Delaware Estuary
Regional Sediment Management Plan
White Paper

SEDIMENT QUALITY

August 2013

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Acronyms and Abbreviations

BaP	Benzo(a)pyrene
COC	Contaminants of concern
CWA	Clean Water Act
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DRBC	Delaware River Basin Commission
ERL	Effects Range-Low
ERM	Effects Range-Median
HNRT	Highest Non-Residential Threshold
LRT	Lowest Residential Thresholds
NJDEP	New Jersey Department of Environmental Protection
NOAA	National Oceanic and Atmospheric Administration
PAH	Polycyclic aromatic hydrocarbons
PBT	Persistent Bioaccumulative and Toxic chemicals
PCB	Polychlorinated biphenyl
PEL	Probable Effects Level
REMAP	Regional Environmental Monitoring and Assessment Program
RSMP	Regional Sediment Management Plan
SQG	Sediment quality guidelines
SQuiRT	Screening Quick Reference Tables
TCLP	Toxicity Characteristic Leaching Procedure
TEL	Threshold Effects Level
TEQ	Toxic Equivalency Quotient
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

Introduction

Summary

Delaware Estuary Regional Sediment Management Plan (RSMP) Sediment Quality Objective: Manage and improve sediment quality in the Delaware Estuary/Basin system to ensure it is capable of supporting a healthy and productive ecosystem, meets water quality standards, and supports beneficial use of the sediment (including dredged material).

The purpose of the *Sediment Quality White Paper* is to evaluate the available sediment quality (i.e. chemistry) data from the Delaware Estuary and its watershed to aid in the development of the Delaware Estuary RSMP. The RSMP Workgroup views dredged material (i.e. sediment) as a resource and the Sediment Quality Committee has chosen to evaluate the quality of this resource in terms of its potential suitability for aquatic habitat restoration and upland beneficial uses.

A comprehensive evaluation of the suitability of sediment/dredged material for an aquatic habitat restoration or upland beneficial use project requires detailed project-specific analyses of the physical and chemical characteristics of the sediment/dredged material (as well as the beneficial use site). In addition, for most habitat restoration projects, potential contaminant bioavailability effects (toxicity and bioaccumulation) must also be evaluated (U.S. Army Corp of Engineers [USACE], 2003; U.S. Environmental Protection Agency [USEPA]/USACE, 1998; New Jersey Department of Environmental Protection [NJDEP], 1997). Given the planning-level objectives and geographic scope of the RSMP, and the limited time and resources available to conduct an assessment of sediment/dredged material quality, the Sediment Quality Committee determined that such project-specific and comprehensive analyses were not realistic. Therefore, a simplified sediment quality evaluation screening protocol was developed to provide the information needed to support the development of the RSMP.

Finally, a comprehensive watershed-level effort to identify and evaluate the factors that result in the observed sediment quality characteristics in the Delaware Estuary is beyond the scope of this project.

Methods

Contaminants of Concern

The Sediment Quality Committee has selected a set of “contaminants of concern” (COCs) whose presence in Delaware Estuary sediment have the potential to limit aquatic habitat restoration or upland beneficial uses of dredged material, and can be used to address the planning level objectives of the Delaware Estuary RSMP. Although not every contaminant that would be assessed as part of a project-specific regulatory review has been evaluated in this white paper, the selected COCs include those that have previously been shown to limit uses within the Delaware Estuary.

Under their Clean Water Act (CWA) Integrated Assessment programs, every even numbered year the States of Delaware and New Jersey, and the Commonwealth of Pennsylvania, compile and submit to the USEPA lists of water bodies not supporting designated uses. These State CWA Section 303(d) lists of water quality impairments also identify the causes of the impairments, including contaminants. A review of the listed segments along the Delaware River for the 2008 Integrated Assessment cycle (Table 1) shows all three States have listed polychlorinated biphenyl (PCBs) as a cause of impaired uses, with both New Jersey and Delaware also listing arsenic, mercury, and chlorinated pesticides.

Table 1. Chemicals Listed in the Delaware Estuary Reaches of the 2008 State Clean Water Act 303(d) Lists.

Delaware	New Jersey	Pennsylvania
PCBs	PCBs	PCBs (fish consumption)
Chlorinated pesticides	DDT/DDD/DDE	
	Dieldrin	
	Chlordane	
Arsenic	Arsenic	
Iron	Cadmium	
	Copper	
	Lead	
Mercury	Mercury	
Dioxin		

The USEPA had developed a list of priority Persistent Bioaccumulative and Toxic (PBT) chemicals (http://www.epa.gov/pbt/pubs/cheminfo.htm). This list also included PCBs, mercury, and chlorinated pesticides (chlordane and dichlorodiphenyltrichloroethane [DDT]/dichlorodiphenyldichloroethane [DDD]/ dichlorodiphenyldichloroethylene [DDE]), as well as dioxins/furans and benzo(a)pyrene.

Given the contaminants listed on the State CWA Section 303(d) and USEPA PBT lists, the planning-level objectives of the Delaware Estuary RSMP, and the limited resources and time available to complete this effort, the Sediment Quality Committee determined that the following COCs would be evaluated in the *Sediment Quality White Paper*:

- total PCBs
- total dioxins/furan Toxic Equivalency Quotient (TEQ)
- DDT and metabolites
- total chlordane
- dieldrin
- benzo(a)pyrene (BaP)
- mercury
- arsenic
- metals – cadmium, cobalt, copper, and lead.

It is important to emphasize that the Sediment Quality Committee's use of these selected COCs is only appropriate to address the planning-level objectives of the Delaware Estuary RSMP. Future project-specific regulatory, management, or remedial decisions concerning sediment/dredged material will not be limited to these contaminants and will require more detailed project-specific evaluations of proposed aquatic habitat restoration and upland beneficial use projects.

Sediment Quality Thresholds

Given the complex nature of sediment, selecting criteria/guidelines to evaluate sediment quality can be difficult. Most ecotoxicologists agree that it is best to use a variety of metrics and a weight of evidence approach to address this problem. The Sediment Quality Committee has considered a variety of criteria and guidelines that are currently in use in the Delaware Estuary to evaluate sediment quality, including:

> State regulatory criteria used to evaluate the placement of fill (soil, dredged material, etc.) at upland sites;

> sediment quality guidelines (SQG) used for ecological effects screening purposes;

> State and Delaware River Basin Commission (DRBC) water quality criteria;

> State criteria used to develop fish advisories; and

> eco-effects data for toxicity, bioaccumulation, and community health indices.

To evaluate sediment quality at the planning level of the Delaware Estuary RSMP, the Sediment Quality Committee has developed a set of thresholds (i.e. critical contaminant concentrations) for each COC that indicates potential/probable limitations on the beneficial use of dredged material in aquatic habitat restoration or upland projects. The primary objective of the *Sediment Quality White Paper* is to use this threshold framework to evaluate the nature and geographical extent of sediment quality in the Delaware Estuary at the planning level, and to categorize sediment along a range in quality from "likely suitable for all beneficial uses" to "likely suitable for none." Figure 1 shows the framework for this evaluation in which sediment is characterized as:

(1) *probably suitable for all beneficial uses* – the concentrations of <u>all COCs</u> are lower than the Effects Range-Low (ERL)/Threshold Effects Level (TEL) for aquatic toxicity;

(2) *probably not suitable for aquatic habitat restoration, but potentially suitable for at least some upland beneficial uses* - the concentration of <u>at least one COC</u> is greater than the Effects Range-Median(ERM)/Probable Effects Level (PEL) for aquatic toxicity and the concentrations of <u>all COCs</u> are less than the Highest Non-residential Threshold for upland beneficial use; or

(3) *probably not suitable for either aquatic habitat restoration or any upland beneficial use* - the concentration of <u>at least one COC</u> is greater than the Highest Non-residential Threshold.

Selection of the sediment quality threshold concentrations used in the analyses is discussed in Appendix A, with the actual thresholds in Table A-1. These thresholds do not consider the physical suitability of dredged material for a specific beneficial use.

The Upland Beneficial Use threshold COC concentrations are derived from the regulatory criteria used by the three States to determine if soil (or other fill material) is acceptable for use in "residential" or "non-residential" areas. While each State has its own set of regulatory criteria, it is relatively simple to combine the individual State criteria into a composite set of thresholds. The use and interpretation of these composite Upland Beneficial Use thresholds are fairly straight-forward, as described below:

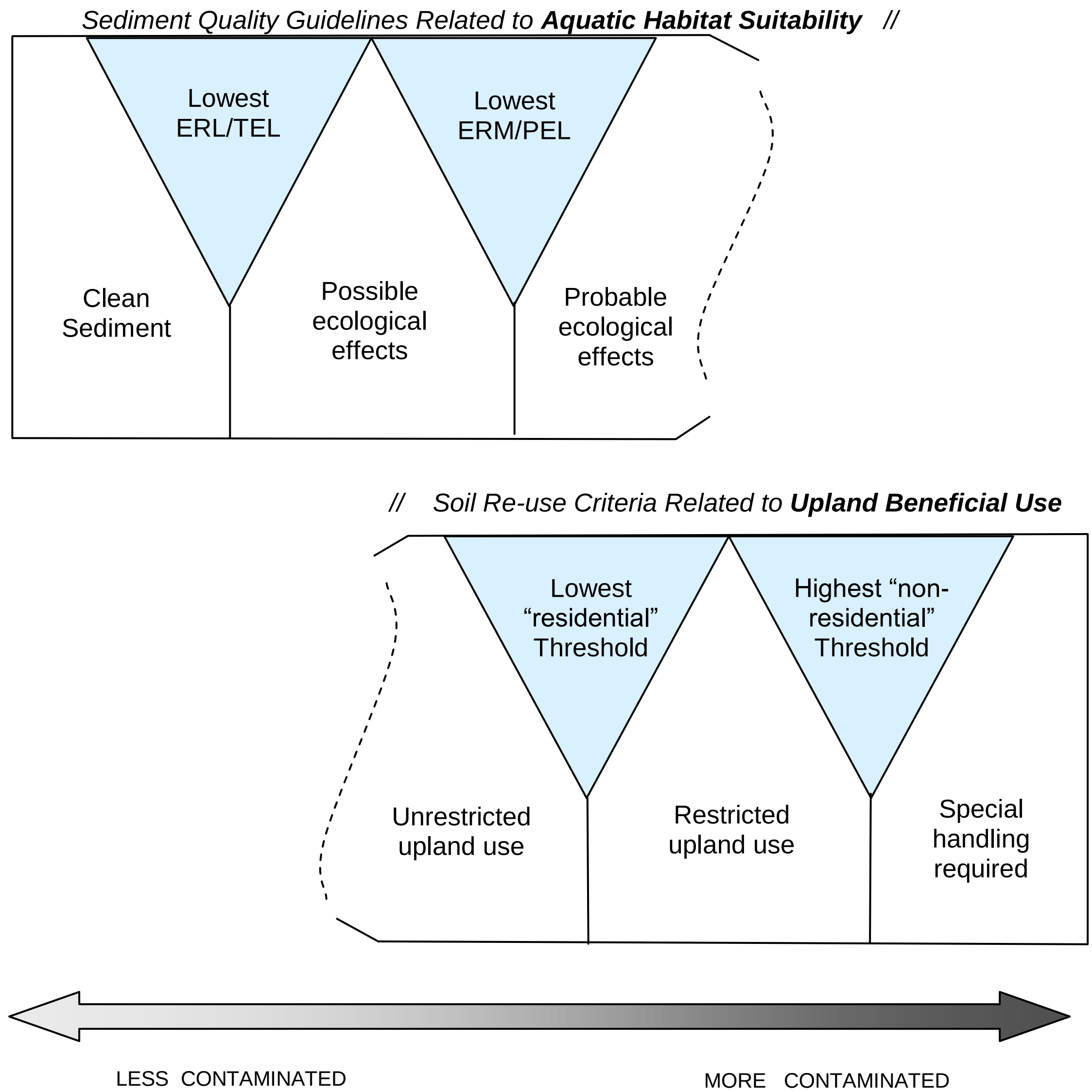
> If all of the COC concentrations in a sediment sample are less than the Lowest Residential Thresholds (LRT), the sediment is probably suitable for "unrestricted" upland beneficial use.

> If the concentration of at least one COC in a sediment sample is greater than the LRT, and the concentrations of all of the COCs are less than the Highest Non-Residential Threshold (HNRT), the sediment is probably suitable for "restricted/limited" upland beneficial uses.

> If the concentration of at least one COC in a sediment sample is greater than the HNRT, the sediment is probably unsuitable for upland beneficial use.

In contrast, the derivation, use, and interpretation of the aquatic habitat restoration suitability threshold COC concentrations are more complex and subjective in nature. Briefly, the SQG used in the threshold analysis - ERL/TEL and ERM/PEL – are derived from statistical analyses of large data sets relating the concentrations of the COCs in sediment and the resulting potential for the sediment to be toxic to benthic biota (Table A-1). The SQGs are not regulatory criteria, but "tools" that can be used (usually as part of a "weight of evidence approach") to provide an indication of the potential likelihood that sediment with given COC concentrations <u>may</u> be toxic. Although it is a simplification, one way to use and interpret the SQG thresholds is the following:

Figure 1. Categories of sediment quality and corresponding thresholds.



> If all of the COC concentrations in a sediment sample are less than the ERL/TELs, the sediment can be considered to be “clean” and probably suitable for aquatic habitat restoration.

> If the concentration of at least one COC in a sediment sample is greater than the ERL/TEL, and the concentrations of all of the COCs are less than the ERM/PELs, there is a small probability that the sediment may be toxic to aquatic biota.

> If the concentration of at least one COC in a sediment sample is greater than the ERM/PEL, there is a moderate probability that the sediment may be toxic to aquatic biota.

The more COCs in a sediment sample that have concentrations greater than the ERL/TEL and/or ERM/PEL, the greater the likelihood (i.e. “weight of evidence”) that the sediment may be toxic to aquatic biota. The higher the concentration of a COC relative to its SQG, the greater the likelihood that the sediment may be toxic to aquatic biota. However, the SQGs do not consider synergistic and antagonistic effects of the COCs on toxicity. The only way to determine if the sediment is actually toxic to biota is to conduct appropriate species- and site-specific sediment toxicity tests. Sediment may be toxic to some species (and to varying degrees), and not to others.

