

Table 4-19. Worst Case Mean Concentrations of Semi-Volatile Organics in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to NJDEP Residential Direct Contact, and Impact to Ground Water Soil Cleanup Criteria.

Parameter	NJDEP Ground Water Standard.	NJDEP Res. Standard	Mean Sed. Conc.
Phenols			
phenol	50	10000	0.59
2,4-dimethylphenol	10	1100	0.59
Substituted Phenols			
2,4,6-trichlorophenol	10	62	0.59
para-chloro-meta-cresol	100	10000	0.87
2-chlorophenol	10	280	0.59
2,4-dichlorophenol	10	170	0.59
4-chloro-3-methylphenol	100	10000	0.54
pentachlorophenol	100	6	2.47
4,6-dinitro-2-methylphenol	NS	NS	2.72
2-nitrophenol	NS	NS	0.59
4-nitrophenol	NS	NS	2.94
2,4-dinitrophenol	10	110	2.94
Organonitrogen Compounds			
benzidine	NS	NS	2.29
3,3'-dichlorobenzidine	100	2	1.02
2,4-dinitrotoluene	10	1	0.59
2,6-dinitrotoluene	10	1	0.59
nitrobenzene	10	28	0.59
N-nitrosodimethylamine	NS	NS	0.59
N-nitrosodiphenylamine	100	140	0.59
N-nitrosodi-n-propylamine	10	0.66	0.59
Chlorinated Aromatic Hydrocarbons			
1,2,4-trichlorobenzene	100	68	0.59
hexachlorobenzene	100	0.66	0.59
2-chloronaphthalene	NS	NS	0.59
1,2-dichlorobenzene	50	5100	0.59
1,3-dichlorobenzene	100	5100	0.59
1,4-dichlorobenzene	100	570	0.59
Chlorinated Aliphatic Hydrocarbons			
hexachlorobutadiene	100	1	0.59
hexachloroethane	100	6	0.59
hexachlorocyclopentadiene	100	400	0.59
Halogenated Ethers			
bis(2-chloroethyl)ether	10	0.66	0.59
4-chlorophenyl-phenylether	NS	NS	0.59
4-bromophenyl-phenylether	NS	NS	0.59
bis(2-chloroisopropyl)ether	10	2300	0.59
bis(2-chlorethoxy)methane	NS	NS	0.59
Miscellaneous Oxygenated Compounds			
isophorone	50	1100	0.59

the final 20 samples were collected in 1994. These 40 samples showed thallium concentrations in channel sediments to be less than two ppm. All 40 samples had laboratory quantification limits or actual detections of thallium below 0.4 ppm. While mean thallium concentrations for channel sediments in Reaches A and B are above the NJDEP standard, it appears that high detection levels from the 1991 sampling event is responsible for skewing the means. Two subsequent sampling events failed to reproduce the earlier results. Like toxaphene, there is no reason to believe that thallium is a contaminant of concern in the Delaware Estuary. Based on the above information, it is concluded that the calculated mean concentrations are high, and that the true mean thallium concentration in channel sediments is actually below two ppm.

The mean cadmium concentration of channel sediment samples collected from Reach A was 1.66 ppm. This is above the NJDEP Residential standard of one ppm, but well below the Non-Residential standard of 100 ppm. Cadmium was detected in a number of samples at concentrations above one ppm, so there is no reason to suspect that the calculated mean is high. Since the material dredged from Reach A would be placed in an upland, dredged material disposal site that would not be used for residential development, and since the mean concentration of cadmium is so far below the NJDEP Non-Residential sediment standard of 100 ppm, it is concluded that the concentration of cadmium in sediments from Reach A would not pose any significant human health concerns.

Heavy metals and polynuclear aromatic hydrocarbons (PAHs) were the two groups of contaminants primarily encountered in channel sediments. The bulk sediment data for several parameters within these groups were also compared to sediment quality guidelines relating to the potential for adverse biological effects in estuarine sediments (Long et al., 1995). Adverse biological effects include measures of altered benthic communities, histopathological disorders in demersal fish, and toxicity. Through a comprehensive review of available data on sediment effects, Long established two guideline values. These two values are referred to as effects range-low (ERL) and effects range-median (ERM). Long et al. (1995) state: "The two guideline values, ERL and ERM, delineate three concentration ranges for a particular chemical. The concentrations below the ERL value represent a minimal-effects range; a range intended to estimate conditions in which effects would be rarely observed. Concentrations equal to and above the ERL, but below the ERM, represent a possible-effects range within which effects would occasionally occur. Finally, the concentrations equivalent to and above the ERM value represent a probable-effects range within which effects would frequently occur."

These guidelines are most appropriate for Reach E sediment, where material would largely be placed in the aquatic environment for beneficial uses. In Reaches A through D, material would be

removed from the aquatic environment and placed in confined, upland sites. As such, any adverse impacts to aquatic resources would be precluded.

Long established ERL/ERM criteria for nine heavy metals. Mean concentrations of these nine metals are compared to the ERL/ERM criteria in Table 4-20. Again, mean concentrations are presented for Reaches A through E. Mean concentrations of the nine heavy metals in Reach E sediment are all below ERL values. Cadmium and nickel are the only metals that have an individual sample concentration above the ERLs. One Reach E sample had a cadmium concentration of 2.8 ppm and a nickel concentration of 21.4 ppm (refer to detection ranges presented in Table 4-2). Both of these values are on the low side of the possible effects range between the ERL and ERM values.

With regard to Reaches A through D, mean concentrations of arsenic, cadmium, mercury and silver were above ERL values in some reaches. Again all of these mean concentrations are on the low end of the possible effects range between the ERL and ERM values. While a number of individual samples had metal concentrations above the ERLs, only mercury and zinc had sample concentrations above the ERMs (Table 4-2). One Reach C sample had a mercury concentration of 1.4 ppm, which is above the ERM of 0.71 ppm. One Reach A sample and one Reach C sample had zinc concentrations of 607 and 630 ppm, respectively. These are above the ERM value of 410 ppm.

Bulk sediment data for 12 individual PAHs were also compared to ERL/ERM criteria (Table 4-21). PAHs were detected much less frequently than heavy metals. Benzo(a)pyrene was most frequently detected. As can be seen on Table 4-21, benzo(a)pyrene was only detected in 11 of the 153 samples analyzed. Unfortunately, the calculated means (Table 4-5), based predominantly on quantification limits, are above the majority of ERLs, and even above the ERMs for acenapthene and dibenzo(ah)anthracene. PAHs were not detected in Reach E sediment. The mean quantification limit for the 23 samples analyzed was 350 parts per billion (ppb) for each individual parameter. Only benzo(a)pyrene, chrysene, fluoranthene and pyrene have ERLs above 350 ppb. For the remaining parameters, 350 ppb falls between the ERL and ERM values, and is above the ERM of 260 ppm for dibenzo(ah)anthracene.

As a result of the high quantification limits relative to the ERL/ERM PAH criteria, it is only possible to compare criteria to actual PAH detections. Table 4-21 provides the number of individual PAH detections out of 153 samples analyzed, the number and concentrations of detections greater than the corresponding ERL values, and the ERL/ERM criteria. As can be seen from the table, there were few actual detections above the ERLs and none above the ERMs. These data suggest that the sediments in Reaches A through D are not highly contaminated with PAHs, and that the potential for adverse biological effects is not great, especially

Table 4-20. Worst Case Mean Concentrations of Heavy Metals in Delaware River, Philadelphia to the Sea, Federal Navigation Channel Sediment Compared to ERL/ERM Criteria.

		Mean Channel Sediment Concentrations				
Parameter	ERL/ERM Criteria	Reach A	Reach B	Reach C	Reach D	Reach E
Arsenic	8.2/70	5.97	6.41	[8.37]	[8.97]	2.35
Cadmium	1.2/9.6	[1.66]	0.94	1.00	0.96	0.70
Chromium	81/370	15.95	26.28	28.73	37.18	12.70
Copper	34/270	9.97	11.72	14.74	10.33	5.08
Lead	46.7/218	18.94	19.09	24.80	19.53	7.11
Mercury	0.15/0.71	[0.15]	[0.16]	[0.24]	[0.15]	0.14
Nickel	20.9/51.6	11.20	18.30	15.79	18.33	6.70
Silver	1.0/3.7	[1.04]	0.87	0.67	0.64	0.81
Zinc	150/410	67.41	64.46	84.88	73.88	26.01

- All concentrations in parts per million (mg/kg), dry weight.
- [ ] - Sediment concentrations in brackets exceed ERL criteria.

Long, E.R, D.A. MacDonald, S.L. Smith, and F.C. Calder. 1995. Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environmental Management 19(1):81-97.

Table 4-21. Summary of PAH Bulk Sediment Data Collected in the Delaware River, Philadelphia to the Sea, Federal Navigation Channel Compared to ERL and ERM Criteria.

Parameter	No. of Detections	Detections > ERL	ERL	ERM
Acenapthene	0/153	None	16	500
Naphthalene	2/153	180, 420	160	2100
Acenaphthylene	0/153	None	44	640
Anthracene	3/153	200, 510	85.3	1100
Benzo(a)pyrene	11/153	490, 530, 1120	430	1600
Chrysene	6/153	620, 710, 1270	384	2800
Phenanthrene	4/153	490, 650, 950	240	1500
Fluorene	0/153	None	19	540
Fluoranthene	7/153	850, 860, 2250	600	5100
Benzo(a)anthracene	4/153	590, 1520	261	1600
Dibenzo(ah)anthracene	1/153	None	63.4	260
Pyrene	7/153	810, 870, 1760	665	2600

- All concentrations in parts per billion (ug/kg), dry weight.

Long, E.R., D.A. MacDonald, S.L. Smith, and F.C. Calder. 1995. Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environmental Management 19(1):81-97.

considering that this material would be removed from the aquatic system.

Overall, concentrations of contaminants in channel sediments are considered low. Channel sediments to be dredged from Reaches A through D are sufficiently clean for placement in confined, upland sites. In the Delaware Bay portion of the project area, where material would be used for beneficial uses such as beach nourishment, comparison of data to NJDEP Residential and ERL/ERM criteria suggests that the proposed plan is also acceptable.

4.2 Elutriate Sediment Analyses

While bulk analysis provides an accurate characterization of contaminants associated with the sediments, it does not provide insight into the potential impacts on water quality and aquatic resources associated with sediment disturbance. To predict contaminant levels that would be liberated from sediment during dredging and disposal activities, which would then be biologically available to impact aquatic resources, sediment samples were also evaluated through an elutriate analysis. This test mimics the sediment disturbance that would occur, and determines contaminant levels that would be released. The elutriate test provides the second tier of testing in the national comprehensive testing strategy.

A total of 107 separate sediment samples taken from sediment cores that were also used for bulk analysis were tested using the elutriate procedure. See Plates 7 and 8 for sediment core sample locations. An elutriate sample was prepared by combining sediment and Delaware River water to achieve a slurry concentration of 150 grams/liter. The slurry was thoroughly mixed, and after a settling period, the supernatant water was extracted from the test cylinder. The water sample was appropriately filtered, and analyzed for a variety of chemical parameters. All 107 samples were analyzed for heavy metals, pesticides, PCBs and polynuclear aromatic hydrocarbons. Forty-five samples were analyzed for the complete list of chemical parameters (Table 4-1).

Heavy metals were frequently detected in sediment elutriate samples. See Table 4-22 for a summary of the heavy metal elutriate results. Antimony and selenium were not detected in any of the 107 samples analyzed. Beryllium and mercury were each detected in three samples. Beryllium was detected in three Reach E samples, all at concentrations of 10 parts per billion (ppb). Mercury was detected once in Reaches B, C and D. Mercury concentrations ranged between 0.26 and 0.95 ppb. Silver was detected in seven samples collected in Reaches C, D and E. Silver concentrations ranged between 10 and 40 ppb. Cadmium, chromium, nickel and thallium were each detected in 10 to 20 percent of the 107 samples. Cadmium was detected in Reaches B, C, D and E at concentrations ranging between 10 and 40 ppb. Chromium was detected in Reaches A and B at concentrations

Table 4-22. Heavy Metal Data Summary of Elutriate Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	20	40	23	13	11
Antimony					
Mean Concentration	54.5	43.25	57.39	63.08	321.82
# of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Arsenic					
Mean Concentration	35.69	12.86	14.78	11.87	134.36
# of Detections	1	5	7	7	7
Detection Range	65	6-92.9	8-57	5-33	190-220
Beryllium					
Mean Concentration	5	4.4	4.39	4.62	15.91
# of Detections	ND	ND	ND	ND	3
Detection Range	-	-	-	-	10
Cadmium					
Mean Concentration	5.5	6	7.39	9.23	46.36
# of Detections	ND	5	2	2	4
Detection Range	-	10	20	20	40
Chromium					
Mean Concentration	43.85	22.68	15.65	20	81.82
# of Detections	11	2	ND	ND	ND
Detection Range	28-180	77-130	-	-	-
Copper					
Mean Concentration	47.63	23.18	19.74	21.54	87.27
# of Detections	14	15	3	2	4
Detection Range	22-119	20-130	24-30	30	50-80
Lead					
Mean Concentration	35.82	14.25	4.87	10.28	48.72
# of Detections	9	24	10	3	4
Detection Range	4-127	2-260	3-24	4-5.6	0.2-170

All concentrations presented in parts per billion (ug/l).
ND - Not Detected.