The SQGs used in the Aquatic Habitat Restoration Suitability Threshold Analysis do not consider the bioaccumulation of the COCs in estuarine food webs and the resulting possible effects on the aquatic ecosystem. Some COCs may be bioaccumulated to levels of concern even though the sediment COC concentrations are lower than the ERL/TELs. The use of SQGs that only reflect potential sediment toxicity may underestimate overall impacts to the aquatic ecosystem resulting from sediment contamination.

By its decisions to use the selected SQG/criteria concentrations, the committee is not judging the merits of other SQG/criteria. In addition, the committee emphasizes the inherent limitations on the use of SQGs to predict the suitability of sediment for an aquatic habitat restoration project, because SQGs only consider the potential toxic effects of contaminants.

Methods – Sediment Data Compilation and Analysis

The Sediment Quality Committee used historical data to describe and evaluate the quality of sediment in the Delaware River and Estuary from the head-of-tide at Trenton, New Jersey to the mouth of Delaware Bay. The committee compiled a database (the Delaware Estuary RSMP Sediment Quality Database; see Appendix B) of readily available sediment quality data in the Delaware Estuary. The sources of data included the URS/DuPont “Delaware Estuary Electronic Database”, USACE and non-Federal dredging project reports, National Oceanographic and Atmospheric Administration (NOAA) Status and Trends reports, USEPA Regional Environmental Monitoring and Assessment Program (REMAP) and other reports, U.S. Geological Survey (USGS) and DRBC monitoring data, and university studies. Sediment data collected in association with smaller public and private dredging projects were not included in the database. The database included data from 109 sediment samples collected by NOAA National Coastal Assessment studies completed in 2003 through 2006; however, these data were not included in the analyses[1].

The Delaware Estuary RSMP Sediment Quality Database includes sediment samples collected in the Delaware Estuary from 1990 to 2009 (details included in Appendix C). Although some pre-1990 data are available, the Sediment Quality committee determined the use of older data problematic due to quality assurance concerns (elevated analytical detection limits relative to the selected sediment quality thresholds). Most of the PCB and pesticide data are from older samples (collected before 2001) analyzed using methods with detection limits greater than the aquatic habitat restoration suitability and upland beneficial use threshold criteria. This results in many of the sediment samples having non-detected concentrations for these COCs that are difficult to use and interpret. Elevated analytical detection limits for benzo(a)pyrene pose similar problems when using the sample data.

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[1] The Sediment Quality Committee was unaware of the data when the analyses were conducted.

The rationale used to develop the sediment threshold concentrations is discussed in detail in Appendix A. The data for every sediment sample and COC were compared to the thresholds. Separate matrices have been prepared for each COC that identify the most stringent sediment evaluation criteria (aquatic habitat restoration suitability, upland beneficial use) met by each sediment sample for each COC. In addition, composite matrices have been developed that combine all of the data for the COCs and identify the most stringent sediment evaluation criteria met for each sample. The results of the sediment quality Aquatic Habitat Restoration Suitability and Upland Beneficial Use Threshold Analyses (i.e. the composite matrices) have been displayed on a series of GIS-based maps of the Delaware Estuary RSMP study area using a color-coded display system (Appendix E).

The GIS-based maps were used by the Sediment Quality Committee to evaluate the nature and extent of sediment quality in the Delaware Estuary. This evaluation focused on identifying (a) COCs present at concentrations that would potentially/probably limit the beneficial uses of dredged material, and (b) geographic areas where the concentrations of the COCs would potentially/probably limit the beneficial uses of dredged material. This geographic analysis was conducted at the level of the Delaware River "water quality zones" established by the DRBC (http://www.state.nj.us/drbc/).

Limitations on the Uses of the Results of this Sediment Quality Evaluation

The sediment quality analyses presented and discussed in this white paper are designed and intended solely to support the planning objectives and development of the Delaware Estuary RSMP. The main purpose of this white paper is to screen the available sediment quality data in the Delaware Estuary to evaluate its potential suitability for a variety of dredged material beneficial uses. While the Sediment Quality Committee believes that the evaluations conducted in this white paper are useful for planning purposes, more detailed project-specific sediment/dredged material sampling, testing, and evaluation will be needed to support the review of proposed aquatic habitat restoration or upland beneficial use projects by State and Federal regulatory agencies. **The Delaware Estuary RSMP Sediment Quality Database, selected sediment quality thresholds, and results of the white paper cannot be used to make regulatory decisions concerning specific proposed projects.**

In order to accomplish its objectives, the Sediment Quality Committee established a set of sediment quality benchmarks to screen the available sample data for a selected set of COCs. The data evaluated primarily represent *in situ* bulk sediment chemistry concentrations of these COCs. While the presence of these COCs in the sediment may be indicative of potential problems with the beneficial use of dredged material, additional contaminants not evaluated in this white paper may also prove to be problematic; this limits the project-specific utility of the results.

The benchmarks selected for use by the Sediment Quality Committee were either used in existing regulatory programs (for example, New Jersey's Site Remediation Program) or widely accepted in the scientific literature (Sediment Quality Guidelines). However, the use of these benchmarks is itself subject to limitations and uncertainty as a result of the methods used to develop them, and their application to the Delaware Estuary must be qualified accordingly.

Finally, once dredged and otherwise managed (for example, placed in an upland confined disposal facility, a common practice in the Delaware Estuary), physical and chemical changes in the sediment/dredged material will occur, resulting in changes in the bulk chemistry contaminant concentrations (including the bioavailable fractions). Thus, *in situ* bulk sediment chemistry data provide limited information and can only be used as part of an initial (Tier I; USACE, 2003 and USEPA/USACE, 1998) evaluation of the suitability of dredged material for a proposed beneficial use. Additional Tier II and (potentially) Tier III analyses are needed to fully evaluate the suitability of dredged material for a proposed aquatic habitat restoration or upland beneficial use project. In particular, Tier III analyses – which involve direct assessment of the potential toxic and bioaccumulation impacts of dredged material – are almost always needed to evaluate the suitability of dredged material for a proposed aquatic habitat restoration project.

Results and Discussion

Types of Sediment Samples

Figure 2 shows the locations of the 932 sediment samples in the Delaware Estuary RSMP Sediment Quality Database and evaluated in this white paper. Each surface grab sample location shown in Figure 2 represents a single sample. In contrast, each core or composite sample location shown in Figure 2 can represent one or more sections of a core sample collected at that location. Overall, 77% of the sediment samples were grab samples, 21% core samples, and 2% composite samples.

The majority of the sediment samples were collected in DRBC Zone 5 (25%) of the Delaware River and in Zone 6-Delaware Bay (32%). About 11% of the samples were collected in each of DRBC Zone 3 and Zone 4, while only 4% of the samples were collected in DRBC Zone 2. Seventeen percent (17%) of the sediment samples were collected in estuary watershed tributaries, and almost all of these were grab samples.

The numbers of samples analyzed for each of the COCs are summarized in Table 2. Relatively large numbers of sediment samples were analyzed for metals (including mercury), PCBs, and chlorinated pesticides, with fewer samples analyzed for polycyclic aromatic hydrocarbons (PAHs). There are only limited data available for cobalt, and very few sediment samples were analyzed for dioxins/furans.

With the exception of cobalt and benzo(a)pyrene, most of the available data comes from surface grab samples, and almost all of the core and composite sediment samples were collected in navigation channels. There are also some large spatial gaps in sediment data from core samples, as well as areas with very few core samples (Figure 2). There are comparatively less data on buried sediment and by extension, historical sediment contamination in the Delaware Estuary, than on surface sediment.

The available sediment data for each of the COC also varies among the DRBC Zones (Table 3).

Figure 2: Locations of the surface grab, core, and composite sediment samples compiled into the Delaware Estuary RSMP Sediment Quality Database.

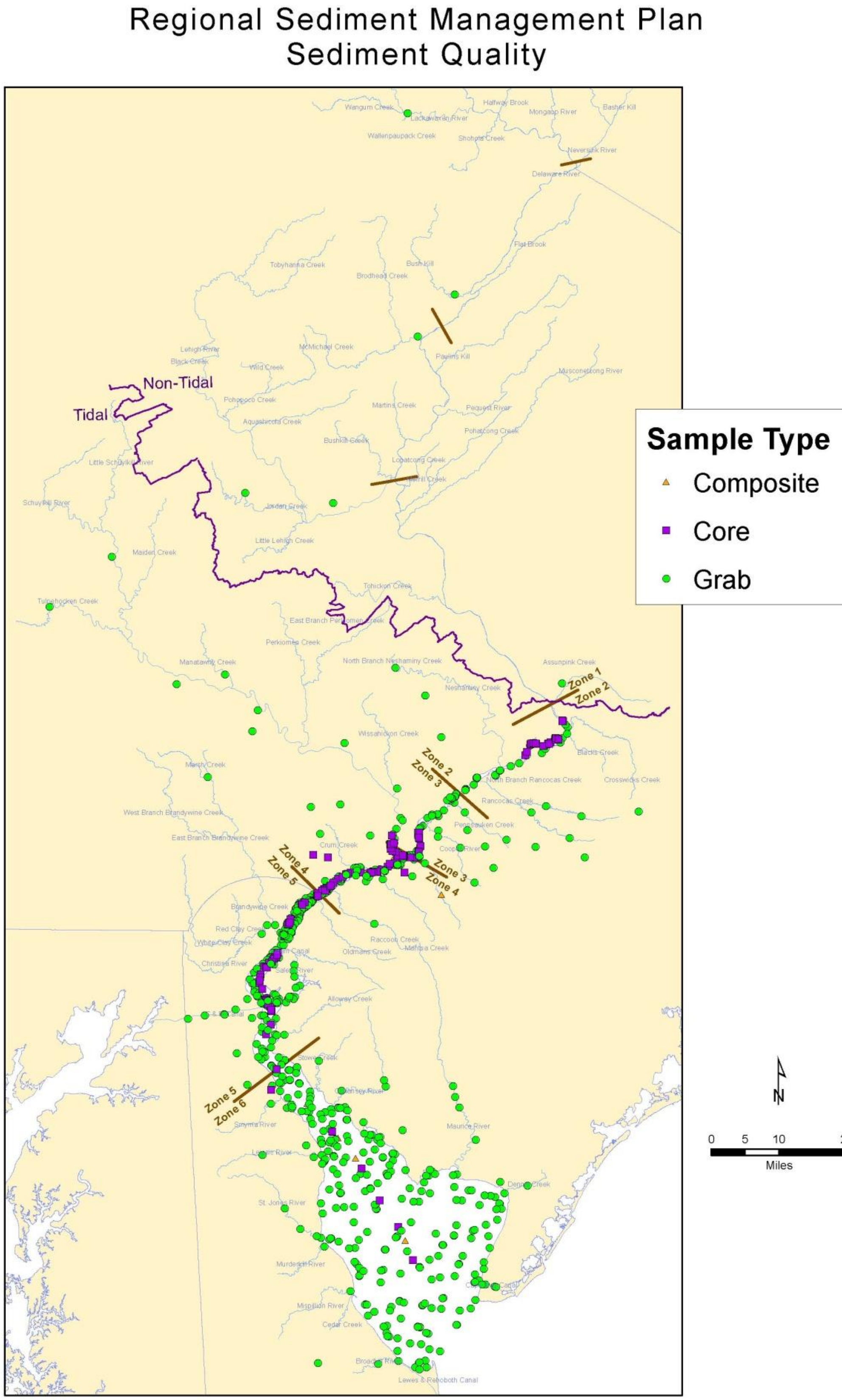


Table 2: Number of sediment surface grab and core samples analyzed for each COC.

Contaminant of Concern	Number of Grab Samples	Number of Core Samples
Mercury Arsenic Cadmium Copper Lead	~ 600 Varies slightly with each COC	~195 Varies slightly with each COC
Cobalt	28	69
Total PCBs	441	151
Total Dioxin/Furan TEQ	24	0
4,4'-DDT	327	193
4,4'-DDD	312	193
4,4'-DDE	312	185
Chlordane	362	193
Dieldrin	311	193
Benzo(a)pyrene	135	193

Table 3: Approximate percentages of available sediment sample data for each COC by DRBC-designated Water Quality Zone.

Contaminant of Concern	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Watershed Tributaries
Mercury Arsenic Cadmium Copper Lead	3	11	12	24	33	17
Cobalt	0	39	12	11	0	37
Total PCBs	4	12	10	28	24	22
Total Dioxin/Furan TEQ	0	0	8	50	42	0
4,4'-DDT	5	17	14	24	20	21
4,4'-DDD	3	16	13	20	24	25
4,4'-DDE	3	15	13	20	24	25
Chlordane	5	16	13	23	22	22
Dieldrin	3	16	13	20	24	24
Benzo(a)pyrene	3	26	15	23	18	16

Sediment Contaminant Concentrations

Statistical summaries of the available bulk sediment chemistry data for each of the COCs are available in Appendix D.

Table 4 shows the observed trends in the magnitude of sediment COC concentrations by DRBC Zones and in tributaries to the estuary. Statistically significant differences in the concentrations of the COCs in the DRBC Zones are delineated in Table 4 (except as noted; pair-wise two-tailed t-tests, unequal variance, $p < 0.05$).

Table 4: Observed Trends in Mean Sediment Contaminant Concentrations by DRBC Zone[#].