Table 4-22. Heavy Metal Data Summary of Elutriate Sediment Sample Analyses Conducte Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	20	40	23	13	11
Mercury					
Mean Concentration	0.87	0.24	0.11	0.15	0.2
# of Detections	ND	1	1	1	ND
Detection Range	-	0.95	0.26	0.3	-
Nickel					
Mean Concentration	86.55	40.5	51.74	55.38	308.18
# of Detections	7	1	3	2	4
Detection Range	42-660	60	40-100	40	110-170
Selenium					
Mean Concentration	4.85	3.7	8.52	11.31	297.27
# of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Silver					
Mean Concentration	18.5	11.25	12.17	13.85	74.55
# of Detections	ND	ND	1	2	4
Detection Range	-	-	10	10	20-40
Thallium					
Mean Concentration	32.1	9.45	11.22	30.69	321.82
# of Detections	ND	ND	7	4	ND
Detection Range	-	-	2-6	3-4	-
Zinc					
Mean Concentration	383.1	135.48	53.35	37.38	149.09
# of Detections	16	35	14	5	4
Detection Range	93-1160	23-921	24-150	21-70	40-90

All concentrations presented in parts per billion (ug/l).
ND - Not Detected.

ranging between 28 and 180 ppb. Nickel was detected in all Reaches at concentrations ranging between 40 and 660 ppb. Thallium was detected in Reaches C and D at concentrations ranging between 2 and 6 ppb. Arsenic, copper, lead and zinc were most frequently detected. These heavy metals were detected in all Reaches in 25, 36, 47 and 69 percent of the 107 samples, respectively. Arsenic concentrations ranged between 5 and 220 ppb. Copper concentrations ranged between 20 and 130 ppb. Lead concentrations ranged between 2 and 260 ppb. Zinc concentrations ranged between 21 and 1160 ppb.

The presence of organic contaminants in sediment elutriates was limited. Refer to Table 4-23 for a summary of organic contaminants detected, and the detection range. PCBs were not detected. Pesticides were only detected in three of 107 samples, which were all collected from Reach B. The pesticide malathion was detected in two samples at concentrations of 2.6 and 6.3 parts per billion (ppb). The pesticide endosulfan was detected in one sample at a concentration of 6 ppb. Polynuclear aromatic hydrocarbons were only detected in one of 107 samples, which was collected from Reach E. Five individual PAHs were detected in this sample for a combined concentration of 13 ppb. No other organic contaminants were detected in samples collected from Delaware Bay. Phthalates were detected in 41 of the 45 samples evaluated. Phthalate concentrations ranged between 1 and 134 ppb. Methylene chloride, a common laboratory contaminant, was detected in five of 45 samples, which were all collected from Reach A. Concentrations ranged between 9 and 30 ppb. 2,4,6 Trichlorophenol was detected in three samples (3 of 45) collected from Reach B at concentrations between 6 and 13 ppb. Bis(2-chloroethyl) ether was detected in one (1 of 45) Reach B sample at a concentration of 62 ppb.

Based on the elutriate analysis results, it is concluded that dredging and dredged material disposal operations would not significantly impact water quality within the Delaware River. The majority of organic contaminants evaluated were not present in any of the sediment elutriates. The few that were encountered were detected on a very limited basis. All concentrations were considered to be relatively low. While more frequently encountered, concentrations of heavy metals in sediment elutriates were also considered low. The metals arsenic, copper, lead and zinc were the only contaminants detected in greater than 20 percent of the samples. Elevated concentrations of contaminants in Delaware River water resulting from dredging or dredged material disposal operations would be lower than the elutriate analysis results, as a result of mixing and dilution with the large volume of water in the river.

4.3 Toxicity Characteristic Leaching Procedure (TCLP) Analyses

In 1994, 20 sediment cores were collected between Philadelphia Harbor and lower Delaware Bay and analyzed using the USEPA Toxicity Characteristic Leaching Procedure (TCLP), as provided in

Table 4-23. Organic Contaminant Data Summary of Elutriate Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	20	40	23	13	11
Bis(2-ethylhexyl) phthalate					
# of Detections	4	10	13	6	ND
Detection Range	1-134	1-16	6-59	16-49	-
Butyl benzyl phthalate					
# of Detections	ND	1	ND	ND	ND
Detection Range	-	2	-	-	-
Di-n-butyl phthalate					
# of Detections	ND	17	6	6	ND
Detection Range	-	1-37	2	2-5	-
Diethyl phthalate					
# of Detections	ND	1	ND	ND	ND
Detection Range	-	2	-	-	-
Methylene chloride					
# of Detections	5	ND	ND	ND	ND
Detection Range	9-30	-	-	-	-
Bis(2-chloroethyl) ether					
# of Detections	ND	1	ND	ND	ND
Detection Range	-	62	-	-	-
2,4,6 Trichlorophenol					
# of Detections	ND	3	ND	ND	ND
Detection Range	-	6-13	-	-	-
Malathion					
# of Detections	ND	2	ND	ND	ND
Detection Range	-	2.6-6.3	-	-	-
Endosulfan					
# of Detections	ND	1	ND	ND	ND
Detection Range	-	6	-	-	-

All concentrations presented in parts per billion (ug/l).
ND - Not Detected.

Table 4-23. Organic Contaminant Data Summary of Elutriate Sediment Sample Analyses Conducted Within the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Reach A	Reach B	Reach C	Reach D	Reach E
Number of Samples	20	40	23	13	11
Fluoranthene					
# of Detections	ND	ND	ND	ND	1
Detection Range	-	-	-	-	3
Pyrene					
# of Detections	ND	ND	ND	ND	1
Detection Range	-	-	-	-	3
Chrysene					
# of Detections	ND	ND	ND	ND	1
Detection Range	-	-	-	-	3
Benzo(b)fluoranthene					
# of Detections	ND	ND	ND	ND	1
Detection Range	-	-	-	-	2
Benzo(k)fluoranthene					
# of Detections	ND	ND	ND	ND	1
Detection Range	-	-	-	-	2

All concentrations presented in parts per billion (ug/l).
ND - Not Detected.

40 CFR Part 261. Sediment core collection locations are shown on Plates 7 and 8. The cores were divided into 44 separate samples, based on observed sediment stratification. Some cores were homogeneous throughout, and were simply divided in half to provide a top and bottom sample.

The TCLP test entails adjusting the sediment and water to a pH of 4.93, and leaching contaminants from the sediment. The samples were leached for volatile organics using zero headspace extraction, and were leached for extractable organics and heavy metals by rotation. The samples were then analyzed for a specific set of contaminants, which have established criteria that represent maximum allowable regulatory levels. A sediment that has a contaminant concentration equal to or greater than the respective regulatory level is considered to exhibit the characteristic of toxicity, and would be treated as a hazardous waste. As the TCLP test simulates the pH changes that sediments may experience when exposed to air and acidic rain in an upland disposal area, the data can also be used to evaluate potential groundwater and surface water impacts.

Table 4-24 provides a list of the TCLP contaminant parameters, the maximum allowable regulatory levels, and the maximum concentrations detected in Delaware River channel sediments. The heavy metals arsenic, barium, cadmium, chromium and lead were the only contaminants detected through the TCLP analysis. Maximum sample detections of these metals were at least one order of magnitude below the respective criteria. As such, channel sediment samples did not exhibit the characteristic of toxicity, and would not be considered a hazardous material.

4.4 Biological Effects Based Testing

In the Record of Decision, which was prepared at the end of the Environmental Impact Statement process, the Corps committed to conducting biological effects based testing to more fully evaluate sediment quality concerns. These tests provide a third tier of sediment investigation. A water column, or suspended solid particulate phase bioassay can be run to evaluate water quality concerns associated with the release of contaminants from sediment into dredging or disposal site water. A whole sediment, or benthic bioassay can be run to evaluate impacts to benthic organisms residing at open water disposal sites. These bioassays are used to provide information on the toxicity of individual contaminants, and also to indicate possible interactive effects of multiple contaminants. Lastly, if there is reason to believe that bioaccumulation is of concern, the potential uptake of contaminants by aquatic organisms at an open water disposal site can be evaluated with a bioaccumulation test. Unless there is continuous dredging/discharge, bioaccumulation from the material remaining in the water column is considered to be of minor concern due to the short exposure time and low exposure concentrations resulting from rapid dispersion and dilution. An overwhelming preponderance of evidence from years of studies has

Table 4-24. USEPA Toxicity Characteristic Leachate Procedure (TCLP) Criteria Compared to Delaware River Channel Sediment Samples. Concentrations in mg/l.

Parameter	Maximum Allowable Concentration	Maximum Sample Detection
Metals		
Silver	5.0	ND
Arsenic	5.0	0.42
Barium	100.0	1.25
Cadmium	1.0	0.013
Chromium	5.0	0.029
Mercury	0.2	ND
Lead	5.0	0.193
Selenium	1.0	ND
Herbicides and Pesticides		
2,4,-D	10.0	ND
2,4,5-TP (Silvex)	1.0	ND
Endrin	0.02	ND
Heptachlor	0.008	ND
Heptachlor Epoxide	0.008	ND
Methoxychlor	10.0	ND
Chlordane	0.03	ND
Toxaphene	0.5	ND
Lindane	0.4	ND
Semi-Volatile Organics		
Pentachlorophenol	100.0	ND
2,4,6-Trichlorophenol	2.0	ND
2,4,5-Trichlorophenol	400.0	ND
2-Methylphenol (o-Cresol)	200.0	ND
4-Methylphenol (p-Cresol)	200.0	ND
3-Methylphenol (m-Cresol)	200.0	ND
O,M,P Cresol (Total Cresols)	200.0	ND
1,4-Dichlorobenzene	7.5	ND
2,4-Dinitrotoluene	0.13	ND
Hexachlorobenzene	0.13	ND
Hexachlorobutadiene	0.5	ND
Hexachloroethane	3.0	ND
Nitrobenzene	2.0	ND
Pyridine	5.0	ND
Volatile Organics		
Methyl ethyl ketone	200.0	ND
Tetrachloroethylene	0.7	ND
Trichloroethylene	0.5	ND
Benzene	0.5	ND
Carbon tetrachloride	0.5	ND
Chlorobenzene	100.0	ND
Chloroform	6.0	ND
1,2-Dichloroethane	0.5	ND
1,1-Dichloroethylene	0.7	ND
Vinyl Chloride	0.2	ND

demonstrated that the potential of water column impacts of contaminants released from dredged material disposal are generally negligible (USACE, 1988).

Bioassays and bioaccumulation tests have been run to directly test the toxic effects of Delaware River channel sediments on aquatic organisms. The water column and whole sediment bioassays exposed living organisms to sediments, to evaluate any differences in mortality between Delaware River channel sediments and clean laboratory sediments used as a control. Early life stages of fish, crustaceans, molluscs, zooplankton and polychaete worms were tested. Young organisms are more sensitive than adults to the effects of sediment contamination, and are considered to be better indicators of problems.

4.4.1 Water Column and Whole Sediment Bioassays

A total of 38 sediment samples were collected and used for bioassay analyses. Sample locations are shown on Plates 9 and 10. In the riverine portion of the project area, 28 sediment samples were collected. One sample was collected from approximately each channel range and each channel bend between the Beckett Street Terminal and Artificial Island. In Delaware Bay, an additional 10 sediment samples were collected from the channel in areas that would require dredging. Sediment samples were collected with two types of grab samplers, the PONAR Grab and Wildco-Petersen Grab. Both units are capable of penetrating a minimum of six inches into the bottom substrate. A sufficient quantity of Delaware River water was also collected at six water sample locations to run all analyses.

To assess the potential effects of dredging and disposal activities on water quality, acute water column bioassays were run on the elutriate of all 38 sediment samples, and unfiltered Delaware River water. Procedures followed those outlined in the USEPA/USACE Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. - Testing Manual (EPA-823-B-94-002). Each sediment sample was combined with unfiltered Delaware River water in a sediment -to- water ratio of 1:4 on a volume basis. The mixture was thoroughly agitated, allowed to settle for one hour, and the supernatant was removed. Two dilutions were prepared from the 100 percent elutriate sample using unfiltered river water, 10 and 5 percent. Subsamples of each dilution, unfiltered river or bay water and laboratory control water were analyzed for total suspended solids. Table 4-25 provides pertinent sediment quality data for sediment samples including the percentage of silt/clay, the concentration of organic carbon (TOC), and the concentration of suspended sediment (SS) in the 100 percent elutriate sample. The concentrations of suspended sediment in Delaware River water samples are also provided. The water sample used to prepare the sediment elutriates is listed before the sediment samples.

The water column bioassays consisted of two controls, laboratory

Table 4-25. Sediment Quality Data for Delaware River Channel Sediment Samples Collected for Bioassay Testing.

Sediment Sample Location	Percent Silt/Clay	TOC (mg/kg)	SS Conc. 100% Elut. (mg/l)
Laboratory Water	-	-	9
Mifflin Range Water	-	-	14
Beckett St. Terminal	34.7	7000	1530
Range M	44.1	7000	308
Bend AF	31.8	4000	408
W. Horseshoe Range	0.2	580	28
Bend G	23.4	3100	434
Mifflin Range	14.8	2000	372
Bend H	57.7	8000	1840
Billingsport Range	14.2	5000	1310
Chester Range Water	-	-	4
Bend I	11.0	650	231
Tinicum Range	59.9	3800	131
Bend J	0.2	5000	37
Eddystone Range	0.4	540	156
Bend K	42.9	3000	592
Bend L	28.1	3000	406
Bellevue Range Water	-	-	13
Marcus Hook Range	97.2	5000	102
Bend M	96.2	4000	28
Bellevue Range	36.4	5000	31
Bend N	82.7	4000	324
Deepwater Range Water	-	-	23
Cherry Island Range	66.5	2100	30
Bend O	95.1	4500	29
Deepwater Range	82.5	4800	138
Bend PQ	0.6	900	171
New Castle Range	60.6	3000	276
Bend R	87.4	5000	414
Baker Range Water	-	-	18
Reedy Island Range	8.0	1200	166
Bend S	17.1	1400	144
Baker Range	97.4	2600	210
Bend T	24.4	1500	209
Delaware Bay #1	97.2	4000	839
Miah Maull Range Water	-	-	42
Delaware Bay #2	0.4	400	326
Delaware Bay #3	0.7	230	161
Delaware Bay #4	8.9	900	84
Delaware Bay #5	59.9	4000	88
Delaware Bay #6	5.1	1500	123
Delaware Bay #7	0.5	500	129
Delaware Bay #8	0.3	200	286
Delaware Bay #9	0.4	330	259
Delaware Bay #10	2.3	1400	265

water and unfiltered river or bay water, and each of the three dilutions (ie. 100, 10 and 5 percent). Five replicates of each dilution and the controls were set up for each of three test species. Ten organisms were tested in each replicate sample. Each test was run for a duration of 48 hours.

For the 28 riverine samples, test species were the fathead minnow (Pimephales promelas), a water flea (Ceriodaphnia dubia) and an amphipod (Hyalella azteca). All organisms were obtained from Aquatic Research Organisms (ARO), a commercial laboratory located in Hampton, New Hampshire. The minnows were hatched the morning prior to test initiation, and were approximately 24 hours old. Stock cultures of adult C. dubia were obtained to yield enough neonates for testing the day of arrival. Juvenile H. azteca were originally obtained from the U.S. Fish and Wildlife Service. The amphipods were acclimated to laboratory conditions for two days prior to test initiation, and were approximately eight days old at the start of the test.

For the 10 Delaware Bay samples, test species were the sheepshead minnow (Cyprinodon variegatus), the American oyster (Crassostrea virginica) and a mysid shrimp (Mysidopsis bahia). Juvenile sheepshead minnow were obtained from ARO, and acclimated to test salinity and laboratory conditions for one day prior to test initiation. Larval mysid shrimp were approximately 4 days old prior to test initiation. Adult oysters in spawning condition were obtained and induced to spawn. Fertilized embryos were used to initiate tests approximately two hours after fertilization.

After 48 hours of exposure, 100 percent survival was recorded for all six species at all test concentrations, and in both the lab water and water controls. With no mortality observed, statistical evaluation of the data was unnecessary.

In Delaware Bay, dredged material would be placed in open water for beneficial uses, as previously discussed. Acute whole sediment bioassays were run to assess the potential sediment quality impacts to benthic organisms that would reside at the site after placement. The 10 Delaware Bay sediment samples were tested. Procedures again followed those outlined in the USEPA/USACE testing manual. Sediment samples were initially gross sieved using a 1.00 mm stainless steel sieve to remove larger material, macroinvertebrates, and interstitial water. Each sample was then thoroughly homogenized, placed into test containers, and allowed to settle for 24 hours before test organisms were introduced.

Test species included an infaunal amphipod (Ampelisca abdita), a burrowing polychaete (Nereis virens) and a bivalve mollusc (Mercenaria mercenaria). Immature A. abdita were field collected by East Coast Amphipod, a commercial laboratory located in Kingston, Rhode Island. The amphipods were collected in Fishing Cove, Wickford Harbor. The organisms were sieved using a 0.5 mm mesh, and randomly distributed into test containers. The

amphipods were of approximately uniform size at test initiation, with a size range of two to four mm. N. virens were field collected in Maine by ARO. The worms were of approximately uniform size at test initiation, with an average length of 6.3 cm. M. mercenaria were collected from southern Chesapeake Bay. The clams were of approximately uniform size at test initiation, with an average hinge length of two to four cm.

The tests consisted of a control sediment, reference sediment, and each of the 10 Delaware Bay channel sediment samples. The control sediment was collected at the same time the test organisms were collected. The reference sediment was collected from proposed Delaware Bay beneficial use sites (Plate 10), and represent conditions that currently exist at these locations. Five replicate samples were run for each species per test; 20 amphipods and polychaetes, and 10 molluscs were tested in each replicate sample. The tests were run for a period of 10 days. After 10 days of exposure, 100 percent survival was recorded for all three species in all test, reference, and control sediment. Statistical evaluation was unnecessary due to the absence of mortality.

4.4.2 Bioaccumulation Testing

Bioaccumulation tests were also run with Delaware Bay sediment to evaluate the potential for bioaccumulation of contaminants by aquatic organisms that would reside in the sediment after placement in the beneficial use sites. It was not necessary to evaluate the bioaccumulation potential of up-river channel sediments, as this material would be removed from the aquatic environment, thus precluding contaminant accumulation in aquatic resources. Two separate bioaccumulation tests were run. See Plate 11 for sediment sample locations. In 1993, five of the 10 Delaware Bay sediment samples collected for bioassays were tested. The five Delaware Bay samples with the highest percentage of fine grain silts and clays were used (Delaware Bay #1, 4, 5, 6 and 10), as fine grain sediment has a greater potential to retain contaminants than coarse grain sands. Again, sediment samples collected from candidate beneficial use sites were used as reference sediment to represent existing conditions at these locations. The bivalve mollusc Mercenaria mercenaria was used as the test organism. The clams were of approximately uniform size at test initiation, with an average hinge length of two to four cm.

Sediment samples were initially gross sieved using a 1.00 mm stainless steel sieve to remove large organic material, macroinvertebrates, and interstitial water. Each sample was then homogenized, placed into test containers, and allowed to settle for 24 hours. M. mercenaria were exposed to approximately three cm of sediment for 28 days. Five replicate test chambers (10 clams per replicate) were prepared for each sediment sample. Test animals were not fed during the test. Clams that died during the test period were removed and discarded daily. After

28 days, surviving individuals were placed in clean, sediment-free water for 24 hours to purge their digestive tracts. The clams were not fed during this purging period. Fecal material was siphoned from the purging chamber twice during the 24-hour period. After the purging period, clam tissue was removed from the shell, combined among replicates for each sediment sample, homogenized, and analyzed for heavy metals, pesticides, PCBs, and PAHs (Table 4-1).

Clam mortality was observed during the final stages of testing, possibly due to starvation since the specimens were not fed during testing. Upon examination at the conclusion of the test, even the live clams appeared flaccid and emaciated. Due to the degree of mortality, live clams from all five replicates were pooled for each test sediment, to provide sufficient tissue for chemical analysis. Pesticides, PCBs, and PAHs were not detected in any of the tissue samples from clams exposed to Delaware Bay channel sediment, or sediment from candidate beneficial use sites. Of the 12 metals, seven were found in quantifiable concentrations in one or more samples (Table 4-26).

Copper, selenium and zinc were the only metals detected in clam tissue exposed to Delaware Bay channel sediment. Zinc was detected in all five tissue samples from clams exposed to channel sediments, with a concentration range of 10.3 to 11.8 mg/kg. Zinc was also detected in all tissue samples from clams exposed to beneficial use site and control sediments, with a concentration range of 12.1 to 16.0 mg/kg. Since zinc concentrations in clams exposed to channel sediments were consistently lower than concentrations in clams exposed to beneficial use site and control sediments, bioaccumulation of zinc is not a concern with regard to placement of Delaware Bay channel sediment at beneficial use site locations.

Copper was also detected in all clam tissue samples exposed to channel, beneficial use site and control sediments. Copper concentrations in channel samples ranged between 1.39 and 1.91 mg/kg. Concentrations in beneficial use site and control samples ranged between 1.64 and 2.34 mg/kg. These ranges are similar, and placement of channel sediment at beneficial use site locations would not be expected to result in any increased bioaccumulation of copper in marine benthic organisms. These concentrations are also below the 2.9 to 5.5 mg/kg copper range reported by Murphy (1990) for hard shell clam tissue collected from Chincoteague Bay, Maryland. Although copper has a high bioaccumulation tendency in marine shellfish and crustaceans, it constitutes a relatively low human health hazard (USEPA, 1978).

Selenium was detected in two of the five tissue samples from clams exposed to channel sediment, at concentrations of 0.256 and 0.342 mg/kg. Selenium was not detected in clams exposed to beneficial use site sediments, but was detected in the control sediment at a concentration of 0.454 mg/kg. Selenium concentrations in clam tissue were at the lower end of the range

Table 4-26. Metal Concentrations (mg/kg - wet weight) of Mercenaria mercenaria Tissue from 28-Day Bioaccumulation Tests of Delaware Bay Channel and Beneficial Use Site Sediments.

Sediment Sample	Arsenic	Chromium	Copper	Lead	Mercury	Selenium	Zinc
Channel Sediment							
DB#1	<0.2	<1.00	1.39	<2.00	<0.07	0.342	10.5
DB#4	<0.2	<1.00	1.85	<2.00	<0.07	<0.200	11.8
DB#5	<0.2	<1.00	1.73	<2.00	<0.07	0.256	10.3
DB#6	<0.2	<1.00	1.91	<2.00	<0.07	<0.200	11.2
DB#10	<0.2	<1.00	1.82	<2.00	<0.07	<0.200	11.8
Beneficial Use Site Sediment							
BUS#2	<0.2	1.04	1.76	<2.00	0.47	<0.200	12.7
BUS#3	<0.2	<1.00	1.95	<2.00	<0.07	<0.200	15.5
BUS#5	0.4	1.16	1.64	<2.00	<0.07	<0.200	12.1
BUS#6	<0.2	1.02	2.31	2.42	<0.07	<0.200	16.0
Control Sediment							
Control	0.5	<1.00	2.34	<2.00	<0.07	0.454	13.2

reported for "bivalve" molluscs (0.1 to 0.9 mg/kg) as a human food source reported by the FDA (1982a and 1982b). Selenium also tends to have a low bioaccumulation tendency in marine shellfish or crustaceans, and presents a low hazard to humans relative to other metals such as mercury and lead (USEPA, 1978).

Arsenic, chromium, lead and mercury were also detected in one or more clam tissue samples. However, these detections were in samples exposed to beneficial use site or control sediments. As such, placement of channel sediments at beneficial use site locations is not a concern with regard to bioaccumulation of these metals. Overall, there was no evidence that contaminants accumulated in clam tissue exposed to Delaware Bay sediment at greater concentrations than clam tissue exposed to clean control sediment. All of the tissue residues were representative of what one would expect in organisms exposed to uncontaminated material.

In 1994, two additional samples of channel sediment were collected from areas containing fine grained material. Two reference sediment samples collected at candidate beneficial use sites LC9 and LC10, and a control sediment were also obtained for analysis. The burrowing polychaete Nereis virens was used as the test organism. The control sediment was obtained in Maine, where the worms were collected. Sediment samples were collected with a PONAR Grab sampler, sufficiently weighted to penetrate bottom sediments to a depth of six inches. Five replicates of each sediment were tested. Twenty individual worms were used in each test replicate, all approximately 8 to 12 cms in length. The worms were not fed during the 28-day test period. At the end of the 28-day period, all dead worms were discarded, living worms were purged in clean water, and the worms in each test replicate were pooled and analyzed for heavy metals, pesticides, PCBs, and PAHs (Table 4-1).

Again, pesticides, PCBs and PAHs were not detected in any of the worm tissue samples. The metals arsenic, chromium, copper, lead and zinc were the only parameters measured above detection levels in some or all of the 25 replicate tissue samples. Table 4-27 presents the mean concentrations of these metals for each test sediment.

With replicate data available for each of the test sediments, it was possible to statistically evaluate the concentration differences of the five metals between channel, beneficial use site and control sediments. The data for arsenic, copper and zinc met all parametric distributional assumptions. Therefore, the navigation channel sediments were compared to the reference sediments using ANOVA and Dunnett's Multiple Comparison procedure. Since the data for chromium and lead did not meet the distributional assumption of variance homogeneity, the nonparametric Steel's Many-One Rank test was used for comparison. There were no statistical differences between metal content in worms exposed to channel sediments and worms exposed to reference sediments, with the exception of arsenic. The mean arsenic

Table 4-27. Mean Metal Concentrations (mg/kg - wet weight) of Neresis virens Tissue from 28-Day Bioaccumulation Tests of Delaware Bay Channel and Beneficial Use Site Sediments.

Sediment Sample	Arsenic	Chromium	Copper	Lead	Zinc
Channel Sediment					
Channel 1	0.380	0.200	2.308	0.200	32.44
Channel 2	0.700	0.266	2.736	0.300	30.48
Beneficial Use Site Sediment					
LC9	0.360	0.339	2.864	0.440	24.50
LC10	0.460	0.300	2.886	0.280	32.72
Control Sediment					
Control	0.680	0.834	3.742	1.900	33.30

concentration in worms exposed to one channel sediment sample (0.700 mg/kg) was statistically significantly higher (p=0.05) than concentrations in worms exposed to beneficial use site sediment samples (0.360 and 0.460 mg/kg). The measured tissue concentration of arsenic in worms exposed to the channel sediment did not appear to be deleterious. No more mortality was observed in the channel sediment test worms than in worms exposed to other sediments. Furthermore, a mean tissue concentration of arsenic in worms exposed to the control sediment (0.680 mg/kg), which was obtained in Maine where the worms were collected, was virtually identical to that measured for the channel sediment worms (0.700 mg/kg). Both of these values are well below the range of acceptable background tissue arsenic concentrations for test organisms from East Coast sites, which is reported to be 1.5 to 3.9 mg/kg in the USEPA Guidance Manual for Bedded Sediment Bioaccumulation Tests (EPA-600-R-93-183). Overall, these test results suggest that open water placement of Bay sediment is acceptable with regard to bioaccumulation concerns.