Contaminant	DRBC Zones or Delaware River Tributaries			
Arsenic	Tributaries = Zone 5 >	Zone 2 = Zone 3 = Zone 4 >		Zone 6
Cadmium	Zone 2 = Zone 3 >	Tributaries >	Zone 4 = Zone 5 >	Zone 6
Cobalt	Tributaries >	[a]Zone 3 = Zone 4 = Zone 5	No Data: Zone 2 & Zone 6	
Copper	Tributaries = Zone 2 >	[b]Zone 3 >	Zone 4 = Zone 5 >	Zone 6
Lead	Tributaries = Zone 2 = Zone 3 >	Zone 5 >	Zone 4 >	Zone 6
Mercury	Tributaries >	[c]Zone 2 = Zone 3 = Zone 5 >	Zone 4 >	Zone 6
Benzo(a)pyrene	Tributaries >	Zone 2 = [d]Zone 3 = Zone 4 = [d]Zone 5 = Zone 6		
4,4'-DDT	Zone 3 >	[e]Zone 2 = Zone 4 = Zone 5 = Tributaries >		Zone 6
4,4'-DDD	Zone 2 = Zone 3 = Zone 4 = Zone 5 = Tributaries >			Zone 6
4,4'-DDE	[f]Zone 2 ≥	[g]Zone 3 = Zone 4 = Zone 5 = Tributaries >		Zone 6
Chlordane *	Zone 4 = Zone 5	Zone 3 >	Zone 6 = Tributaries >	Zone 2
Dieldrin	Tributaries = Zone 3 = Zone 4 = Zone 5 >	Zone 2 = Zone 6		
PCBs	Tributaries = Zone 3 = Zone 5 >	[h]Zone 4 = Zone 2 >		Zone 6
PCDD/Fs**	Zone 5 >	Zone 4 = Zone 6	No Data: Zone 2, Zone 3, & Tributaries	

Statistical Exceptions:

a: cobalt – Zone 3 > Zone 4 p = 0.0066

b: copper - Tributaries > Zone 3 p = 0.081 NS

c: mercury – Tributaries > Zone 2 p = 0.066 NS

d: benzo(a)pyrene - Zone 3 & Zone 5 > Zone 6 p << 0.001

e: 4,4'-DDT - Zone 3 > Zone 2 p = 0.166 NS

f: 4,4'-DDE - Zone 2 > Zone 3 p = 0.98 NS; Zone 2 > Zone 4 p = 0.725 NS

g: 4,4'-DDE Zone 3 > Zone 5 p = 0.040

h: PCBs – Tributaries > Zone 4 p = 0.064 NS

** Due to the limited number of samples, statistical analyses were not performed on the PCDD/F data.

*Due to a large percentage of samples with non-detected Chlordane concentrations (55% of the available data), with variable detection limits, trends in the mean and median total Chlordane concentrations among the DRBC Zones differed. Trends in the mean total Chlordane concentrations are as shown in Table 4:

Zones 4 & 5 (~ 42 ug/kg) > Zone 3 (25 ug/kg) > Zone 6 (11 ug/kg) > Zone 2 & Tributaries (6 ug/kg).

Median total Chlordane concentrations were substantially lower, and with different trends:

Zones 2, 3 & 4 (~ 5 ug/kg) > Zone 5 (1.4 ug/kg) > Tributaries (0.8 ug/kg) > Zone 6 (0.2 ug/kg).

Despite the statistically significant differences shown in Table 4, the concentration of each COC in the available sample data varied considerably within each DRBC Zone. However, sediment COC concentrations were consistently lowest in DRBC Zone 6 (Delaware Bay).

For each of the COCs, contaminant concentrations were not detected in some of the sediment samples. To avoid the bias created by using a zero (0) value in place of a non-detect, one-half the detection limit was used for all non-detects. This is a common practice even though it may under or overestimate the actual COC concentrations.

Table 5 lists the percentages of the available data for each COC that were non-detect. For some COCs, the number of non-detects reported was a large percentage (pesticides and benzo(a)pyrene). For these COCs, the concentrations in the database may be more indicative of the elevated detection limits of the analytical methods than of actual sediment concentrations. Some of the non-detect samples were not used in the Aquatic Habitat Restoration Suitability and/or Upland Beneficial Use Threshold Analyses; for a more detailed discussion, see Appendix C.

Table 5: Percentage of non-detects

COCs	Percentage of Non-Detects
Mercury	20.2%
Arsenic	1.1%
Cadmium	8.8%
Cobalt	0%
Copper	1.8%
Lead	1.0%
Total PCBs	22.5%
Total Dioxin/Furan TEQ	4.2%
4,4'-DDT	64.5%
4,4'-DDD	42.5%
4,4'-DDE	34.3%
Chlordane	54.7%
Dieldrin	61.9%
Benzo(a)pyrene	41.6%

Aquatic Habitat Restoration Suitability Threshold Analysis Results

Figure 3 (and Appendix E) shows the results of the Aquatic Habitat Restoration Suitability Threshold Analysis. Overall, the samples were fairly evenly split among the three sediment quality categories:

> 35% of the samples did not have a COC concentration greater than the ERL/TEL (Category 0);

> 34% of the samples had at least one COC concentration greater than the ERL/TEL and no COC concentration greater than the ERM/PEL (Category 1);

> 31% of the samples had at least one COC concentration greater than the ERM/PEL (Category 2).

Based on concentrations of the selected COCs, approximately 35% of the sediment samples are <u>probably</u> clean enough to be beneficially used in aquatic habitat restoration projects (no COC > ERL/TEL), and an additional 34% of the samples are <u>potentially</u> clean enough for such beneficial uses (one or more COC > ERL/TEL, but none > ERM/PEL). About 31% of the samples are problematic for their suitability for beneficial use in aquatic habitat restoration projects (at least one COC > ERM/PEL). This threshold analysis did not consider the magnitude of the observed ERL/TEL and ERM/PEL COC exceedances.

In general, sediment quality relative to the three aquatic habitat restoration suitability threshold categories is heterogeneous throughout the Delaware River - "cleaner" sediment samples are usually interspersed among "more contaminated" samples (Figure 3). Despite this, a number of "geographic locations of interest" were identified where a large percentage of the sediment samples had at least one COC with a concentration greater than the ERM/PEL. Except in Delaware Bay (DRBC Zone 6), sediment samples with at least one COC concentration greater than the ERM/PEL can be frequently found throughout the Delaware River and its tributaries.

Figure 4 shows the fraction of samples in each DRBC Zone from the three aquatic habitat suitability restoration threshold categories; this analysis did not include a number of samples that were non-detect for pesticides and PCBs (Appendix C). DRBC Zone 6 had the largest percentage of samples with no COC concentration greater than the ERL/TEL (71.5%), and the smallest percentage of samples with a COC concentration greater than the ERM/PEL (1.3%; only 4 samples). Sediment samples with at least one COC concentration greater than the ERM/PEL were found most frequently in DRBC Zone 3 (70.5%), Zone 2 (58.3%), and in the tributary samples (50.6%). These three regions also had the lowest percentages of samples that did not have a COC concentration greater the ERL/TEL (10.5-16%).

Based on this analysis, from a contaminant standpoint, dredged material from DRBC Zone 6 would probably be suitable for aquatic habitat restoration beneficial use projects. In contrast, the beneficial use of dredged material from DRBC Zone 2, Zone 3, and the estuary tributaries would probably be problematic for such projects. Dredged material from DRBC Zone 4 and Zone 5 appear to have some potential to be beneficially used for aquatic habitat restoration projects. This uncertainty underscores the committee's belief that the **suitability of dredged material for a proposed aquatic habitat restoration beneficial use project must be thoroughly evaluated using project-specific data.**

Figure 3: Results of the aquatic habitat suitability threshold analysis.

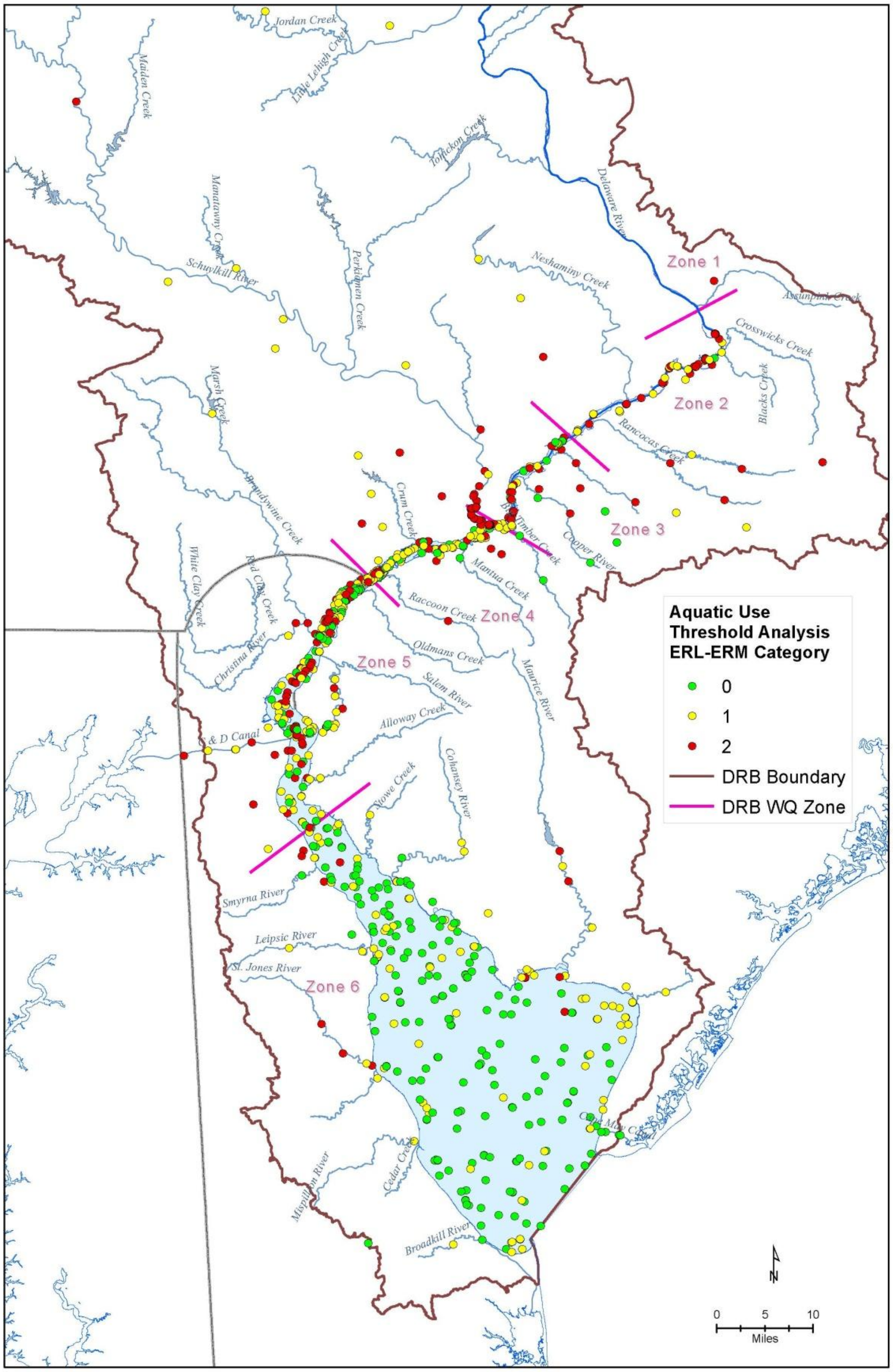


Figure 4: Aquatic Habitat Suitability Restoration Threshold Analysis - Fraction of the Sediment Samples in Each DRBC Zone

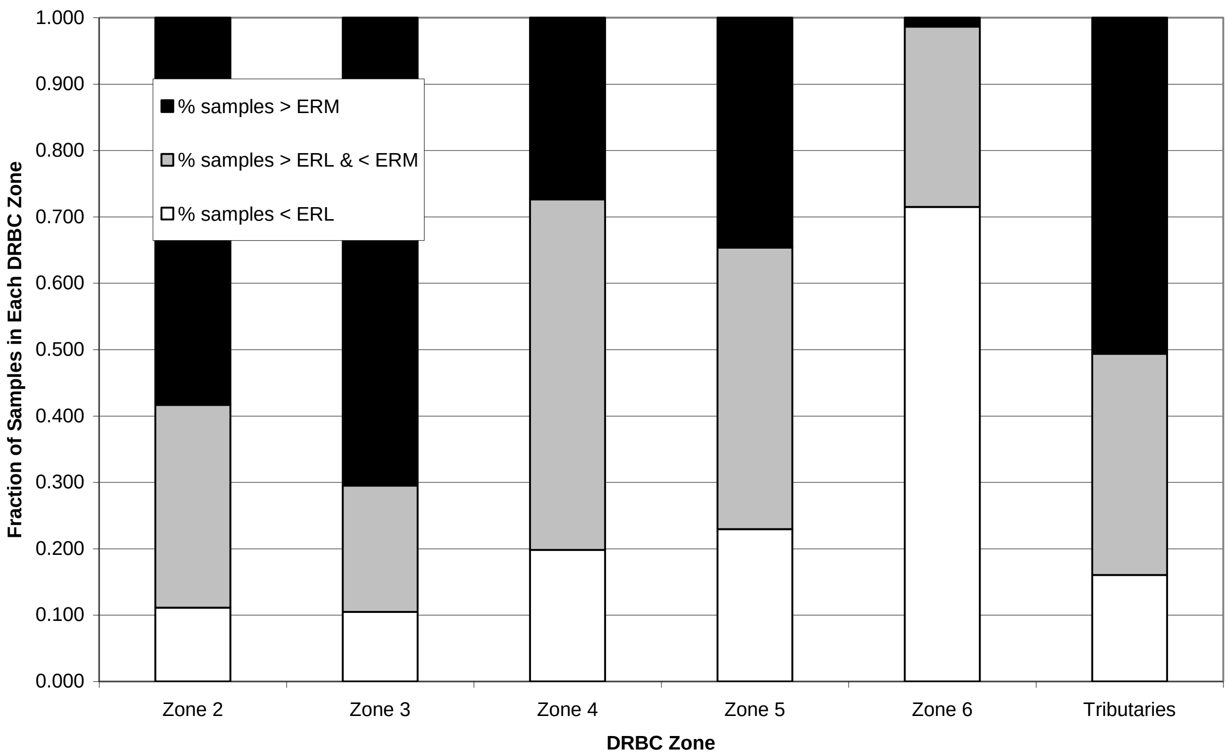


Table 6 shows the percentage of samples collected in each of the DRBC Zones that exceeded the ERM/PEL for each COC; this analysis did not include a number of samples that were non-detect for pesticides and PCBs (Appendix C). Only four of the samples from DRBC Zone 6 had a COC concentration greater than the ERM/PEL: arsenic (3 samples) and cadmium (1 sample). A wide variety of the COCs are present in the other areas of the estuary at concentrations that could potentially make dredged material unsuitable for aquatic habitat restoration beneficial use projects. In particular, the following COCs were found at concentrations greater than the ERM/PEL in about 10% or more of the samples collected in a DRBC Zone:

- DRBC Zone 2 – cadmium, 4,4’-DDT/DDD/DDE, and chlordane;
- DRBC Zone 3 – cadmium, total PCBs, and 4,4’-DDT/DDD/DDE;
- DRBC Zone 4 – total PCBs and 4,4’-DDD/DDE;
- DRBC Zone 5 – arsenic and total PCBs
- Tributaries – mercury, arsenic, copper, lead, benzo(a)pyrene, total PCBs, dieldrin, 4,4’-DDD/DDE, and chlordane.