4.5 Bulk Sediment Analyses at Associated Berthing Areas

An associated feature of the main channel deepening project is the deepening of berthing areas used for docking ships at the various industrial facilities and port terminals along the Delaware River. These berths are currently maintained at a depth that accommodates ships loaded with cargo for transiting the 40-foot channel. With deepening to 45 feet, ships would be more fully loaded to take advantage of the increased channel depth. Berthing areas would also require deepening to allow the ships to dock and load or unload cargo.

To examine sediment quality within these berthing areas a series of 16 sediment cores were collected at seven different industrial facilities and port terminals. These facilities were Beckett Street Terminal, Packer Avenue Terminal, Conrail, Sun Oil Refinery - Fort Mifflin, Sun Oil Refinery - Hog Island, Tosco Refinery, and Sun Oil Refinery - Marcus Hook (Figure 4-1). Vibrocoring equipment was used to collect the sediment cores, similar to the technique used in the main channel. Cores were divided into 35 separate samples based on observed sediment stratification, and all samples were tested for the chemical parameter list provided as Table 4-1.

Tables 4-28 through 4-32 provide a data summary for the contaminants that were detected in the various berthing locations. The Sun Oil refineries are abbreviated on these tables to identify the location of the facility (ie. Fort Mifflin - FM, Hog Island - HI, and Marcus Hook - MH). These tables provide the mean concentration of the contaminants detected at each facility, the number of actual detections, and the detection range. All 35 samples from all seven facilities were also combined to provide an overall mean concentration and detection range. This data presentation is comparable to the bulk summary data provided for the main channel. Refer to the previous


LEGEND
A Beckett Street Terminal
B Packer Ave Terminal
C Conrail
D Sun Oil - Ft. Mifflin
E Sun Oil - Hog Island
F TOSCO
G Sun Oil - Marcus Hook
Main Channel
State Boundaries
Water Features
0 2 4 6 8
MILES
1" = 4.5 Miles
PENNSYLVANIA
Philadelphia
Schuylkill River
Camden
Ben Franklin Bridge
Walt Whitman Bridge
Commadore Barry Bridge
Marcus Hook
Marcus Hook Anchorage
NEW JERSEY
Delaware Memorial Bridge
Salem River
DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT
Berth Facilities Sediment Sampling Locations
U.S. Army Corps of Engineers, Philadelphia District
Figure 4-1

Table 4-28. Heavy Metal Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Tosco	Beckett	Conrail	Packer	Sun FM
Number of Samples	4	4	5	8	6
Antimony					
Mean Concentration	1.24	0.55	2.50	1.44	1.07
# of Detections	4	4	4	6	2
Detection Range	0.57-1.6	0.38-0.98	0.59-5.3	0.73-3.0	2.0-2.4
Arsenic					
Mean Concentration	10.9	1.64	9.43	6.69	9.07
# of Detections	4	4	5	8	6
Detection Range	0.54-14.8	0.59-4.10	0.97-19.5	0.82-14.2	3.2-25.2
Beryllium					
Mean Concentration	0.10	0.29	0.40	0.30	0.07
# of Detections	1	3	3	5	2
Detection Range	0.31	0.15-0.73	0.16-0.78	0.14-0.69	0.05-0.25
Cadmium					
Mean Concentration	1.19	0.09	3.21	1.68	1.00
# of Detections	4	3	5	7	6
Detection Range	0.05-2.0	0.04-0.15	0.08-8.0	0.05-5.2	0.06-3.2
Chromium					
Mean Concentration	55.98	16.18	73.56	48.25	54.82
# of Detections	4	4	5	8	6
Detection Range	26.2-71.0	3.6-32.8	7.5-197	6.0-128	16.0-169
Copper					
Mean Concentration	46.28	5.43	70.28	41.61	28.20
# of Detections	4	4	5	8	6
Detection Range	11.8-65.7	3.4-6.8	2.3-165	1.9-104	4.2-97.0
Lead					
Mean Concentration	57.1	4.35	88.02	49.70	39.12
# of Detections	4	4	5	8	6
Detection Range	6.8-79.8	1.3-7.3	2.8-205	2.9-154	4.4-140

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-28. Heavy Metal Data Summary of Bulk Sediment Sample Analyses Conducted Wit Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Sun HI	Sun MH	ALL
Number of Samples	4	4	35
Antimony			
Mean Concentration	1.18	0.61	1.21
# of Detections	3	3	26
Detection Range	0.7-1.9	0.52-0.96	0.38-5.3
Arsenic			
Mean Concentration	8.70	3.78	7.29
# of Detections	4	4	35
Detection Range	1.10-14.9	1.4-6.4	0.54-25.2
Beryllium			
Mean Concentration	0.04	0.02	0.18
# of Detections	1	ND	15
Detection Range	0.05	-	0.05-0.78
Cadmium			
Mean Concentration	1.51	0.17	1.35
# of Detections	3	3	31
Detection Range	0.11-3.0	0.09-0.39	0.04-8.0
Chromium			
Mean Concentration	59.35	22.25	48.51
# of Detections	4	4	35
Detection Range	5.0-114	9.1-37.8	3.6-197
Copper			
Mean Concentration	40.05	15.73	36.67
# of Detections	4	4	35
Detection Range	1.2-78.8	8.0-24.7	1.2-165
Lead			
Mean Concentration	53.60	10.20	44.95
# of Detections	4	4	35
Detection Range	1.8-110	1.6-22.8	1.3-205

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-28. Heavy Metal Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Tosco	Beckett	Conrail	Packer	Sun FM
Number of Samples	4	4	5	8	6
Mercury					
Mean Concentration	0.32	0.12	0.42	0.27	0.29
# of Detections	3	ND	3	3	1
Detection Range	0.33-0.46	-	0.39-0.85	0.39-0.55	0.97
Nickel					
Mean Concentration	29.65	4.86	26.26	20.14	18.98
# of Detections	4	4	5	8	6
Detection Range	18.9-37.2	0.12-11.9	4.7-47.2	4.7-32.7	10.7-34.9
Selenium					
Mean Concentration	1.21	0.31	1.65	0.81	0.72
# of Detections	3	1	5	6	4
Detection Range	1.2-2.0	0.51	0.31-2.5	0.45-1.3	0.32-2.2
Silver					
Mean Concentration	1.31	0.07	2.12	1.12	1.03
# of Detections	4	2	4	6	5
Detection Range	0.15-2.30	0.06-0.10	0.11-4.4	0.12-3.0	0.19-3.5
Thallium					
Mean Concentration	2.05	0.47	1.58	1.25	1.26
# of Detections	4	1	3	6	6
Detection Range	0.79-2.7	0.80	1.6-3.1	0.89-2.2	0.62-2.2
Zinc					
Mean Concentration	222.0	18.70	356.5	189.3	123.8
# of Detections	4	4	5	8	6
Detection Range	42.1-319	2.0-44.5	16.7-817	18.1-467	30.3-337

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-28. Heavy Metal Data Summary of Bulk Sediment Sample Analyses Conducted Wit Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Sun HI	Sun MH	ALL
Number of Samples	4	4	35
Mercury			
Mean Concentration	0.36	0.13	0.28
# of Detections	2	ND	12
Detection Range	0.52-0.64	-	0.33-0.97
Nickel			
Mean Concentration	20.98	14.43	19.60
# of Detections	4	4	35
Detection Range	3.9-34.6	7.7-21.8	0.12-47.2
Selenium			
Mean Concentration	0.73	0.24	0.78
# of Detections	3	ND	22
Detection Range	0.37-1.3	-	0.31-2.5
Silver			
Mean Concentration	1.26	0.13	1.05
# of Detections	3	2	26
Detection Range	0.16-2.8	0.09-0.30	0.06-4.4
Thallium			
Mean Concentration	1.48	0.88	1.28
# of Detections	4	4	28
Detection Range	0.60-2.6	0.59-1.3	0.59-3.1
Zinc			
Mean Concentration	192.9	46.68	170.3
# of Detections	4	4	35
Detection Range	9.6-380	22.2-98.6	2.0-817

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-28. Heavy Metal Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Tosco	Beckett	Conrail	Packer	Sun FM
Number of Samples	4	4	5	8	6
Barium					
Mean Concentration	135.1	18.78	182.5	101.0	78.28
# of Detections	4	4	5	8	6
Detection Range	98.2-159	6.5-47.3	15.6-258	11.2-180	40.8-160
Vanadium					
Mean Concentration	47.68	24.48	70.38	31.88	43.05
# of Detections	4	4	5	8	6
Detection Range	29.2-58.3	8.2-63.5	6.3-158	5.3-66.7	16.2-123

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-28. Heavy Metal Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Concluded.

Parameter	Sun HI	Sun MH	ALL
Number of Samples	4	4	35
Barium			
Mean Concentration	101.6	69.90	94.53
# of Detections	4	4	35
Detection Range	14.0-184	43.1-104	6.5-258
Vanadium			
Mean Concentration	49.45	32.05	40.27
# of Detections	4	4	35
Detection Range	5.9-87.0	24.6-44.8	5.3-158

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.

Table 4-29. PAH Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Tosco	Beckett	Conrail	Packer	Sun FM
Number of Samples	4	4	5	8	6
Acenapthene					
Mean Concentration	0.65	0.33	1.19	1.03	0.47
# of Detections	ND	1 (1J)	ND	2 (1J)	1 (J)
Detection Range	-	0.14	-	1.6-1.7	0.10
Naphthalene					
Mean Concentration	0.65	0.32	0.93	0.75	0.47
# of Detections	ND	1 (1J)	2 (2J)	ND	1 (1J)
Detection Range	-	0.04	0.07-0.11	-	0.09
Acenaphthylene					
Mean Concentration	0.65	0.31	1.19	0.75	0.53
# of Detections	ND	1 (1J)	ND	ND	ND
Detection Range	-	0.07	-	-	-
Anthracene					
Mean Concentration	0.65	0.35	0.95	0.58	0.38
# of Detections	ND	1 (1J)	2 (2J)	2 (2J)	2 (2J)
Detection Range	-	0.22	0.11-0.14	0.15-0.16	0.09-0.16
Benzo(a)pyrene					
Mean Concentration	0.18	0.36	0.33	0.31	0.29
# of Detections	3 (3J)	2 (1J)	4 (4J)	6 (5J)	5 (4J)
Detection Range	0.10-0.13	0.04-0.62	0.14-0.46	0.04-0.50	0.14-0.50
Benzo(b)fluoranthene					
Mean Concentration	0.20	0.40	0.43	0.40	0.46
# of Detections	3 (3J)	1 (1J)	3 (3J)	5 (4J)	2 (1J)
Detection Range	0.12-0.14	0.41	0.36-0.50	0.06-0.56	0.22-0.51
Benzo(k)fluoranthene					
Mean Concentration	0.19	0.41	0.19	0.32	0.44
# of Detections	3 (3J)	1	2 (2J)	5 (5J)	2 (2J)
Detection Range	0.10-0.16	0.45	0.34-0.57	0.04-0.36	0.20-0.36

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-29. PAH Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Sun HI	Sun MH	ALL
Number of Samples	4	4	35
Acenapthene			
Mean Concentration	0.56	0.43	0.70
# of Detections	ND	ND	4 (3J)
Detection Range	-	-	0.10-1.70
Naphthalene			
Mean Concentration	0.42	0.43	0.59
# of Detections	1 (1J)	ND	5 (5J)
Detection Range	0.09	-	0.04-0.11
Acenaphthylene			
Mean Concentration	0.56	0.43	0.64
# of Detections	ND	ND	1 (1J)
Detection Range	-	-	0.07
Anthracene			
Mean Concentration	0.42	0.43	0.52
# of Detections	1 (1J)	ND	8 (8J)
Detection Range	0.07	-	0.07-0.22
Benzo(a)pyrene			
Mean Concentration	0.16	0.43	0.30
# of Detections	4 (4J)	ND	24 (21J)
Detection Range	0.05-0.30	-	0.04-0.62
Benzo(b)fluoranthene			
Mean Concentration	0.30	0.43	0.38
# of Detections	2 (2J)	ND	16 (14J)
Detection Range	0.10-0.21	-	0.06-0.56
Benzo(k)fluoranthene			
Mean Concentration	0.31	0.43	0.45
# of Detections	2 (2J)	ND	15 (14J)
Detection Range	0.12-0.20	-	0.04-0.57

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-29. PAH Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Tosco	Beckett	Conrail	Packer	Sun FM
Number of Samples	4	4	5	8	6
Chrysene					
Mean Concentration	0.21	0.45	0.47	0.39	0.51
# of Detections	3 (3J)	1	3 (3J)	5 (4J)	2 (1J)
Detection Range	0.12-0.18	0.62	0.42-0.54	0.04-0.61	0.42-0.61
Phenanthrene					
Mean Concentration	0.18	0.60	1.05	0.37	0.47
# of Detections	3 (3J)	1	2 (2J)	4 (4J)	2 (1J)
Detection Range	0.08-0.15	1.20	0.35-0.43	0.09-0.48	0.18-0.58
Fluorene					
Mean Concentration	0.65	0.33	1.19	0.75	0.53
# of Detections	ND	1 (1J)	ND	ND	ND
Detection Range	-	0.15	-	-	-
Fluoranthene					
Mean Concentration	0.25	0.70	0.64	0.53	0.54
# of Detections	3 (3J)	1	3 (1J)	5 (4J)	2 (1J)
Detection Range	0.17-0.23	1.60	0.70-0.88	0.08-0.92	0.24-0.92
Benzo(a)anthracene					
Mean Concentration	0.17	0.46	0.40	0.39	0.47
# of Detections	3 (3J)	1	3 (3J)	4 (3J)	2 (1J)
Detection Range	0.08-0.12	0.65	0.32-0.40	0.21-0.50	0.25-0.50
Benzo(ghi)perylene					
Mean Concentration	0.65	0.35	0.97	0.48	0.48
# of Detections	ND	1 (1J)	2 (2J)	2 (2J)	1 (1J)
Detection Range	-	0.20	0.14-0.20	0.13-0.15	0.13