Table 6: Percentage of samples in each DRBC Water Quality Zone that exceeded the ERM/PEL for each COC.

COC	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Chlordane	30.6	7.6	2.8	0.9	0.0
Cadmium	19.4	11.4	2.8	3.0	0.3
4,4'- DDT	33.3	22.9	4.7	3.0	0.0
4,4'- DDD	30.6	21.0	9.4	5.6	0.0
4,4'- DDE	36.1	38.1	14.2	5.6	0.0
Total PCBs	0.0	31.4	12.3	22.1	0.0
Arsenic	2.8	1.0	6.6	10.8	1.0
Mercury	2.8	0.0	3.8	7.8	0.0
Lead	8.3	8.6	3.8	8.2	0.0
Total # samples =	36	105	106	231	298
Note: < 3% of the samples were > ERM/PEL for copper, benzo(a)pyrene, dieldrin, and total PCDD/F TEQ in all zones – data not shown.					

Sample Data - Tributaries: 50.6% of the samples collected in the tributaries had at least one COC with a concentration exceeding the ERM/PEL.

All 35 sediment samples collected in the Schuylkill River had at least one COC with a detected concentration greater than the ERM/PEL (Figure 3). Multiple COCs were found at elevated concentrations in 30 of the Schuylkill River samples, with 18 having 4 or more COC concentrations greater than the ERM/PEL. Total PCBs, benzo(a)pyrene, 4,4’-DDD, 4,4’-DDE, copper, lead, and mercury were found at concentrations greater than the ERM/PEL in 10 or more of the Schuylkill River samples; lead concentrations exceeded the ERM/PEL in 32 of the samples. In addition, non-detects with elevated detection limits affected the usability of 13 PCB samples, 22 4,4’-DDT samples, and 14 4,4’-DDD and 4,4’-DDE samples. Based on these data, it is unlikely that dredged material from the Schuylkill River will be suitable for aquatic habitat restoration beneficial use projects.

The remaining 44 tributary sediment samples with elevated COC concentrations were distributed throughout the estuary watershed. A variety of COCs had concentrations greater than the ERM/PEL, with arsenic and lead most frequently found at elevated concentrations. Thirty-four (34) of these 44 samples had only one or two COCs present at elevated concentrations. More detailed project-specific investigations and geospatial analyses are needed to further evaluate the potential suitability of dredged material from the individual tributaries for aquatic habitat restoration beneficial use projects.

Sample Data - Delaware River DRBC Zones 2 through 5: Considering only the samples collected in DRBC Zones 2-5, 204 samples (42.7%) collected along this length of the Delaware River had at least one COC concentration greater than the ERM/PEL. Only four of the COCs were found at elevated concentrations in more than 10% of the samples: total PCBs (20.3%), 4,4’-DDE (16.9%), 4,4’-DDD (11.7%), and 4,4’-DDT (10.0%).

There appear to be trends along the Delaware River DRBC Zones in those COCs that are more frequently found in sediment at concentrations greater than the ERM/PELs:

Zone 2	Zone 3	Zone 4	Zone 5
chlordane			
cadmium	cadmium		
4,4'-DDT/D/E	4,4'-DDT/D/E	4,4'-DDD/E	
	total PCBs	total PCBs	total PCBs
			arsenic

Based on all of the sample data, the mean chlordane concentration in DRBC Zone 2 is significantly lower than in DRBC Zones 3-5 (Table 4). However, while chlordane was detected in all of the Zone 2 samples, it was not detected in 63% of the DRBC Zone 3-5 samples. Eighty-three per cent (83%) these non-detects had one-half detection limits greater than the ERL/TEL, and thus were omitted from the Aquatic Habitat Restoration Suitability Threshold Analysis (Appendix C). In DRBC Zones 3-5, where chlordane was detected, its concentration was greater than the ERM/PEL in only 12% of the samples (compared to 30.6% of the DRBC Zone 2 samples). Thus, while it appears that chlordane may frequently limit aquatic habitat restoration beneficial uses of dredged material from DRBC Zone 2, the evaluation and interpretation of the chlordane data in DRBC Zones 3-5 are hampered by the large number of non-detects.

The mean cadmium concentrations in DRBC Zone 2 and Zone 3 were comparable, and statistically significantly greater than the mean concentrations for DRBC Zone 4 and Zone 5 (Table 4). The mean arsenic concentration in DRBC Zone 5 was significantly greater than in DRBC Zones 2-4 (Table 4). The Aquatic Habitat Restoration Suitability Threshold Analysis results and the sediment concentration data indicate that cadmium (in DRBC Zone 2 and Zone 3) and arsenic (in DRBC Zone 5) may frequently limit potential dredged material aquatic habitat restoration beneficial uses compared to other areas along the Delaware River.

Based on all of the sample data, the mean 4,4'-DDT, 4,4'-DDE, and 4,4'DDD concentrations were generally similar in DRBC Zones 2-5 (Table 4). Non-detects that had one-half detection limits greater than the ERL/TEL was omitted from the Aquatic Habitat Restoration Suitability Threshold Analysis (Appendix C). The sediment concentration data and results of the Aquatic Habitat Restoration Suitability Threshold Analysis indicate that 4,4'-DDT/DDD/DDE may frequently limit aquatic habitat restoration beneficial uses of dredged material from DRBC Zones 2-4 along the Delaware River.

Mean total PCB concentrations were significantly higher in DRBC Zone 3 and Zone 5 compared to DRBC Zone 2 and Zone 4 (Table 4). PCBs were detected in all of the DRBC Zone 2 samples, but 29-33% of the samples in each of DRBC Zones 3-5 were non-detects. Ninety-six samples from DRBC Zones 3-5 had a total PCB concentration greater than the ERM/PEL, but 66 of these samples (69%) were non-detects with one-half detection limits greater than the ERM/PEL. Use of the total PCB non-detects could potentially give false exceedances of the aquatic habitat restoration suitability threshold in a substantial percentage of the samples in DRBC Zones 3-5 (Appendix C).

Geographic Locations of Interest: In addition to the general trends in COC concentrations along the Delaware River that could potentially limit the suitability of dredged material for aquatic habitat restoration beneficial uses, a number of geographic locations were identified (e.g. the Schuylkill River) where 100% of the samples had at least one COC with a concentration greater than the ERM/PEL.

In DRBC Zone 3, downstream of the Walt Whitman Bridge, nine samples exceeded the ERM/PEL for at least one COC (Figure 3 and Figure 5). Three of these samples, collected in the Delaware River Main Navigation Channel, were non-detects for PCBs, 4,4'-DDD, 4,4'-DDE, and chlordane, with one-half detection limit values greater than the ERM/PEL. The remaining samples were collected closer to the western shoreline of the river and in pier areas, where samples exceeded the ERM/PEL for a variety of metals (copper, cadmium, lead), total PCBs, and/or pesticides (4,4'-DDT/DDD/DDE, chlordane).

Thirteen samples collected in the Philadelphia Naval Shipyard upstream of the mouth of the Schuylkill River (DRBC Zone 4) had a variety of COCs with detected concentrations greater than the ERM/PEL (Figure 3 and Figure 6). The total PCB concentration was greater than the ERM/PEL in all of these samples, and the 4,4'-DDT, 4,4'-DDD, and/or 4,4'-DDE concentrations were greater than the ERM/PEL in at least five samples. Except for 4,4'-DDT, these COCs were also found at elevated concentrations in the Schuylkill River. These observations suggest localized contaminant sources (e.g. industrial or stormwater discharges) and/or sediment/contaminant transport processes (from the Schuylkill River) may affect COC concentrations in the sediment in this area of the Delaware River.

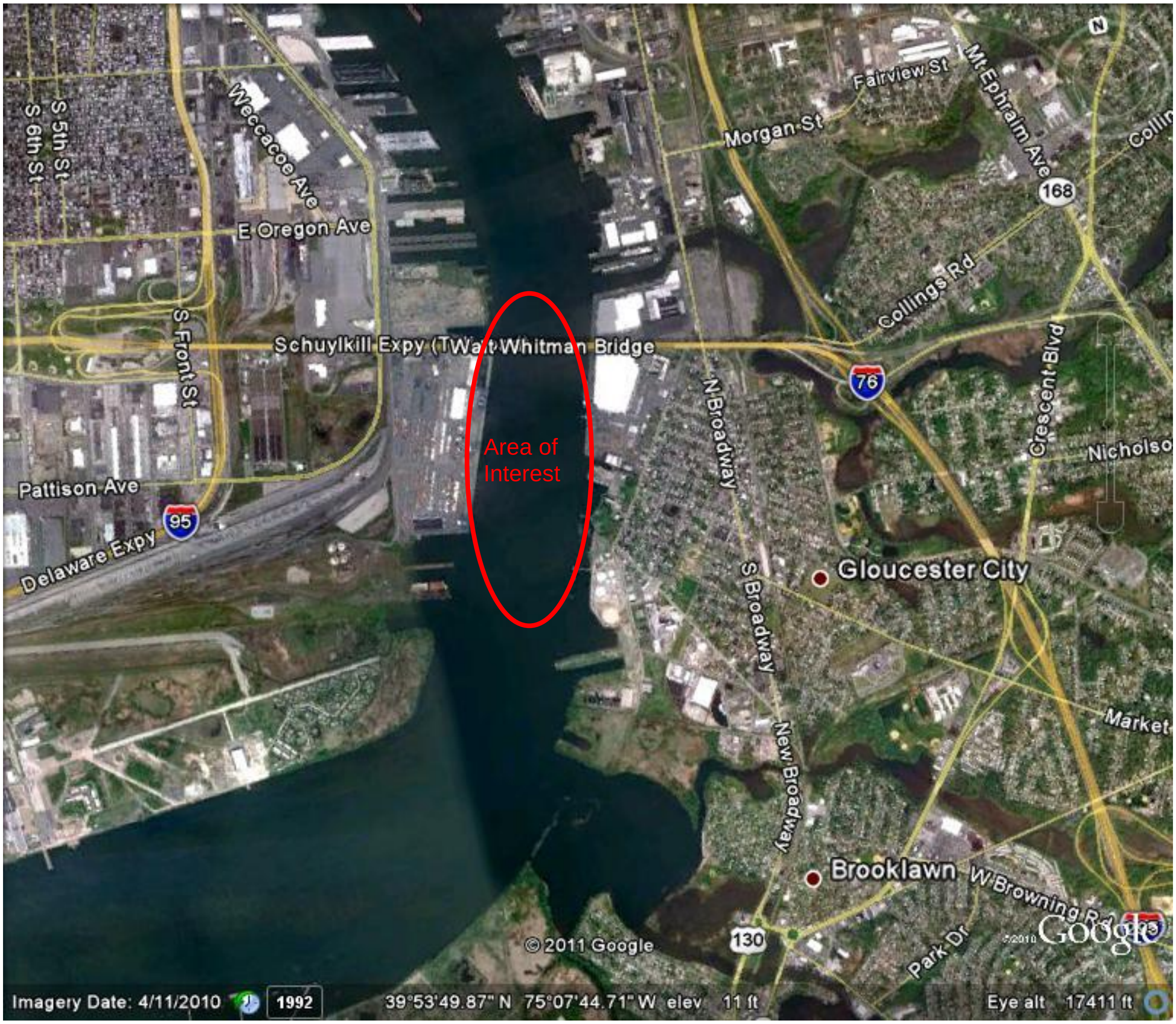


Figure 5: Area downstream of the Walt Whitman Bridge (DRBC Zone 3) with 100% sediment samples with COC concentrations greater than the ERM/PEL.

Figure 6: Area of the Philadelphia Naval Shipyard (DRBC Zone 4) with 100% sediment samples with COC concentrations greater than the ERM/PEL.

In DRBC Zone 5, upstream of Shellpot Creek, samples have a variety of COC concentrations greater than the ERM/PEL. Downstream from Shellpot Creek, samples collected off the mouth of the Christina River also have elevated COC concentrations (Figure 3 and Figure 7). Contaminants detected in the samples at concentrations greater than the ERM/PEL included arsenic, mercury, lead, and total PCBs. Three samples collected in the Christina River also had elevated mercury and/or lead concentrations, but arsenic and total PCB concentrations were less than the ERM/PEL.

Figure 7: Delaware River (DRBC Zone 5) offshore of Shellpot Creek (and upstream of the Christina River) with 100% sediment samples with COC concentrations greater than the ERM/PEL.

Also in DRBC Zone 5, offshore of the C & D Canal, a number of samples were found to have a variety of COC concentrations greater than the ERM/PEL (Figure 3 and Figure 8). Most of the samples from this area collected in the Main Channel of the Delaware River had detected concentrations of 4,4'-DDE greater than the ERM/PEL. Total PCBs were not detected in any of the navigation channel samples, with one-half detection limit values greater than the total PCB ERM/PEL (Appendix C). The samples located closer to the western shoreline of the Delaware River near Saint Georges Creek had detected concentrations of arsenic, mercury, and/or lead greater than the ERM/PEL.

Figure 8: Delaware River (DRBC Zone 5) offshore of the C & D Canal with 100% of sediment samples with COC concentrations greater than the ERM/PEL.