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-29. PAH Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Sun HI	Sun MH	ALL
Number of Samples	4	4	35
Chrysene			
Mean Concentration	0.32	0.43	0.41
# of Detections	2 (2J)	ND	16 (13J)
Detection Range	0.11-0.27	-	0.04-0.62
Phenanthrene			
Mean Concentration	0.30	0.43	0.49
# of Detections	2 (2J)	ND	14 (12J)
Detection Range	0.09-0.21	-	0.08-1.20
Fluorene			
Mean Concentration	0.56	0.43	0.64
# of Detections	ND	ND	1 (1J)
Detection Range	-	-	0.15
Fluoranthene			
Mean Concentration	0.35	0.31	0.49
# of Detections	2 (2J)	1 (1J)	17 (12J)
Detection Range	0.14-0.36	0.08	0.08-1.60
Benzo(a)anthracene			
Mean Concentration	0.30	0.43	0.37
# of Detections	2 (2J)	ND	15 (12J)
Detection Range	0.09-0.21	-	0.08-0.65
Benzo(ghi)perylene			
Mean Concentration	0.56	0.43	0.55
# of Detections	ND	ND	6 (6J)
Detection Range	-	-	0.13-0.20

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-29. PAH Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Tosco	Beckett	Conrail	Packer	Sun FM
Number of Samples	4	4	5	8	6
Ideno(123-cd)pyrene					
Mean Concentration	0.65	0.35	0.95	0.43	0.48
# of Detections	ND	1 (1J)	2 (2J)	3 (3J)	1 (1J)
Detection Range	-	0.23	0.10-0.16	0.12-0.14	0.14
Pyrene					
Mean Concentration	0.26	0.54	0.63	0.88	0.52
# of Detections	3 (3J)	2 (1J)	3 (2J)	6 (4J)	2 (1J)
Detection Range	0.18-0.26	0.04-1.30	0.72-0.82	0.07-2.30	0.30-0.77

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-29. PAH Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Concluded.

Parameter	Sun HI	Sun MH	ALL
Number of Samples	4	4	35
Ideno(123-cd)pyrene			
Mean Concentration	0.56	0.43	0.54
# of Detections	ND	ND	7 (7J)
Detection Range	-	-	0.10-0.23
Pyrene			
Mean Concentration	0.36	0.31	0.55
# of Detections	2 (2J)	1 (1J)	19 (14J)
Detection Range	0.16-0.38	0.08	0.04-2.30

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-30. Pesticide and PCB Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Tosco	Beckett	Conrail	Packer	Sun FM
Number of Samples	4	4	5	8	6
4,4'-DDE					
Mean Concentration	0.05	0.02	0.05	0.06	0.08
# of Detections	2 (2J)	ND	3 (2J)	3 (2J)	2
Detection Range	0.04-0.05	-	0.07-0.08	0.07-0.15	0.12-0.26
4,4'-DDD					
Mean Concentration	0.06	0.02	0.06	0.05	0.04
# of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
4,4'-DDT					
Mean Concentration	0.06	0.02	0.06	0.05	0.04
# of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
Endrin					
Mean Concentration	0.06	0.02	0.06	0.05	0.03
# of Detections	ND	ND	ND	ND	1 (1J)
Detection Range	-	-	-	-	0.03
PCB Aroclor 1254					
Mean Concentration	0.12	0.12	0.24	0.24	0.20
# of Detections	3 (3J)	ND	2 (2J)	1 (1J)	2 (1J)
Detection Range	0.10-0.15	-	0.14-0.31	0.19	0.16-0.55

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-30. Pesticide and PCB Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Concluded.

Parameter	Sun HI	Sun MH	ALL
Number of Samples	4	4	35
4,4'-DDE			
Mean Concentration	0.05	0.03	0.05
# of Detections	2	ND	12 (6J)
Detection Range	0.08	-	0.04-0.26
4,4'-DDD			
Mean Concentration	0.04	0.03	0.04
# of Detections	ND	2 (1J)	2 (1J)
Detection Range	-	0.02-0.05	0.02-0.05
4,4'-DDT			
Mean Concentration	0.04	0.17	0.06
# of Detections	ND	1	1
Detection Range	-	0.57	0.57
Endrin			
Mean Concentration	0.04	0.03	0.04
# of Detections	ND	ND	1 (1J)
Detection Range	-	-	0.03
PCB Aroclor 1254			
Mean Concentration	0.16	0.14	0.19
# of Detections	2 (2J)	ND	10 (9J)
Detection Range	0.21-0.23	-	0.10-0.55

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-31. Semi-Volatile Organic Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Tosco	Beckett	Conrail	Packer	Sun FM
Number of Samples	4	4	5	8	6
Di-n-butyl phthalate					
Mean Concentration	0.20	0.40	0.96	0.75	0.30
# of Detections	3 (3J)	ND	2 (2J)	ND	3 (3J)
Detection Range	0.11-0.16	-	0.09-0.24	-	0.06-0.10
Bis(2-ethylhexyl) phthalate					
Mean Concentration	0.83	0.24	2.63	1.18	0.74
# of Detections	4 (1J)	2 (2J)	5 (2J)	5 (2J)	4 (2J)
Detection Range	0.48-1.30	0.05-0.09	0.06-4.70	0.11-3.20	0.06-1.70
Di-n-octyl phthalate					
Mean Concentration	0.65	0.40	1.05	0.75	0.53
# of Detections	ND	ND	1 (1J)	ND	ND
Detection Range	-	-	0.15	-	-
1,4-Dichlorobenzene					
Mean Concentration	0.65	0.40	1.19	1.02	0.53
# of Detections	ND	ND	ND	2	ND
Detection Range	-	-	-	1.40-1.80	-
1,2,4-Trichlorobenzene					
Mean Concentration	0.65	0.40	1.19	1.00	0.53
# of Detections	ND	ND	ND	2	ND
Detection Range	-	-	-	1.40-1.60	-
4-Chloroaniline					
Mean Concentration	0.65	0.40	1.19	0.75	0.53
# of Detections	ND	ND	ND	ND	ND
Detection Range	-	-	-	-	-
2,4-Dinitrotoluene					
Mean Concentration	0.65	0.40	1.19	1.08	0.53
# of Detections	ND	ND	ND	2	ND
Detection Range	-	-	-	1.80-1.90	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-31. Semi-Volatile Organic Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Sun HI	Sun MH	ALL
Number of Samples	4	4	35
Di-n-butyl phthalate			
Mean Concentration	0.28	0.06	0.47
# of Detections	2 (2J)	4 (4J)	14 (14J)
Detection Range	0.08-0.13	0.05-0.11	0.05-0.24
Bis(2-ethylhexyl) phthalate			
Mean Concentration	1.00	0.37	1.05
# of Detections	3 (1J)	4 (2J)	27 (12J)
Detection Range	0.05-2.60	0.20-0.60	0.05-4.70
Di-n-octyl phthalate			
Mean Concentration	0.56	0.43	0.64
# of Detections	ND	ND	1 (1J)
Detection Range	-	-	0.15
1,4-Dichlorobenzene			
Mean Concentration	0.56	0.43	0.73
# of Detections	ND	ND	2
Detection Range	-	-	1.40-1.80
1,2,4-Trichlorobenzene			
Mean Concentration	0.56	0.43	0.72
# of Detections	ND	ND	2
Detection Range	-	-	1.40-1.60
4-Chloroaniline			
Mean Concentration	0.42	0.43	0.65
# of Detections	1 (J)	ND	1 (1J)
Detection Range	0.10	-	0.10
2,4-Dinitrotoluene			
Mean Concentration	0.56	0.43	0.73
# of Detections	ND	ND	2
Detection Range	-	-	1.80-1.90

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-31. Semi-Volatile Organic Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Continued.

Parameter	Tosco	Beckett	Conrail	Packer	Sun FM
Number of Samples	4	4	5	8	6
Phenol					
Mean Concentration	0.65	0.40	1.19	1.31	0.53
# of Detections	ND	ND	ND	3 (1J)	ND
Detection Range	-	-	-	0.10-3.10	-
Pentachlorophenol					
Mean Concentration	3.23	2.03	5.96	4.06	2.68
# of Detections	ND	ND	ND	2	ND
Detection Range	-	-	-	3.50-3.90	-
2-Chlorophenol					
Mean Concentration	0.65	0.40	1.19	1.26	0.53
# of Detections	ND	ND	ND	2	ND
Detection Range	-	-	-	2.20-2.90	-
4-Methylphenol					
Mean Concentration	0.33	0.40	0.63	0.63	0.44
# of Detections	2 (2J)	ND	3 (3J)	1 (1J)	1 (1J)
Detection Range	0.08-0.13	-	0.32-1.40	0.16	0.10
4-Chloro-3-methylphenol					
Mean Concentration	0.65	0.40	1.19	1.35	0.53
# of Detections	ND	ND	ND	2	ND
Detection Range	-	-	-	2.90	-
4-Nitrophenol					
Mean Concentration	3.23	2.03	5.96	3.94	2.68
# of Detections	ND	ND	ND	2	ND
Detection Range	-	-	-	3.10-3.30	-
N-Nitroso-di-n-propylamine					
Mean Concentration	0.65	0.40	1.19	0.98	0.53
# of Detections	ND	ND	ND	2	ND
Detection Range	-	-	-	1.40-1.50	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-31. Semi-Volatile Organic Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Concluded.

Parameter	Sun HI	Sun MH	ALL
Number of Samples	4	4	35
Phenol			
Mean Concentration	0.56	0.43	0.79
# of Detections	ND	ND	3 (1J)
Detection Range	-	-	0.10-3.10
Pentachlorophenol			
Mean Concentration	2.83	2.13	3.41
# of Detections	ND	ND	2
Detection Range	-	-	3.50-3.90
2-Chlorophenol			
Mean Concentration	0.56	0.43	0.78
# of Detections	ND	ND	2
Detection Range	-	-	2.20-2.90
4-Methylphenol			
Mean Concentration	0.44	0.43	0.49
# of Detections	1 (1J)	ND	8 (8J)
Detection Range	0.15	-	0.08-1.40
4-Chloro-3-methylphenol			
Mean Concentration	0.56	0.43	0.80
# of Detections	ND	ND	2
Detection Range	-	-	2.90
4-Nitrophenol			
Mean Concentration	2.83	2.13	3.38
# of Detections	ND	ND	2
Detection Range	-	-	3.10-3.30
N-Nitroso-di-n-propylamine			
Mean Concentration	0.56	0.43	0.70
# of Detections	ND	ND	2
Detection Range	-	-	1.40-1.50

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-32. Volatile Organic Data Summary of Bulk Sediment Sample Analyses Conducted Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel.

Parameter	Tosco	Beckett	Conrail	Packer	Sun FM
Number of Samples	4	4	5	8	6
Methylene Chloride					
Mean Concentration	0.01	0.004	0.01	0.01	0.01
# of Detections	4 (4J)	4 (4J)	3 (3J)	6 (6J)	6 (6J)
Detection Range	0.01	0.003-0.005	0.005-0.01	0.003-0.01	0.003-0.01
Toluene					
Mean Concentration	0.02	0.01	1.35	0.01	0.02
# of Detections	1 (1J)	ND	1	3 (3J)	ND
Detection Range	0.003	-	6.70	0.003-0.01	-
Acetone					
Mean Concentration	0.02	0.01	0.02	0.02	0.02
# of Detections	ND	ND	ND	1	ND
Detection Range	-	-	-	0.04	-
Ethylbenzene					
Mean Concentration	0.02	0.01	0.01	0.02	0.02
# of Detections	ND	ND	1 (1J)	ND	ND
Detection Range	-	-	0.003	-	-
Xylenes					
Mean Concentration	0.02	0.01	0.02	0.02	0.02
# of Detections	ND	ND	1 (1J)	ND	ND
Detection Range	-	-	0.01	-	-

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

Table 4-32. Volatile Organic Data Summary of Bulk Sediment Sample Analyses Conducte Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel. Concluded.

Parameter	Sun HI	Sun MH	ALL
Number of Samples	4	4	35
Methylene Chloride			
Mean Concentration	0.01	0.01	0.01
# of Detections	4 (4J)	4 (3J)	31 (30J)
Detection Range	0.004-0.01	0.01-0.02	0.003-0.02
Toluene			
Mean Concentration	0.01	0.01	0.20
# of Detections	1 (1J)	ND	6 (5J)
Detection Range	0.002	-	0.002-6.70
Acetone			
Mean Concentration	0.02	0.01	0.02
# of Detections	ND	ND	1
Detection Range	-	-	0.04
Ethylbenzene			
Mean Concentration	0.02	0.01	0.02
# of Detections	ND	ND	1 (1J)
Detection Range	-	-	0.003
Xylenes			
Mean Concentration	0.02	0.01	0.02
# of Detections	ND	ND	1 (1J)
Detection Range	-	-	0.01

All concentrations presented in parts per million (mg/kg), dry weight.
ND - Not Detected.
(#J) - Number of detections below quantification limits; concentrations are estimated values.

portion of this section for a discussion of how these tables were derived.

Similar to the data collected from the main channel, the most frequently encountered contaminants were heavy metals and polynuclear aromatic hydrocarbons (PAHs). Concentrations of these contaminants were generally in the range of those found in the main channel. PCB aroclor 1254 and the pesticide 4,4'-DDE were found at all of the facilities except the Beckett Street Terminal and the Sun Oil refinery at Marcus Hook. Concentrations ranged between 0.16 and 0.55 ppm for PCB aroclor 1254, and between 0.12 and 0.26 ppm for 4,4'-DDE. The pesticides 4,4'-DDD and 4,4'-DDT were found at the Sun Oil refinery at Marcus Hook at concentrations ranging between 0.02 and 0.57 ppm. Endrin was the only other pesticide detected. Endrin was detected in one sample collected from the Sun Oil refinery at Fort Mifflin, at a concentration of 0.03 ppm.

Of the semi-volatile organic contaminants, di-n-butyl phthalate and bis(2-ethylhexyl) phthalate were most frequently found, which is also similar to the main channel. These contaminants were found at concentrations ranging between 0.05 and 0.24 ppm, and 0.05 and 4.70 ppm, respectively. The only other semi-volatile organic contaminant frequently detected was 4-methylphenol. This compound was detected at all of the facilities except the Beckett Street Terminal and the Sun Oil refinery at Marcus Hook. Concentrations ranged between 0.08 and 1.40 ppm. Of the volatile organic contaminants, methylene chloride was most frequently detected. Methylene chloride was detected in 31 of the 35 samples at concentrations ranging between 0.003 and 0.02 ppm. As previously stated methylene chloride is commonly used in laboratory analyses, and it is likely that detection of this compound was a byproduct of laboratory testing. Toluene was the only other volatile organic contaminant frequently detected. Toluene was detected in six of the 35 samples at concentrations ranging between 0.002 and 6.70 ppm.

Table 4-33 lists the mean sediment contaminant concentrations within the various port facilities that exceed NJDEP Residential Soil Cleanup Criteria. The contaminants that exceeded these standards at some facilities include the heavy metals cadmium and thallium, the PAH ideno(123-cd)pyrene, and the semi-volatile organic contaminants 2,4-dinitrotoluene and N-nitrosodi-n-propylamine. Mean cadmium concentrations exceeded the NJDEP Residential standard of 1 ppm at the Tosco, Sun Oil - Fort Mifflin and Sun Oil - Hog Island refineries, and the Conrail and Packer Avenue terminals. Mean cadmium concentrations at these facilities ranged between 1.00 and 3.21 ppm. Cadmium concentrations detected in individual sediment samples were similar to those detected in samples from the main channel. Concentrations in samples collected from the port facilities ranged between 0.04 and 8.0 ppm; concentrations in samples collected from the main channel ranged between 0.09 and 5.24 ppm. As discussed with the main channel data, the NJDEP

Table 4-33. Worst Case Mean Concentrations of Sediment Contaminants Within Selected Berthing Areas Along the Delaware River, Philadelphia to the Sea, Federal Navigation Channel that Exceed NJDEP Residential Direct Contact Soil Cleanup Criteria.

Parameter	NJDEP Res. Standard	Mean Facility Sediment Concentrations				
		Tosco	Conrail	Packer	Sun FM	Sun HI
Cadmium	1	1.19	3.21	1.68	1.00	1.51
Thallium	2	2.05				
Ideno(123-cd) pyrene	0.9		0.95			
2,4-Dinitro toluene	1		1.19	1.08		
N-nitrosodi-n-propylamine	0.66		1.19	0.98		

All concentrations in parts per million (mg/kg), dry weight.

NJDEP residential direct contact soil cleanup criteria from: NJDEP. April 1994. Revisions to the soil cleanup criteria. Site Remediation News 6(1): 17-19.

Non-Residential sediment standard for cadmium is 100 ppm. Since the material dredged from the port facilities would be placed in an upland, dredged material disposal site that would not be used for residential development, and since the mean concentration of cadmium is so far below the NJDEP Non-Residential sediment standard of 100 ppm, it can be concluded that the concentration of cadmium in these sediments would not pose any significant human health concerns.

The mean thallium concentration derived from samples collected from berths at the Tosco refinery was 2.05 ppm. This concentration is slightly above both the NJDEP Residential and Non-Residential standards of 2 ppm. Three of the four samples collected at this location had thallium concentrations above 2 ppm (ie. 2.2 - 2.7 ppm). The mean concentrations of thallium at the other six facilities were all below the standard of 2 ppm. The mean concentration of thallium derived from all 35 samples was 1.28 ppm. This slight exceedence at the Tosco refinery berthing area is not expected to result in any significant impacts due to dredging and upland dredged material disposal operations.

The mean concentration of the PAH ideno(123-cd) pyrene at the Conrail facility was 0.95 ppm, which exceeded the NJDEP Residential standard of 0.9 ppm. Of the five sediment samples analyzed from the Conrail berthing area, two samples had ideno(123-cd) pyrene at concentrations of 0.10 and 0.16 ppm. These concentrations are below the Residential standard. One sample had a quantification limit of 3.60 ppm, which was included in the calculation of the mean. This high quantification limit elevated the mean concentration, and is the reason why the Residential standard was exceeded. It is reasonable to assume that the true mean concentration of ideno(123-cd) pyrene at the Conrail facility is below 0.9 ppm. The Non-Residential standard for this contaminant is 4 ppm. This standard was met in all cases.

The semi-volatile organic compounds 2,4-dinitrotoluene and N-nitrosodi-n- propylamine were the only other contaminants that did not meet NJDEP Residential standards at all facilities. The Residential standards for these compounds are 1 and 0.66 ppm, respectively. These standards for both compounds were exceeded at the Conrail and Packer Avenue facilities. Mean concentrations of 2,4-dinitrotoluene at the Conrail and Packer Avenue berthing areas were 1.19 and 1.08 ppm, respectively. Mean concentrations of N-nitrosodi-n-propylamine at the Conrail and Packer Avenue berthing areas were 1.19 and 0.98 ppm, respectively. These compounds were not detected at the Conrail facility. Similar to ideno(123-cd) pyrene, the high quantification limit of 3.60 ppm for one sample at the Conrail site is responsible for elevating the calculated mean concentrations of these compounds above the Residential standards. Again, it is reasonable to assume that the true mean concentrations of these compounds at the Conrail facility are below the Residential standards. At the Packer

Avenue Terminal, both compounds were detected in two of the eight sediment samples analyzed. 2,4-dinitrotoluene was detected at concentrations of 1.80 and 1.90 ppm. N-nitrosodi-n-propylamine was detected at concentrations of 1.40 and 1.50 ppm. Three additional samples had quantification limits above the Residential standards (ie. 1.10, 1.30 and 1.30 ppm). The Non-Residential standards for 2,4-dinitrotoluene and N-nitrosodi-n-propylamine are 4 and 0.66 ppm, respectively. Since these compounds were only detected in two of the 35 sediment samples analyzed, it is not anticipated that any significant environmental impacts would result from dredging and dredged material disposal operations involving sediment from these port facilities.

In conclusion, the bulk sediment data derived from 35 sediment samples collected within seven port facilities along the Delaware River did not significantly differ from data derived from the main navigation channel. Heavy metals and polynuclear aromatic hydrocarbons (PAHs) were the chemical parameters most frequently detected. Concentrations were similar to what is found in the navigation channel, upstream of Delaware Bay. Phthalates were the next most frequently encountered, which was also the case for the navigation channel. Concentrations were again similar. The pesticide 4,4'-DDE and PCB aroclor 1254 were detected more frequently in the berthing areas than the navigation channel. Concentrations of these parameters were low, and no significant adverse environmental impacts are anticipated as a result of dredging and upland dredged material disposal operations. The remaining compounds in the sediments were detected on a limited basis, and at low levels. Overall, these test results suggest that sediments within port facility berthing areas are sufficiently clean to conclude that dredging and upland dredged material disposal operations would not result in any significant environmental impacts.

High Resolution PCB Analyses

The PCB content of Delaware River, Philadelphia to the Sea navigation channel sediments were investigated in 1991, 1992 and 1994; however, the laboratory analyses were based on the traditional Arochlor method of determining PCB content in sediments which had detection limits averaging about 0.21 mg/kg (or 210 ppb) dry weight. Recent advances in PCB analyses have developed state-of-the-art techniques which can detect congener-specific PCBs in parts per billion and coplanar PCBs in parts per trillion. In 1994, the Delaware Estuary Program conducted PCB tests using these high resolution techniques on sediments collected at 16 shallow water stations from areas ranging from Egg Island Point, New Jersey to Neshaminy Creek, Pennsylvania (Arthur D. Little, 1994). This study indicated that PCB contaminants were widespread throughout the estuary and suggested concentrations were highest in upper industrialized portions of the river. In addition, high resolution tissue testing conducted by Greene and Miller (1994) revealed that striped bass contained

PCBs ranging from 0.499 to 2.25 ppm. In an earlier study between the Schuylkill River and Burlington Island the Delaware River Basin Commission (DRBC, 1988, as cited by Greene and Miller, 1994) reported PCB contamination in channel catfish above the FDA limit of 2.0 ppm, and concentrations ranging from 0.1 to 1.4 ppm for white perch. Health advisories on the consumption of channel catfish, all bottom feeding fish, and striped bass have been issued for the estuary. Because of concern over PCB contamination in Delaware estuary sediments and finfish, additional sampling using high resolution PCB analyses were conducted within the Delaware River, Philadelphia to the Sea, Federal navigation channel. The following discussion is taken from the report of the investigation conducted by Versar, Inc. (1997).

PCBs are a class of synthetic organic compounds used primarily in the electronic industry. The class is comprised of 209 individual compounds, more commonly referred to as congeners. Individual congeners are identified by the number and position of insertion of chlorine atoms on a biphenyl group. The biphenyl group is a framework for the PCB molecule and is comprised of two linked benzene rings. PCBs are extremely stable compounds, and degrade slowly in the environment. Microbial decomposition of PCBs occurs in natural environments, but the rate depends on the degree of chlorination and the position of the atoms on the biphenyl molecule. PCBs with four or fewer chlorine atoms decompose at a greater rate than those with more atoms. PCBs have very low solubilities in water, and in natural conditions, they typically adsorb to suspended particles or in bottom sediments. Adsorption rates among PCB congeners increase with the degree of chlorination. Most of the PCBs used in industry are termed Arochlor groups. Arochlor groups are identified by a four digit number that defines their composition. The first two digits identify the Arochlor as a mixture of PCBs and the last two digits express the percentage of chlorine content by weight. For example, Arochlor 1260 is a PCB mixture with an average chlorine content of 60 percent.

The toxicity of PCBs is directly related to the reactivity of the chlorine atoms inserted on the biphenyl group. The reactivity of the atoms is determined by their position on the two benzene rings. Chlorine atoms in the outer portions of the rings (e.g., meta and para positions) are more reactive, and thus more toxic than those in the inner part. The inner positions are closer to the bond that joins the two benzene rings, which limits their reactivity. Another factor that determines PCB toxicity is molecular geometry. Current research indicates that non-ortho substituted coplanar congeners, where both benzene rings basically lie in the same plane, are the most toxic forms of PCB. The toxicity of PCB coplanar congeners is generally regarded as comparable to that of dioxin.

For this investigation, sediment samples were collected at 15 sites ranging from 10 miles north of Cape May, New Jersey to

Penn's Landing, Philadelphia, Pennsylvania. Samples were collected the first week of October 1996. Sediment sample locations are shown on Figure 4-2. All collections were conducted in the navigation channel. At each station, four separate five foot cores were taken with a vibrocore (a hydraulically activated boring device) containing a three inch diameter plexiglass liner. The plexiglass liner allowed the core to be removed from the device intact for sectioning. Sample locations for the four cores taken at each station were randomized using the following procedures: 1) the vessel anchored at the selected sampling coordinates; 2) four random numbers between 0 and 250 feet were selected (250 feet was the maximum anchor line length the vessel could deploy after the initial setting of the anchor); and 3) the anchor line was deployed for the number of feet selected for each sample.

After retrieving the core, the plastic liners were cut longitudinally. Each core was then split into two separate samples. The top three inches of the core was separated from the remaining sub-surface portion of the core. Sediment from the top portion of the core was removed using pre-cleaned stainless steel knives and spoons and placed in a pre-cleaned stainless steel bowl. The bowl was placed on ice in a closed cooler to reduce the temperature of the sample and to prevent contamination. In a similar manner, sediment for the sub-surface portion of the core was removed using a second set of pre-cleaned stainless steel utensils and bowl. Between collections the surface and sub-surface collection bowls were stored in separate coolers. Only sediment from the inner portion of the core was sampled. Sediment sampling for the lower sub-surface core was conducted uniformly along its entire length so that all layers would be equally represented in the sample.

Sediment sub-sampling procedures were repeated for all four cores taken at each station. After each coring, the surface and sub-surface sediments were added to their respective bowls. After all four cores were collected, the surface and sub-surface bowls were thoroughly homogenized and transferred into factory sealed 500 ml I-Chem Jars for a total of 30 samples. Sediments remaining in the bowls were transferred to whirl-pacts for grain size and total organic carbon analyses. All samples for chemical testing and TOC were stored in the dark at four degrees Celsius until analysis.