The data and results of the Aquatic Habitat Restoration Suitability Threshold Analysis for the DRBC Zone 5 samples are evaluated in further detail in Appendix C.

Only four sediment samples from DRBC Zone 6 had COC concentrations greater than the ERM/PEL. Most of the sediment samples from central locations in Delaware Bay had no COCs greater than the ERL/TEL (Figure 3). The concentrations of some COCs tended to be greater than the ERL/TEL along some shoreline areas of Delaware Bay and in some of its tributaries. Those areas that may need additional study include:

- Embayment near the mouths of Dennis Creek and East/West Creeks, NJ (arsenic, mercury, and cadmium);
- St. Jones River, DE (mercury, arsenic, copper, lead, total PCBs, and dieldrin);
- Maurice River, NJ and areas offshore of its mouth (mercury, arsenic, and lead).

Another indicator of the level of sediment contamination in each DRBC Zone is the number of COC ERMs/PELs exceeded by each sample (Table 7). Of the 287 sediment samples that exceeded at least one COC ERM/PEL, 134 samples (47%) exceeded only one ERM/PEL value.

Table 7: Number of Samples in Each DRBC Zone that Exceeded One or More COC ERM/PEL.

# COC ERM/PEL Exceeded	DRBC Zone 2	DRBC Zone 3	DRBC Zone 4	DRBC Zone 5	DRBC Zone 6	Tributaries	Total
1	7	34	12	49	4	28	**134**
2	3	14	7	10	0	12	**46**
3	2	14	5	7	0	10	**38**
4	6	9	3	8	0	7	**33**
5	1	3	0	1	0	7	**12**
6	2	0	2	3	0	4	**11**
7	0	0	0	2	0	6	**8**
8	0	0	0	0	0	1	**1**
9	0	0	0	0	0	3	**3**
10	0	0	0	0	0	1	**1**
Total # Samples	21	74	29	80	4	78	**287**

Five samples exceeded the ERM/PEL for eight or more of the COC, four of which were collected in the Schuylkill River; the fifth was collected from the Wissahickon Creek, a tributary of the Schuylkill River. In addition, 11 of the 17 tributary samples that exceeded the ERM/PEL for five to seven COCs were collected in the Schuylkill River. These samples were collected from 1997 to 2008, which suggests sediment in this tributary have been impacted by multiple contaminants over extended periods of time.

The remaining six tributary samples that exceeded the ERM/PEL for five to seven COCs were collected in the following tributaries: Shabakunk Creek (NJ; 7 COCs), South Branch Pennsauken Creek (NJ; 7 COCs), Cooper River (NJ; 7 COCs), Darby Creek (PA; 5 COCs), Maurice River (NJ; 5 COCs). In addition to the Darby Creek sample, four additional samples in the Delaware River (DRBC Zone 4) near the mouth of Darby Creek exceeded the ERM/PEL for two or four COCs, including mercury, arsenic, lead, total PCBs, 4,4'-DDD, 4,4'-DDE, and chlordane (Figure 9).

Six samples collected in DRBC Zone 5 exceeded the ERM/PEL for five to seven COCs (Figure 10).

Sample Data – Sample Type: Figure 11 shows that the type of sediment sample (composite, core, or grab) may be a factor affecting the aquatic habitat restoration suitability threshold. Only 18% of the composite samples exceeded the ERL/TEL or ERM/PEL, while 58% of the grab samples and 94% of the core samples exceeded the ERL/TEL or ERM/PEL. Possible explanations for these differences include:

> Thirty-nine percent (39%) of the grab samples were collected in DRBC Zone 6, compared to only 6% of the core samples; 81.5% of the core samples were collected in DRBC Zone 3, Zone 4, and Zone 5, compared to 38% of the grab samples.

> The core samples collected deeper sediment, which may have higher concentrations of the COCs (due to historical discharges), compared to the grab samples (which collect more recently deposited surface sediment).

> The core samples have been almost entirely collected by the USACE in support of Federal navigation dredging projects. Analytical detection limits for many of the COC s (particularly PCBs and the other organic COCs) were elevated in many of the USACE studies, resulting in exceedances of the ERL/TEL and ERM/PEL when one-half the detection limit is used.

The potential effect of sample type on the Aquatic Habitat Restoration Suitability Threshold Analysis results is evaluated in greater detail in Appendix C. Except in DRBC Zone 5, sample type did not have a large effect on the Aquatic Habitat Restoration Suitability Threshold Analysis category.

Figure 9: Samples with multiple COCs with elevated concentrations in the Delaware River (DRBC Zone 4) offshore of Darby Creek.

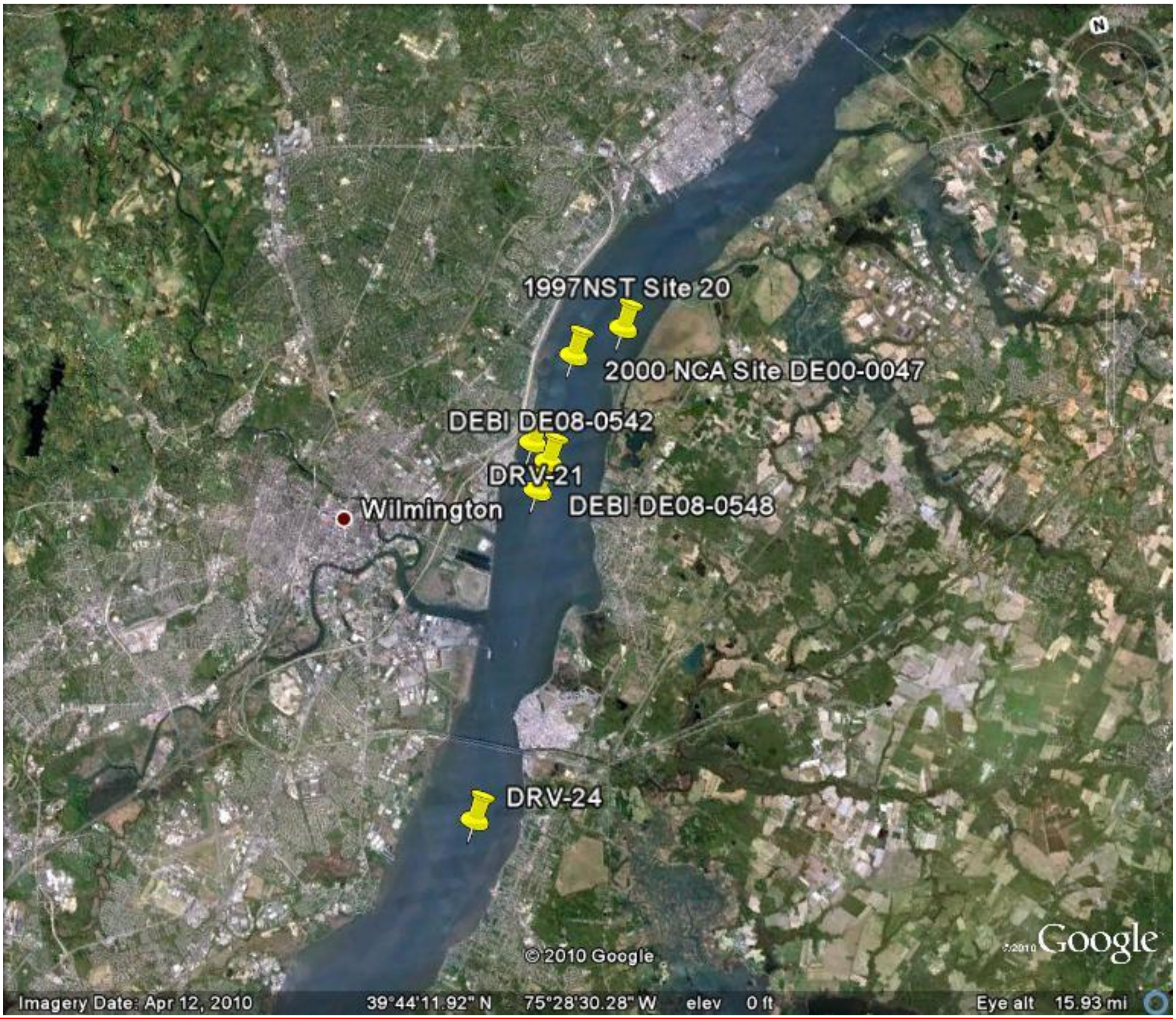
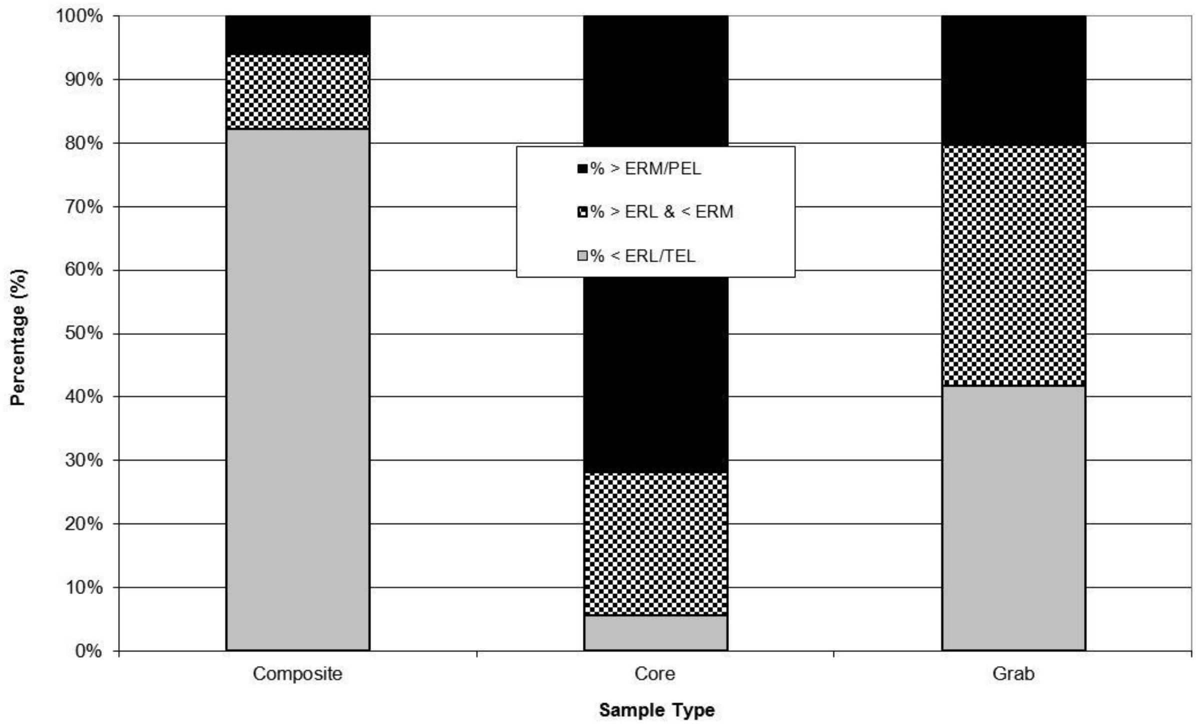


Figure 10: DRBC Zone 5 sediment samples that exceed the ERM/PEL for five to seven COCs.

Figure 11: Aquatic Habitat Restoration Suitability Threshold Analysis - Percentages of the Sediment Samples in each Threshold Category by Type of Sample



Upland Beneficial Use Threshold Analysis Results

Figure 12 (and Appendix E) shows the results of the Upland Beneficial Use Threshold Analysis for all sediment samples:

- 63% of the samples did not have a COC concentration greater than the Lowest Residential Threshold (LRT);
- 35% of the samples had at least one COC concentration greater than the LRT and no COC concentration greater than the HNRT;
- 2% of the samples had at least one COC concentration greater than the HNRT.

Based on concentrations of the selected COCs, approximately 63% of the samples are clean enough for "unrestricted" dredged material upland beneficial uses (no COCs > LRT), and an additional 35% of the samples are indicative of sediments that are potentially suitable for "limited/restricted" upland beneficial uses (at least one COC concentration > LRT and no COC > HNRT). Only 2% of the samples are indicative of sediments that are probably unsuitable for any dredged material upland beneficial uses (at least one COC concentration > HNRT). This analysis did not consider the magnitude of the observed exceedances of the LRT and HNRT.

Note: Subsequent to the completion of the threshold analysis, the sediment data for 4,4'-DDD, 4,4'-DDE, and total chlordane were added to the database and the analysis re-run. None of the samples exceeded the LRT for 4,4'-DDD and 4,4'-DDE. Four samples exceeded the LRT for chlordane, three of which were non-detects. Based on this, it was decided that revising the Upland Beneficial Use Threshold Analysis was not necessary.

In general, sediment samples suitable for “unrestricted” dredged material upland beneficial uses are interspersed among samples acceptable for “limited/restricted” upland beneficial uses. Very few locations have sediment contaminated at high levels that would make them unsuitable for any type of dredged material upland beneficial use.

Figure 13 shows the percentages of the samples in each DRBC Zone that were in each of the three upland beneficial use threshold categories. DRBC Zone 6 (Delaware Bay) had the largest percentage of samples with no COC concentration greater than the LRT (92%), and no sample from DRBC Zone 6 had a COC concentration greater than the HNRT. No samples in DRBC Zone 2 and Zone 4 had a COC concentration greater than the HNRT, and only 1-2% of the samples from DRBC Zone 3 and Zone 5 had such elevated COC concentrations. In contrast, 6.4% of the tributary samples had a COC concentration greater than the HNRT. This suggests that the tributaries are likely to be sources of contaminants to the Delaware River.

The data in Figure 13 suggest, from a contaminant standpoint, dredged material from DRBC Zone 6 (Delaware Bay) would probably be suitable for “unrestricted” upland beneficial use projects. Dredged material from DRBC Zones 2 through 5 and the tributaries would (except in a few instances) be suitable for either “unrestricted” or “limited/restricted” upland beneficial uses.

Figure 12: Results of the upland beneficial use threshold analysis.