Laboratory analyses of the 30 sediment samples were conducted by Midwest Research Institute (MRI) using High Resolution Gas Chromatography (HRGC) and High Resolution Mass Spectrometry (HRMS). The HRGC/HRMS analytical method used by MRI was developed as a modification of EPA SW-846 Method 8290. The analytical approach to the 30 sediment samples included analyses for 75 PCB congeners at a detection limit of 2 to 5 ng/g (parts per billion). Additionally, all samples were analyzed for five of the more toxic, non-ortho substituted coplanar PCB congeners (IUPAC numbers 77, 81, 126, 127, and 169) using HRGC/HRMS to a

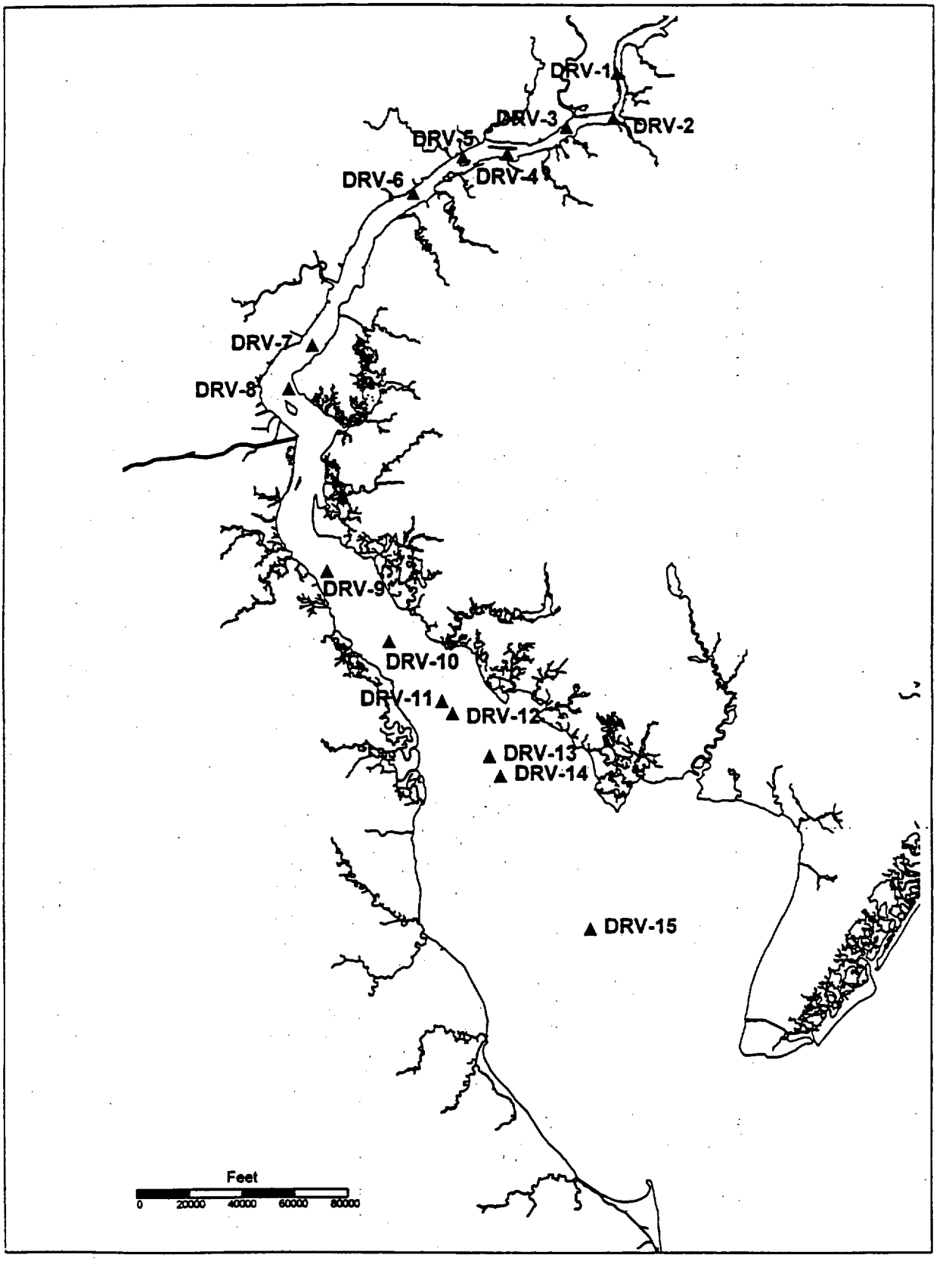

Figure 4-2. Locations of primary sampling stations for the PCB sediment cores collected in the Delaware River, Philadelphia to the Sea Federal Navigation Project in October 1996

detection limit of 1 pg/g (parts per trillion). All sediment PCB congener concentrations were reported on a dry weight basis.

Total PCBs were calculated by summing the concentrations of all congeners found in each sample. Non-detects were treated as zeros for all analyses. To evaluate potential sediment toxicity, total PCB concentrations were compared to Long et al's. (1995) Effects Range-Low (ERL) and Effects Range-Median (ERM) marine and estuarine sediment guideline values (22.7 and 180 ng/g, respectively). The ERL concentration is the threshold at which biological effects of PCBs begin to occur while the ERM concentration is the point at which biological effects are likely to occur. Sediment concentrations were also compared to draft guidelines for the protection of human health (33.8 ng/g) recently developed by Mr. Rick Greene of the Delaware Department of Natural Resources and Environmental Control. The human health guideline is a biomagnification-based sediment quality criteria where no increase in cancer at a rate of 1 in 100,000 would be expected for humans consuming fish.

Out of a total 75 PCB congeners assayed, 32 were detected in sediments collected from the Delaware River, Philadelphia to the Sea navigation channel. The tetra homolog IUPAC 77 was detected in all but one of the sediment samples. Among the samples which had detectable concentrations, the tetra homolog, IUPAC 44, had the greatest concentration (14.4 ng/g). However, this congener was only observed in one sample. Other congeners which were detected in a single sample included IUPAC numbers 42, 47, 66, 70, 80, 118, 84/101, 168, 170/190, 189, 194, and 205. The second most commonly observed congeners were IUPAC numbers 81 and 169, which were found in 13 of the 30 collections. IUPAC number 169 (hexa homolog) was the third most commonly detected PCB congener. Among the four most frequently detected congeners listed above, all were tested in the parts per trillion range. For all other PCB congeners which were measured in the parts per billion range, no one congener was consistently found in the samples as the frequency of detections ranged from only 1 to 7.

The concentrations of all PCB congeners were summed to determine the total PCB distribution among the surface and sub-surface collections at the 15 sites included in the study (Figure 4-3). Relative to sediment guidelines established by Long et al. (1995) for the protection of aquatic biota (22.7 ng/g), and sediment limits suggested by the Delaware DNREC for the protection of human health (33.8 ng/g), most of the channel sediments had PCB concentrations below levels of concern. Surface and sub-surface PCB concentrations at Stations DRV-11 through DRV-15 in the lower bay ranged from below detection limits to only 0.01 ng/g. Total PCB concentrations above aquatic and human health guidelines were observed at Station DRV-6 (Marcus Hook Range) in the surface sediments, and at Stations DRV-6 and DRV-4 (Tinicum Range) in the sub-surface sediments. Surface concentrations at Marcus Hook were approximately two times greater than the ERL, and 1.2 times greater than DNREC's guidance value for the protection of human

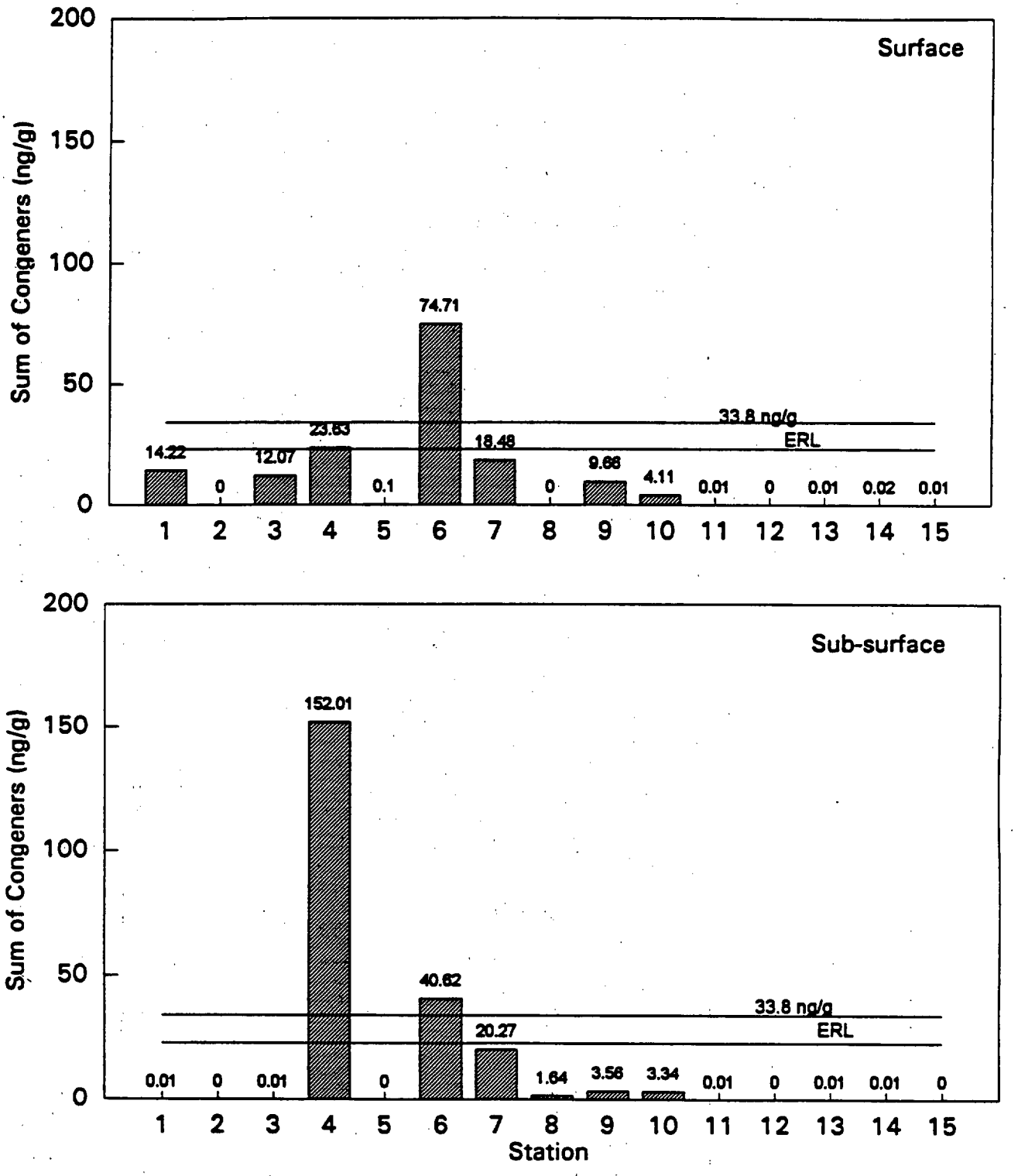

Figure 4-3. Concentrations of total PCBs (ng/g) in surface (0-3") and sub-surface (3" to 5') sediments collected in the Delaware River, Philadelphia to the Sea Federal navigational channel in October 1996

health. Among the surface sediments, the greatest concentration was observed at Station DRV-6 (Marcus Hook Range) where the PCB congeners totaled 74.7 ng/g dry weight. Surface sediments at Stations DRV-5 (Eddystone Range) through DRV-1 (Reach M near Philadelphia) were either equal to or well below the ERL value indicating generally low sediment toxicity conditions. Sub-surface concentrations at the Tinicum Range station (DRV-4) were over six times greater than the ERL value as the sum of the PCB congeners totaled 152 ng/g. All concentrations observed in the navigation channel sediments were below Long et al.'s (1995) Effects Range-Median (ERM) sediment guidance value of 180 parts per billion.

4.6 Trace level analysis of the non-ortho substituted coplanar PCB congeners (in the parts per trillion range) followed a similar pattern of low concentrations in the lower estuary (Stations DRV-11 through 15), higher values in the mid-estuary (New Castle Range through Tinicum Range), and intermediate levels from the Mifflin Range (DRV-3) to Reach M near downtown Philadelphia. A regression analysis of total PCBs (excluding the five coplanar forms) versus total coplanar concentrations was significant (R^2=0.80) indicating that the coplanar PCBs were correlated well with total PCBs as would be expected. The PCB congener IUPAC 77 (3,3',4,4'-Tetrachlorobiphenyl) was the most common coplanar congener found comprising over 99 percent of the five coplanar PCBs tested in the study. Average coplanar PCB concentrations among all surface sediments (0.133 ng/g) were generally lower than sub-surface concentrations which averaged about 0.277 ng/g. The greatest concentration of coplanar PCBs in surface sediments was observed in the Marcus Hook Range (Station DRV-6) where the total concentration among the four composited samples was 0.713 ng/g. In contrast, the sub-surface sediments from the New Castle Range (Station DRV-8) showed the greatest coplanar PCB concentration at 1.635 ng/g.

Surface PCB concentrations observed in the navigation channel during this study were compared to surface PCB concentrations observed in a recent study conducted by Arthur D. Little for the Delaware Estuary Program (Arthur D. Little, 1994). Only the surface concentrations from this study were compared because the Arthur D. Little study only conducted surface grab samples. The Arthur D. Little study used the same high resolution methods; thus, the data are directly comparable. All of the sediments for the Arthur D. Little study were taken from shoal habitats and at stations which were often located in the mouths of major tributaries to the Delaware River. Figure 4-4 shows the position of each station sampled for the Arthur D. Little study, relative to samples collected for this study. The Arthur D. Little study also partitioned the contaminant results into four estuary reached (A through D) for data analysis. Reach A was located up-river and included an area ranging from the mouth of the Neshaminy Creek to north of the Ben Franklin Bridge. Reach B ranged from the mouth of Mantua Creek to Raccoon Creek, Reach C ranged from Stone Creek to just north of the C&D Canal, and Reach

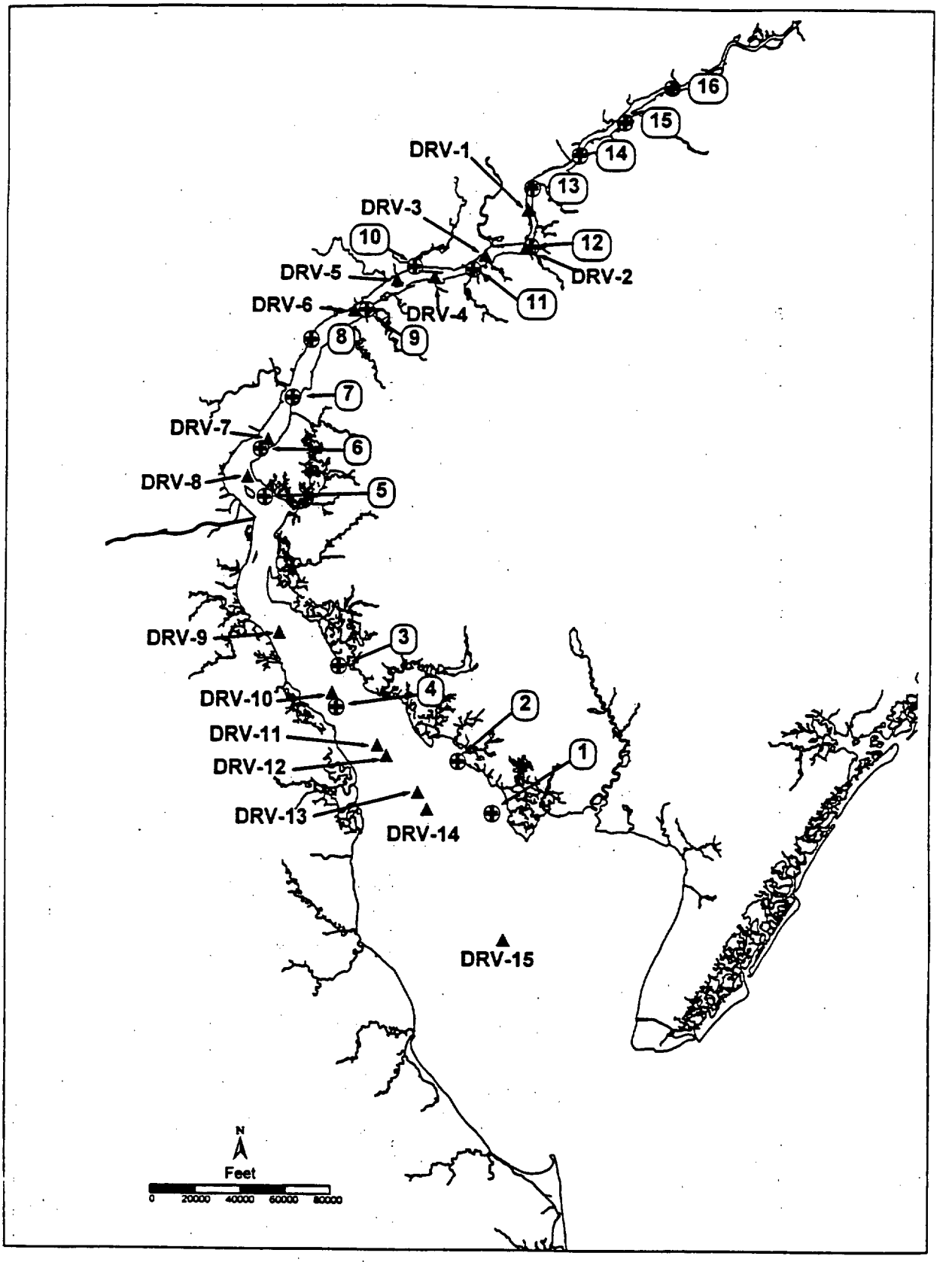

Figure 4-4. Comparison of station locations for the primary stations sampled in the Delaware River, Philadelphia to the Sea Federal navigation channel in October 1996 and stations sampled by the Arthur D. Little study in May 1993

D was located in the lower bay and ranged from south of Artificial Island to Egg Island Point, New Jersey. Data from this study were categorized into approximately the same reaches and the mean concentrations of the sum of the congeners were compared. No comparison of shoal and channel concentrations were available for Reach A as no sampling was conducted north of Philadelphia during this study.

The results of this comparison suggest that PCB concentrations in the navigation channel are much lower than concentrations observed in the shoal habitats sampled by Arthur D. Little (Figure 4-5). Mean concentrations in the up-river shoal areas (177.8 ng/g) were more than eight times greater than those observed in the channel sediments (21.9 ng/g). Lower concentrations were observed in the shoal samples from Reaches C and D relative to Reach B. However, average total PCB concentrations in the navigation channel in Reaches C and D were 9 and 28 times lower than the respective shoal concentrations. Analysis of variance tests indicated that these differences were significant suggesting that the accumulation of PCBs in the estuary occurs primarily in shoal areas outside the navigation channel.

The dredged material disposal plan for the Delaware River, Philadelphia to the Sea main channel deepening project includes using dredged material from the lower portion of the estuary (Liston Range to Crossledge Range) for the creation of shallow marsh habitat around Egg Island Point in New Jersey, and Kelly Island in Delaware. In addition, some of the sediments will be stockpiled in the lower Delaware Bay at sites L-5 and MS-19 for use in future beach replenishment activities along the Delaware shoreline. A major environmental concern expressed by the State of Delaware was that placement of material containing high levels of PCBs could expose aquatic and terrestrial natural resources to toxic concentrations and potentially increase the biomagnification of PCBs through the food chain.

The results of this study indicate that these concerns are unwarranted as the sediments slated for the beneficial projects contain only trace concentrations of PCBs (Figure 4-3). Sediments for the wetland creation and sand stockpile projects will be taken from sampling areas DRV-11, 12, 13, 14, and 15. These particular areas had the lowest concentration of PCBs found in the entire study region. Furthermore, the results of the comparison of channel concentrations and shoal concentrations reported by Arthur D. Little (1994) indicate that PCB contamination in the navigation channel is significantly lower than levels observed in shallower non-channel areas (Figure 4-5). Thus, use of channel sediments for construction of wetlands and beach nourishment projects may have an added benefit by capping shallow water sediments known to have higher PCB concentrations. PCB levels reported by Arthur D. Little at the stations closest to the Egg Island Point project (Station 1; Figure 4-4) had a total concentration of 36.9 ng/g while this study suggests that

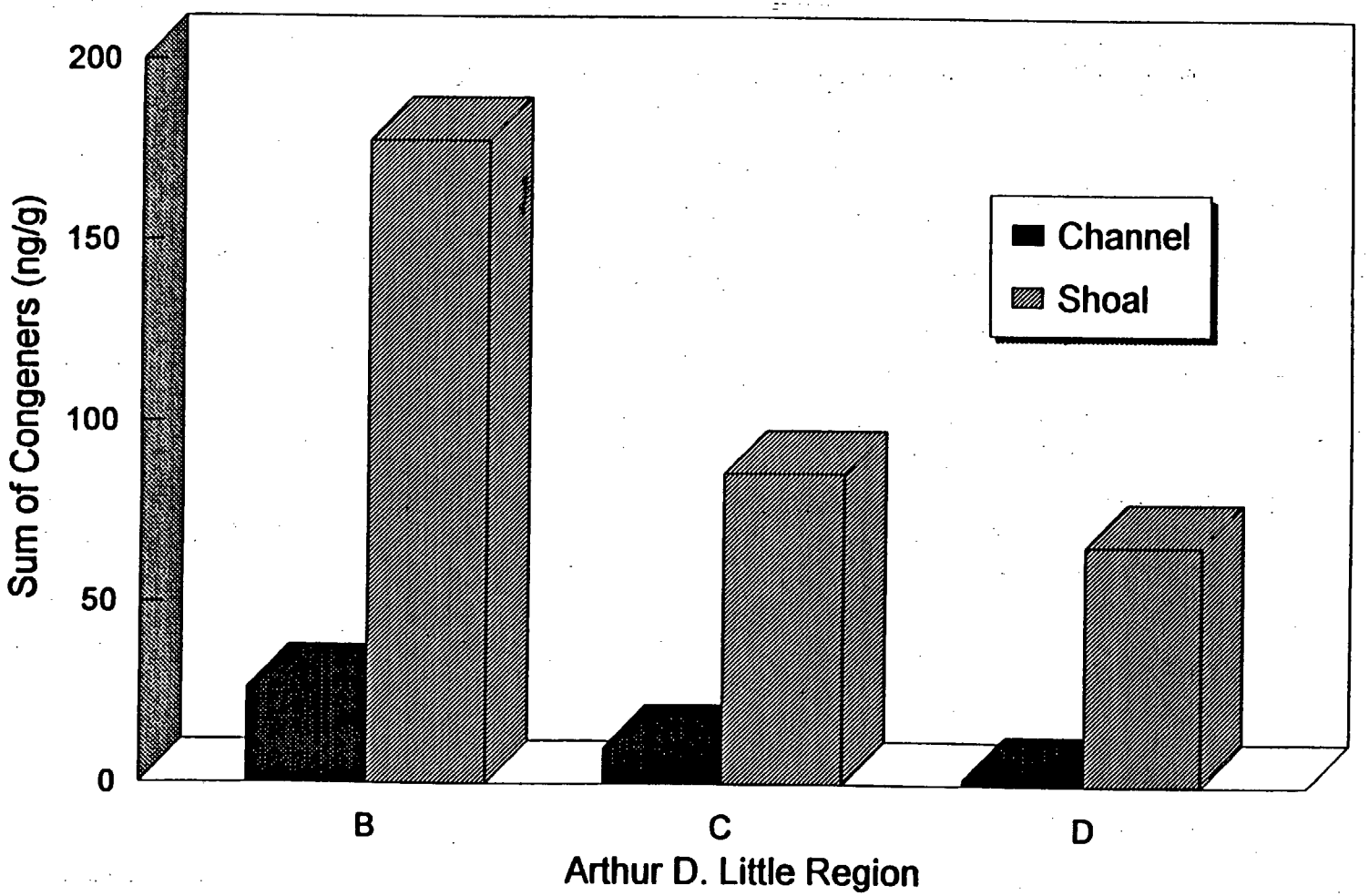

Figure 4-5. Comparison of total PCB concentrations (ng/g) observed in the navigational channel to concentrations observed in the shoal sampling conducted by Arthur D. Little in May 1993

the navigation channel sediments that will be placed there may only have an average concentration of 0.003 ng/g.

One mechanism where dredging activities can potentially mobilize PCBs in the estuary is through the discharge of water from upland disposal sites. In the riverine portion of the project area, dredged material is placed in seven upland disposal sites located between Artificial Island and the Schuylkill River. Discharge water from these sites may contain PCBs dissolved in the pore water of the dredged sediments. In addition, the process of dredging and pumping the dredge slurry to the upland disposal sites may increase dissolved PCB concentrations due to changes in sediment/interstitial water equilbrium. However, PCB solubilities are known to be extremely low ranging from 0.00009 mg/l for nonachlorobiphenyl to 0.17 mg/l for some tetrachlorobiphenyls (USEPA, 1987). PCBs are also known to firmly attach to organic particles and fine grained sediments. Thus, only a very small percentage of the PCBs in dredged material will be discharged in the dissolved phase. The specific percentage of PCBs that will be released will depend on the solubilities and concentrations of the various congeners in the material. This is usually measured for a particular sediment in elutriate tests. Although no high resolution sediment tests were conducted in conjunction with high resolution elutriate tests, a recent study conducted in Wilmington Harbor, Delaware suggests that PCB discharges from upland disposal sites pose no appreciable risk to aquatic biota in the Delaware River (Greeley-Polhemus Group, 1994).

Using high resolution tests the Greeley-Polhemus Group (1994) quantified the concentration of PCB congeners in the sediments and in weir discharge of the upland disposal site which received the material dredged for maintenance of the harbor (the same contract lab used for this study conducted the PCB analysis). A total of 12 congeners were detected in two composite samples of the sediments prior to dredging, the sum of which averaged 23.1 ng/g. Two separate 24 hour composite samples of the weir discharge waters were collected during the dredging operations and only one congener (IUPAC 77) was detected in extremely low concentrations which averaged only 0.00004 ug/L.

Efficient operation of upland disposal sites can reduce the mobilization of PCBs in the estuary by removing the majority of the suspended material. Maintenance of the proper ponding levels (by adjusting the weir height) increases the retention time of water within the upland site allowing suspended material more time to settle out. In addition, many of the upland sites used in the Delaware River contain large stands of Phragmites and other upland vegetation. Typically the dredged slurry is pumped into the site as far inland as possible and upgradient of the vegetation. This effectively maximizes the distance a parcel of water must traverse to the discharge weir. In addition, the flows of turbid water discharged from the dredge pipe is further detained by the plant material increasing the removal of

suspended solids. In recent monitoring of weir discharges for the Wilmington Harbor and Salem River dredging projects, TSS levels at the weir were often much less than background concentrations measured in the river.