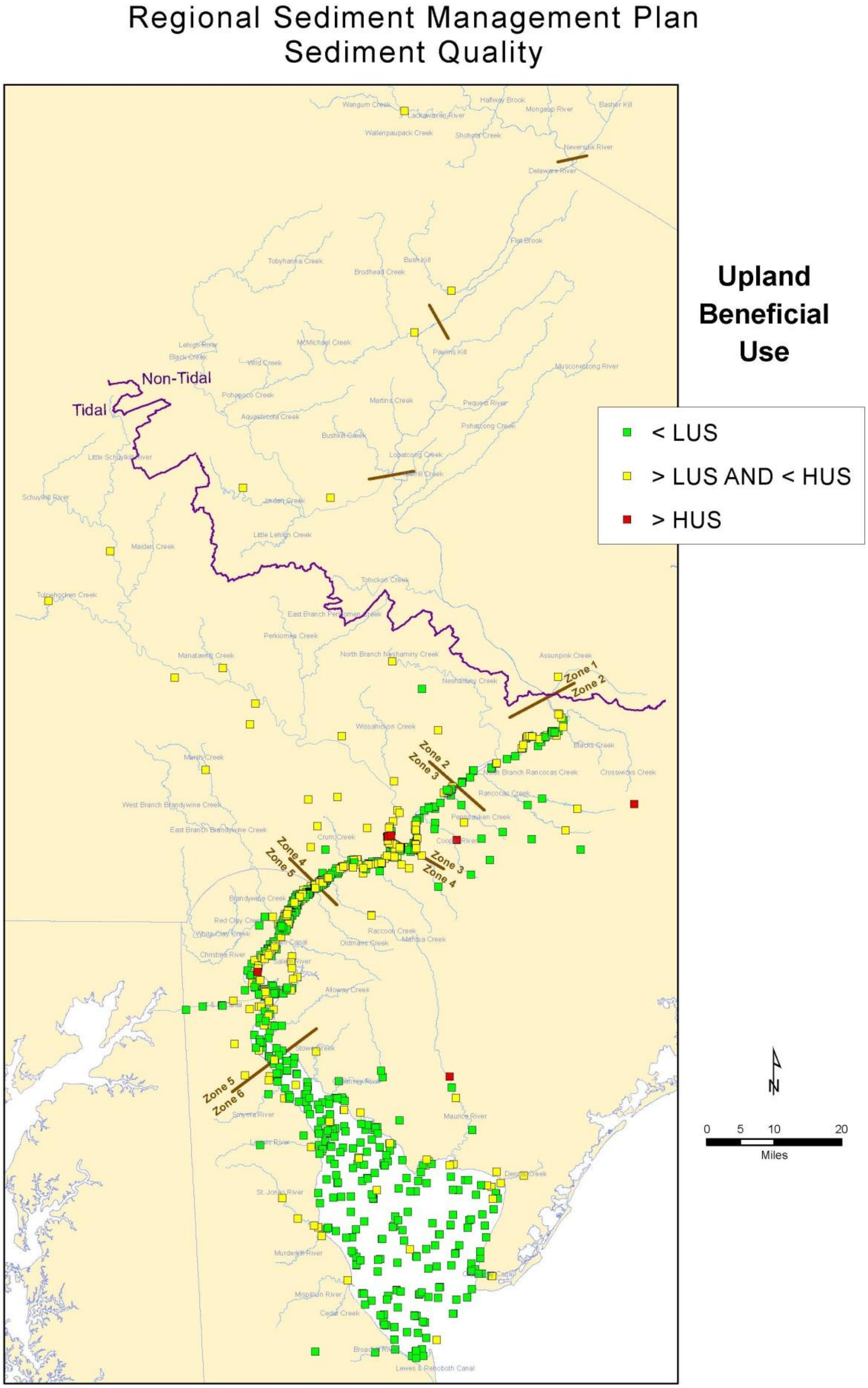
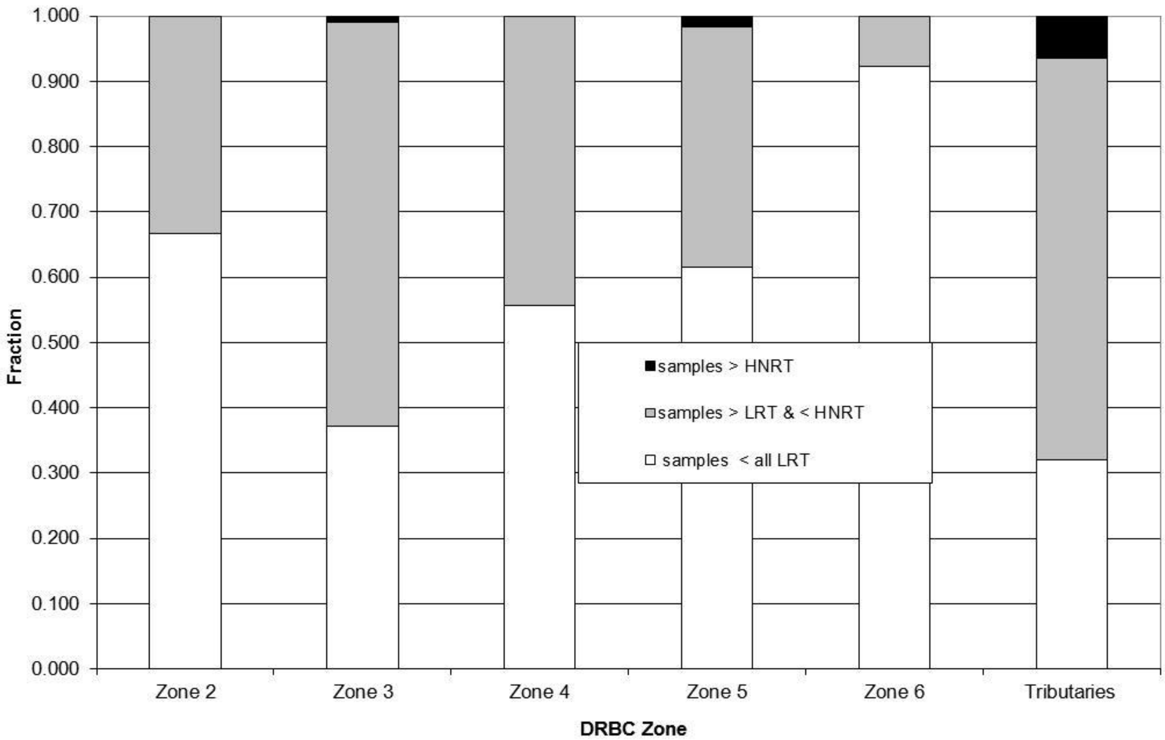


Figure 13: Upland Beneficial Use Threshold Analysis
Fraction of the Sediment Samples in Each DRBC Zone



The HNRT for arsenic, lead, and/or total PCBs were exceeded in 14 samples (Table 8).

Table 9 shows the percentage of sediment samples collected in each of the DRBC Zones that exceed the LRT for each COC. Very few of the sediment samples from DRBC Zone 6 (8%) are impacted by the COCs. Within DRBC Zones 2 through 5, potentially problematic COCs are limited to arsenic, cobalt, benzo(a)pyrene, and total PCBs. In addition to the COCs found at elevated concentrations in the Delaware River, small percentages of the tributary samples exceeded the LRT for lead (1.3%) and dieldrin (2.6%). As discussed in Appendix C, many of the samples with elevated benzo(a)pyrene, dieldrin, or total PCB concentrations may actually be non-detects, with one-half detection limits that result in false exceedances of the LRT.

Table 8: Observed Exceedances of the HNRT.

Sample ID	Arsenic	Lead	Total PCBs	Location/Date
1465950		X		1998 - N. Branch Rancocas Creek
USGS1467150	X			1999 – Cooper River
NJ01-0090-A	X			2001 – Maurice River
DE08-0542	X		X	2008 - DRBC Zone 5
DE08-0548	X			2008 - DRBC Zone 5
DRV-4			X	2005 – DRBC Zone 3
PQ-2 (surface)			X*	1992 - DRBC Zone 5
PQ-2 (depth)			X*	1992 - DRBC Zone 5
SR-771	X		X	2007 – Schuylkill River
SR-772	X		X	2007 – Schuylkill River
SR-773			X	2007 – Schuylkill River
SR-774	X		X	2007 – Schuylkill River
SR-775			X	2007 – Schuylkill River
SR-785	X			1997 – Schuylkill River
SR-787			X	1997 – Schuylkill River
X* = PCBs were not detected with detection limits 2-3 times the Highest "Non-Residential" Threshold.				

Table 9: Percentage of samples in each DRBC Water Quality Zone that exceeded the LRT for each COC.

COC	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Cobalt	NSA	29.5	6.6	3.0	NSA
Total PCBs	0.0	31.4	10.4	21.6	0.0
Arsenic	22.2	12.4	10.4	21.2	3.4
Benzo(a)pyrene	13.9	37.1	29.2	15.6	4.7
Total # samples =	36	105	106	231	298
NSA = no samples analyzed for that COC					

Only 97 samples were analyzed for cobalt, 80 of which exceeded the LRT. Cobalt exceedances were observed in DRBC Zone 3 (including the Fairless Turning Basin and the Philadelphia Naval Shipyard), Zone 4, Zone 5, the Schuylkill River, and a number of other smaller tributaries to the Delaware River.

The LRT for total PCBs was exceeded in 124 samples, and 10 samples exceeded the HNRT. PCBs were not detected in 77 of these samples due to elevated analytical detection limits (mean $\pm$ SD detection limit = 987 $\pm$ 372 ug/kg in these samples; LRT = 200 ug/kg); also see Appendix C.

The LRT for benzo(a)pyrene was exceeded in 161 samples. However, benzo(a)pyrene was not detected in 74 of these samples due to elevated analytical detection limits (mean $\pm$ SD detection limit = 0.562 $\pm$ 0.126 mg/kg in these samples; LRT = 0.2 mg/kg); also see Appendix C.

Sample Data - Tributaries: Ten of the 156 sediment samples (6.4%) collected in the tributaries had at least one COC with a concentration that exceeded the HNRT.

Seven of the samples were collected in the Schuylkill River, which has been identified as a potential contaminated sediment “hot spot” (also see ***Aquatic Habitat Restoration Suitability Threshold Analysis Results***). Arsenic and total PCBs were present at concentrations greater than the HNRT (Table 8). All but one of the other samples collected in the Schuylkill River exceeded the LRT for arsenic, total PCBs, cobalt and benzo(a)pyrene. Overall, 97% of the Schuylkill River samples had at least one COC concentration greater than the LRT.

The three remaining tributary samples with COC concentrations greater than the HNRT were collected in New Jersey waterbodies: North Branch Rancocas Creek (lead), Cooper River (arsenic), and Maurice River (arsenic). None of the other Rancocas Creek or Cooper River samples exceeded the LRT for lead or arsenic, suggesting that the very high concentrations may be isolated cases. Three of the six additional Maurice River samples had arsenic concentrations greater than the LRT, suggesting arsenic contamination may be more widespread in this tributary.

Sample Data – DRBC Zone 5: Four of the five Delaware River samples with COC concentrations greater than the HNRT were collected in DRBC Zone 5. Two of these samples had elevated concentrations of total PCBs and/or arsenic, and were collected near the mouth of Shellpot Creek (Table 8 and Figures 7 and 10). Additional samples collected in the vicinity of Shellpot Creek also exceeded the LRT for arsenic, cobalt, total PCBs, and/or benzo(a)pyrene. However, some (but not all) of the exceedances for total PCBs and benzo(a)pyrene occurred in samples with non-detects. The Shellpot Creek area has been identified a geographic location of interest (see ***Aquatic Habitat Restoration Suitability Threshold Analysis Results***).

The other two samples were collected in different strata of the same core sample, and were non-detect for PCBs.

Sample Data – DRBC Zone 3: One sample collected in DRBC Zone 3 had a detected total PCB concentration greater than the HNRT. This sample was collected just downstream of the Walt Whitman Bridge (Figure 5) in a previously identified geographic location of interest (see ***Aquatic Habitat Restoration Suitability Threshold Analysis Results***).

Another indicator of the level of sediment contamination in each DRBC Zone is the number of sediment samples that exceed the LRT for varying numbers of COCs (Table 10). Of the 344 sediment samples that exceeded at least one LRT, 217 samples (63%) exceeded the threshold for only one COC. This indicates that throughout the Delaware Estuary and its watershed the presence of multiple contaminants at elevated levels in sediment will probably not be of concern when evaluating the suitability of dredged material for potential upland beneficial uses.

Only seven sediment samples (2%) exceeded the LRT for four or more of the COCs. Four of these samples are located in the Schuylkill River and two were collected in DRBC Zone 5. The four Schuylkill River samples also exceeded the HNRT for at least one COC.

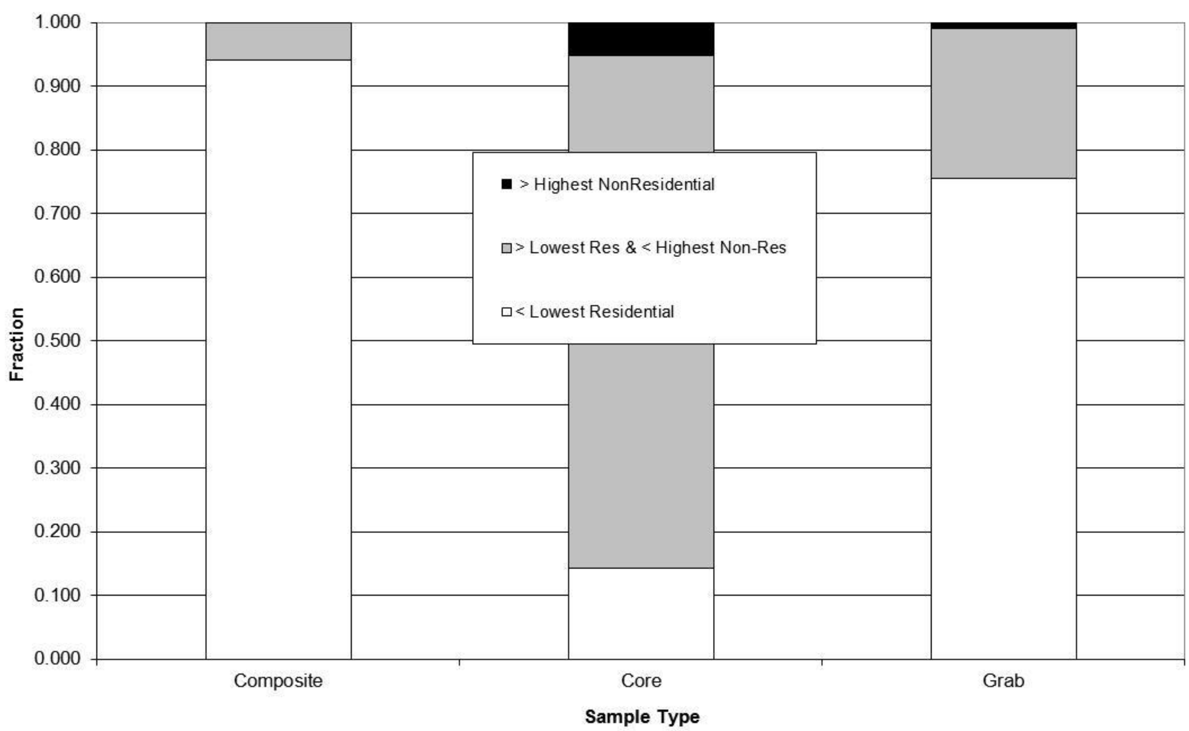
Most of the sediment samples from DRBC Zone 6 (Delaware Bay) appear to be suitable for “unrestricted” upland beneficial use; there is a very low probability of exceeding the LRT for any COC (Figure 13). However, as was the case for aquatic habitat restoration suitability, sediment of potential concern in DRBC Zone 6 appear to be limited to areas near the Delaware Bay shoreline and the mouths of certain tributaries (Maurice River, NJ; Dennis Creek, NJ; St. Jones River, DE). Arsenic and benzo(a)pyrene are potential concerns in these areas.

Table 10: Number of Samples in Each DRBC Zone that Exceeded One or More COC LRT.

# COC LRT Exceeded	DRBC Zone 2	DRBC Zone 3	DRBC Zone 4	DRBC Zone 5	DRBC Zone 6	Tributaries	Total
1	11	26	37	47	24	72	217
2	1	31	7	32	0	24	95
3	0	8	3	8	0	6	25
4	0	1	0	2	0	1	4
5	0	0	0	0	0	3	3

Figure 14 shows that the type of sediment sample (composite, core, or grab) may be a factor affecting the upland beneficial use threshold. Only 6% of the composite samples exceeded a LRT, while no composite sample exceeded a HNRT. Eighty-six per cent (86%) of the core samples exceeded a LRT, compared to 24% of the grab samples. Possible explanations for the differences observed in Figure 16 have been previously discussed in the ***Aquatic Habitat Restoration Suitability Threshold Analysis Results*** section of this report.

Figure 14: Upland Beneficial Use Threshold Analysis
Fraction of the Sediment Samples by Type of Sample



Quality Assurance Issue

When reviewing and comparing the metadata in the Delaware Estuary RSMP Sediment Quality Database with the sample locations shown on the GIS-based figures in this white paper, it was observed that some samples that were listed in the database as being located in one DRBC Zone were located within an adjacent DRBC Zone on the GIS-based maps. Such samples are usually located close to the border between DRBC Zones. These inconsistencies have not been evaluated in detail, but could result in limited errors in the various DRBC Zone-based analyses presented in this white paper.

Sediment Toxicity Data

In addition to analyzing sediment for contaminants, a number of studies conducted by NOAA and USEPA also evaluated the toxicity of the sediment to benthic biota. One method used to assess toxicity is to compare the survival of the amphipod *Ampelisca abdita* exposed to the collected sediment and a control/reference sediment in a bioassay under laboratory conditions. It should be noted that use of *A. abdita* to evaluate potential aquatic toxicity, while acceptable for marine waters, may be problematic in less saline waters of the Delaware Estuary. Additional toxicity testing of sediment from the Delaware Estuary is needed, preferably with an organism that is less sensitive to variation in salinity, such as *Leptocheirus plumulosus*.

Publicly available data (302 samples) from NOAA and USEPA bioassay studies were evaluated. Only 25 of these sediment samples (8%) had a mean survival of less than 80% in the acute toxicity tests, which is the value typically used to indicate that the sediment may be toxic to biota. Seventeen (17) of these samples exceeded one or more ERM/PEL, and three exceeded at least one ERL/TEL. Five of the samples did not exceed an ERL/TEL (Table 11).

Table 11: Number of toxic samples in various analyses for the 302 samples with *Ampelisca abdita* acute toxicity test data.

# Toxic samples	# samples > ERM/PEL	# samples > ERL/TEL
25	84	120
# Toxic samples:	17	3

Nine of the 25 toxic samples were collected in tributaries, seven in DRBC Zone 6, five in DRBC Zone 5, two in DRBC Zone 4, and one each in DRBC Zone 3 and DRBC Zone 2. This is a relatively large number of toxic samples from DRBC Zone 6 compared to the low percentage of samples in the larger database that exceed an ERL/TEL or ERM/PEL (Figure 4).

Sixty-seven (67) of the 302 samples that had a COC concentration greater than the ERM/PEL, and 117 of the samples that had a COC concentration greater than the ERL/TEL, were not toxic to *A. abdita* (Table 11). This suggests that the results of the Aquatic Habitat Restoration Suitability Threshold Analysis used in this white paper may, in general, be conservative in its predictions of the suitability of dredged material in relation to toxicity. However, five samples were toxic to *A. abdita* but did not have a COC concentration greater than the ERL/TEL.

The white paper sediment analyses did not consider potential effects of bioaccumulation and biomagnification of the COCs in aquatic food webs, populations, and communities. These effects typically occur at sediment contaminant concentrations lower than those that result in acute toxicity.

Summary and Conclusions

1. The *Sediment Quality White Paper* presents and discusses the results of a screening protocol that was developed to evaluate the potential suitability of sediment/dredged material for aquatic habitat restoration and upland beneficial uses. **Future regulatory, management, or remedial decisions concerning beneficial uses of dredged material will require more comprehensive project-specific evaluations. These would include, for most habitat restoration projects, an evaluation of potential contaminant bioavailability effects (toxicity and bioaccumulation).**

2. The Sediment Quality Committee has compiled a database of 932 *in situ* bulk chemistry sediment samples with data for the following COCs: arsenic, cadmium, cobalt, copper, lead, mercury, total chlordane, dieldrin, 4,4'-DDT/DDD/DDE, benzo(a)pyrene, total PCBs, and total dioxin/furan TEQ. Statistical analyses of the mean COC concentrations in each DRBC Water Quality Zone identified significant differences between DRBC Zones. In general, COC concentrations are consistently lowest in DRBC Zone 6 (Delaware Bay).

3. Most of the PCB and pesticide data are from older sediment samples, collected before 2001, and analyzed using methods with detection limits greater than the aquatic habitat restoration suitability and upland beneficial use threshold criteria. This results in many of the samples having non-detected concentrations for these COCs that are difficult to use and interpret. Likewise, elevated analytical detection limits for benzo(a)pyrene pose similar problems when using the data.

Aquatic Habitat Restoration Suitability Threshold Analysis

1. This analysis compared the bulk sediment chemistry data to threshold criteria based on established SQGs for toxicity to benthic organisms (ERL/TEL and ERM/PEL). Approximately 35% of the sediment samples are <u>probably</u> clean enough to be beneficially used in aquatic habitat restoration projects (no COC > ERL/TEL), and an additional 34% of the samples are <u>potentially</u> clean enough for such beneficial uses (one or more COCs > ERL/TEL, but none > ERM/PEL). About 31% of the samples appear to be problematic in regards to their suitability for beneficial use in aquatic habitat restoration projects (at least one COC > ERM/PEL).

2. Sediment quality is heterogeneous throughout Delaware River, with "cleaner" sediment samples interspersed among "more contaminated" samples. Except in Delaware Bay (DRBC Zone 6), sediment samples with at least one COC greater than the ERM/PEL can be frequently found throughout the Delaware River and its tributaries. The data suggest that dredged material from DRBC Zone 6 would probably be suitable for aquatic habitat restoration beneficial use projects, with that from DRBC Zone 4 and Zone 5 potentially suitable for such uses. In contrast, the beneficial use of dredged material from DRBC Zone 2, Zone 3, and the estuary tributaries would probably be problematic for such projects.

3. In DRBC Zones 2 through 5, some COCs are present at concentrations greater than the ERM/PEL in at least 10% of the samples collected in each zone. There appear to be trends along the Delaware River DRBC Zones in these COC:

Zone 2	Zone 3	Zone 4	Zone 5
chlordane			
cadmium	cadmium		
4,4'-DDT/D/E	4,4'-DDT/D/E	4,4'-DDD/E	
	total PCBs	total PCBs	total PCBs
			arsenic

Upland Beneficial Use Threshold Analysis

1. This analysis compared the bulk sediment chemistry data to threshold criteria for each COC based on State regulatory criteria for the placement of soil/fill at upland sites (LRT and HNRT). Approximately 63% of the samples are clean enough for "unrestricted" dredged material upland beneficial uses (no COC > LRT). An additional 35% of the samples are indicative of sediments that are potentially suitable for "limited/restricted" upland beneficial uses (at least one COC concentration > LRT, no COC > HNRT). Only 2% of the samples are indicative of sediments that are probably unsuitable for any dredged material upland beneficial uses (at least one COC concentration > HNRT). The only COCs found at concentrations greater than the HNRT were arsenic, lead, and total PCBs.

2. In general, sediment samples suitable for "unrestricted" upland beneficial uses are usually interspersed among samples acceptable for "limited/restricted" upland beneficial uses throughout the Delaware Estuary. The data suggest that dredged material from DRBC Zone 6 (Delaware Bay) would probably be suitable for "unrestricted" upland beneficial use projects. Dredged material from DRBC Zones 2 through 5 and the tributaries would (except in a few instances) appear to be suitable for either "unrestricted" or "limited/restricted" upland beneficial uses

3. The following geographic locations of interest have been identified where samples had at least one COC with a concentration greater than the HNRT, and/or a large percentage of the samples had at least one COC with a concentration greater than ERM/PEL:

   > Schuylkill River

   > DRBC Zone 3 – downstream of the Walt Whitman Bridge

   > DRBC Zone 4 – Philadelphia Naval Shipyard (near mouth of the Schuylkill River)

   > DRBC Zone 5 – near the mouths of Shellpot Creek, the Christina River, and the C & D Canal.

   > North Branch Rancocas Creek

   > Cooper River

   > Maurice River.

Recommended Actions

1. A number of data gaps have been identified that need additional study. Since sediment contamination in the Delaware Estuary appears to be present only rarely at concentrations that would preclude upland beneficial uses, these studies should focus on evaluating contaminant impacts on the suitability of the sediment for aquatic habitat restoration projects.

   a) Continued development, maintenance, and evaluation of the white paper database to include available sample data from small (i.e. non-USACE) dredging projects, as well as future larger dredging projects, research studies, etc.
   b) Collection and analysis of additional sediment core samples from areas outside of navigation channels and berthing areas to provide additional spatial and temporal data. This work should focus on areas where few core samples have been collected in the past and locations along the shoreline of the Delaware River and Bay.
   c) Analysis of additional samples using State of the art methods (with low detection limits) for cobalt, dioxins/furans, PCB congeners, pesticides, and PAHs.

2. Additional studies are needed to evaluate and confirm the presence of tentatively identified contaminated sediment "hot spots" in the Delaware River and its tributaries. This should be followed by trackdown studies to identify the source(s) of contamination. Remediation alternatives for the contaminated sediment should also be evaluated

3. Additional studies are needed to evaluate the bioavailability of the contaminants of concern, including risks to the aquatic ecosystem resulting from acute and chronic sediment toxicity, and the bioaccumulation of these contaminants.

References Cited

New Jersey Department of Environmental Protection (NJDEP) Dredging Task Force 1997. The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters. October 1997, 55 pp. + appendices.

U.S. Army Corps of Engineers (USACE) 2003. Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual. Technical Report ERDC/EL TR-03-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS, January 2003, 337 pp.

U.S. Environmental Protection Agency (USEPA) and Department of the Army - U.S. Army Corps of Engineers (USACE) 1998. Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. - Testing Manual (Inland Testing Manual). EPA 823-B-98-004, February 1998, 409 pp.

Sediment Quality White Paper Committee

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Appendix A

Sediment Quality Thresholds

Appendix A: Sediment Quality Thresholds

Sediment quality can be a complex ecosystem index to evaluate, due in part to the lack of a clear definition of "impaired sediment". In addition sediment, unlike the water column, tends to be spatially and temporally heterogeneous in both physical and chemical characteristics. Since the Delaware Estuary Regional Sediment Management Plan (RSMP) is a planning exercise, it is less important to argue the scientific merits of methods to assess sediment quality than it is to define a way to partition Delaware Estuary sediment into categories of greater or lesser quality. A relatively simple procedure is needed to determine the nature and extent of sediment contamination, and the suitability of sediment for aquatic habitat restoration and upland beneficial uses.

The simplest threshold analysis would allow the Sediment Quality Committee to divide the sediment of the Delaware Estuary into two categories: "clean" and "contaminated". For several hundred years the Delaware River and its watershed have been used for extensive industrial, commercial, and agricultural land uses. It is unlikely that any of the sediment can be considered truly clean. Therefore, more discerning thresholds are necessary, with the basic presumption that the cleanest sediment is suitable for a wide range of uses, while potential uses become more restricted as contamination increases.

Development of the sediment quality thresholds by the Sediment Quality Committee relied upon the use of (1) nationally-recognized Sediment Quality Guidelines (SQG), and (2) State soil, sediment, and dredged material regulatory criteria. Because the choice of criteria can be controversial, the committee chose not to determine the merits of any of the SQG/criteria when developing the thresholds. Rather, the Sediment Quality Committee chose to use as thresholds either the highest or lowest SQG/criteria concentrations available for each contaminant-application. This provides a conservative approach suitable for the Delaware Estuary RSMP planning exercise.

The Sediment Quality Committee recognizes the limits of the analyses and does not advocate the use of the selected sediment quality thresholds for regulatory purposes. By choosing to use one SQG/criteria over others, the committee is not judging the merits of the other SQG/criteria. One of the limitations of the use of SQGs to predict sediment suitability for aquatic habitat restoration is that it only considers potential toxic effects of contaminants. The committee did not consider potential effects of bioaccumulation on aquatic food webs and the aquatic ecosystem.

Sediment Quality Guidelines (SQG)

The National Oceanic and Atmospheric Agency (NOAA) has published tables of widely accepted SQGs to help predict the potential for a specific concentration of a sediment contaminant to result in a measurable biological effect in the aquatic environment (Screening Quick Reference Tables, SQuiRT; http://response.restoration.noaa.gov/book_shelf/122_NEW-SQuiRTs.pdf). Typically, SQGs provide both a lower (ERL/TEL; Effects Range Low/Threshold Effects Level) and an upper (ERM/PEL; Effects Range Median/Probable Effects Level) concentration threshold for each COC. The Sediment Quality Committee has decided to use a similar approach, dividing the sediment into categories of Clean, Possible Eco-Effects, and Probable Eco-Effects (Figure A-1). The criteria were primarily used to identify sediment contaminant levels that would limit uses of sediment for aquatic habitat restoration. The thresholds chosen varied with the COC, but were the lowest contaminant concentrations available of the two SQG (ERL or TEL, ERM or PEL) in the SQuiRT tables.

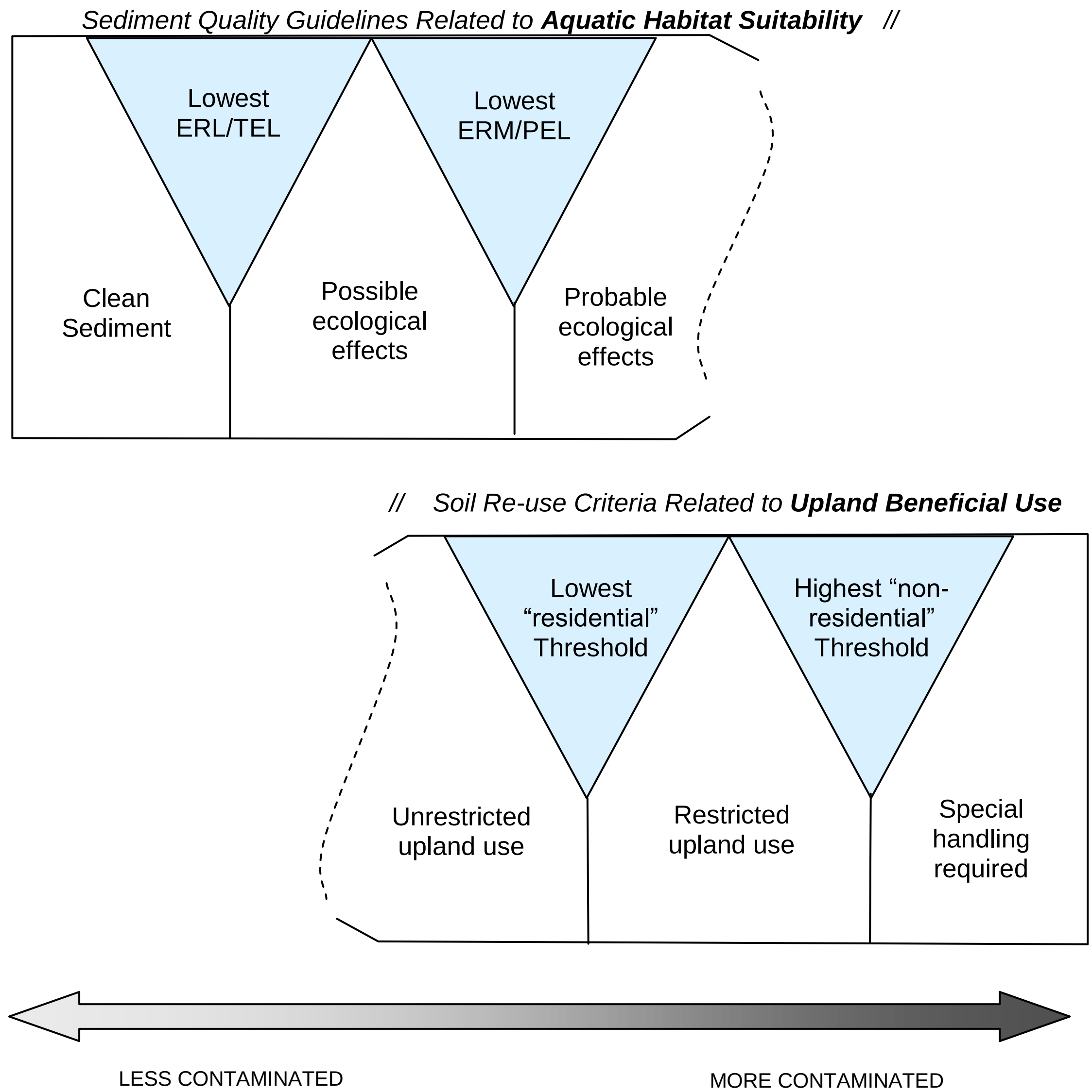
State Soil, Sediment, and Dredged Material Regulatory Criteria:

The States of Pennsylvania, New Jersey, and Delaware have incorporated contaminant specific sediment (dredged material) quality criteria into fill and use limits associated with the regulatory review of dredged material upland beneficial use projects.

In New Jersey, sediment/dredged material sampling and analyses are required on a project-specific basis, and typically would include bulk sediment chemistry analyses of a representative number of core/composite samples. Analytical results are compared to the New Jersey Residential and Non-residential Soil Remediation Standards (N.J.A.C. 7:26D; http://www.nj.gov/dep/srp/regs/rs/rs_appendix1.pdf) to determine suitable upland uses for the dredged material after it has been dewatered. Some dredged material may be processed (e.g. through the addition of lime or other additives) to allow for a variety of beneficial uses.

The upland criteria for the State of Delaware were published in the 1999 revision to the Uniform Risk-Based Remediation Standards (Remediation Standards Guidance Under the Delaware Hazardous Substance Cleanup Act, DNREC, 1999). The standards are for human health based cleanups. The lower standard is for unrestricted use in critical water resource areas and the upper standard for restricted use in non-critical water resource areas.

Figure A-1. Categories of sediment quality and corresponding thresholds.



In Pennsylvania, bulk sediment chemistry data are required to (1) develop Clean Water Act Section 401 Water Quality Certificate conditions, and (2) identify waste management options for the sediment/dredged material. Most dredged material falls into one of four categories[22]:

1. Hazardous Waste, which exceeds the criteria for the Toxicity Characteristic Leaching Procedure (TCLP);
2. Wastes which do not meet regulated fill limits (materials may be placed pursuant to a project-specific permit);
3. Regulated fill (meets all limits for regulated fill);
4. Clean fill (meets all values for clean fill).

The committee adopted the standards currently used to make decisions regarding the suitability of soils for beneficial use in Delaware, Pennsylvania, and New Jersey. These standards, while developed primarily to determine potential human health impacts, are also used by the States to evaluate the suitability of dredged material for upland beneficial use. Thus, they provide a convenient and accepted set of thresholds for the COCs, and are particularly relevant to the Delaware Estuary RSMP planning exercise. The States make a distinction between residential and commercial/industrial (i.e. non-residential) uses of soils, and have two thresholds for each COC. Since the States differ on their promulgated standards, for each COC the Sediment Quality Committee chose to use the Lowest "Residential" Threshold, and the Highest "Non-residential" Threshold (Figure A-1) from the different States' values. The rationale for using the highest of the State's "non-residential standards" is that sediment that exceeded the highest standard would not be suitable in any of the three States for upland placement without special handling.

Sediment Quality Thresholds

The Sediment Quality Committee integrated the various SQGs and State soil/sediment regulatory criteria to develop a set of sediment quality thresholds for each COC. The main objective of this effort was to identify sediment contamination levels (i.e. thresholds) that would distinguish clean sediment suitable for all potential uses from those that would potentially limit the suitability of sediment for aquatic habitat restoration or upland beneficial uses of dredged material. Figure A-1 shows the conceptual scheme developed to establish the sediment quality thresholds, and Table A-1 shows the thresholds developed for each COC.

In most cases, the white paper sediment quality thresholds progress from lower COC concentrations to higher COC concentrations in the order ERL/TEL < ERM/PEL < Lowest Residential < Highest Non-residential. However, exceptions were found for arsenic and benzo(a)pyrene, both of which are human health concerns. In these two cases, the Lowest Residential threshold concentration was less than the ERM/PEL threshold.

It is important to stress that the concentrations of the various COCs present in a single sediment sample are likely to meet different sediment quality thresholds. However, the COC present at a concentration that exceeds the least stringent (i.e. highest COC concentration) sediment quality threshold essentially establishes the overall sediment quality for that sample.

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[2] PA Department of Environmental Protection, Bureau of Land Recycling and Waste Management, Document No. 258-2182-773 – "Management of Fill", April 24, 2004; PA Department of Environmental Protection, Bureau of Waste Management, General Permit for Processing/Beneficial Use of Residual Waste, Permit No. WMGR096SE003, April 23, 2009)

Table A-1: Sediment Quality Thresholds

	Clean Sediment Threshold *Lower of ERL/TEL (marine and freshwater)*	Probable Eco-Effects Threshold *Lower of ERM/PEL (marine and freshwater)*	Unrestricted Upland Use Threshold *Lower of DE, NJ, or PA Clean/Residential Fill*	Restricted Upland Use Threshold *Higher of DE, NJ, or PA WMGR/Non-Residential Fill*
Sum PCBs (ug/kg)	21.6[3]	189[4]	200[7]	1,000[8]
4,4'-DDT (ug/kg)	1[1]	4.77[4]	2,000[7]	230,000[10]
4,4'-DDE (ug/kg)	1.42[5]	6.75[6]	2,000[7]	170,000[10]
4,4'-DDD (ug/kg)	1.22[3]	7.81[4]	3,000[7]	30,000[10]
Dieldrin (ug/kg)	0.02[3]	4.3[4]	40[7]	440[10]
Benzo(a)pyrene (ug/kg)	31.9[5]	763[4]	90[12]	11,000[10]
Dioxin/furan TEQ (ug/kg)	0.00085[3]	0.0215[4]	0.120[9] 0.5[11]	1.0[11]
Chlordane (ug/kg)	0.5[1]	6[2]	200[7]	16,000[13]
Cobalt (mg/kg)	Not Available	Not Available	8[9]	12,000[13]
Arsenic (mg/kg)	5.9[5]	17[6]	12[9]	53[10]
Mercury (mg/kg)	0.13[3]	0.49[6]	10[9]	610[13]
Copper (mg/kg)	18.7[3]	108[4]	310[12]	45,000[8]
Lead (mg/kg)	30.24[3]	91.3[6]	400[7]	1,000[13]
Cadmium (mg/kg)	0.596[5]	3.53[6]	4[12]	100[13]

[1] Effects Range Low – Marine (Long and Morgan ERL)
[2] Effects Range Medium – Marine (Long and Morgan ERM)
[3] Threshold Effect Level – Marine (Persaud, TEL)
[4] Probable Effect Level – Marine (Persaud, PEL)
[5] Threshold Effect Level – Freshwater (Persaud, TEL)
[6] Probable Effect Level – Freshwater (Persaud, PEL)
[7] NJ Residential Cleanup Standard
[8] NJ Non Residential Cleanup Standard
[9] PA Clean Fill Standard
[10] PA Regulated Fill Standard
[11] NJ Upland Fill criterion
[12] DNREC URS Unrestricted Use
[13] DNREC URS Restricted Use

Appendix B

Data Compilation Methods

Appendix B: Data Compilation Methods

In order to develop the Delaware Estuary RSMP *Sediment Quality White Paper*, it was necessary to compile readily available sediment quality data into an appropriate electronic database (Delaware Estuary RSMP Sediment Quality Database). In this paper sediment quality refers to sediment concentrations (expressed on a mass per dry weight sediment basis) for the selected contaminants of concern (COCs). Other parameters that can be used to characterize the quality of sediment (e.g. grain size distribution and percentage organic carbon) were not evaluated.

The Delaware Estuary RSMP Sediment Quality Database (Final Version 1.1) and analysis matrices developed and used by the Sediment Quality Committee can be obtained by contacting Joel A. Pecchioli (NJDEP Office of Dredging and Sediment Technology, joel.pecchioli@dep.state.nj.us).

The Sediment Quality Committee did not conduct an independent Quality Assurance review of the sediment data compiled and used in its evaluations. The absence of such a review was deemed acceptable by the committee given the objectives of this effort, and the planning and management (i.e. non-regulatory) purposes of the Delaware Estuary RSMP.

When sediment data were reported as non-detect, a value of one-half the detection level was used in the database. If the detection limit was not reported in the original data source, a value of zero was used.

For replicate/split samples (i.e. two concentrations for a COC), to be conservative the higher COC concentration was used. In general, there was very little difference in these two COC concentrations, and the replicate/split samples would each have met the same threshold.

The database includes 109 sediment samples from NOAA National Coastal Assessment studies completed in 2003 through 2006; however, the existence of this data was not known until the white paper analyses had been completed.

Data Compilation – Geographic Scope

The geographic scope of the Delaware Estuary RSMP consists of the tidal Delaware River and Bay and its non-tidal contributing watershed. The Sediment Quality Committee attempted to obtain data from all readily available sources within this geographic area. However, given the limited resources and time available to complete this white paper, this effort was undoubtedly not 100% successful. In addition, at this point in time, the Delaware Estuary RSMP Sediment Quality Database does not include sediment data collected in association with smaller public and private dredging projects that are available only in hard copy form. The committee's data compilation activities have been prioritized to focus on sediment quality data from the tidal Delaware River and Delaware Bay and their major tributaries.

Data Compilation – Electronic Sources of Sediment Data

A "Delaware Estuary Electronic Database" has been recently developed by URS and DuPont. This database includes a compilation of all existing sediment quality data that was available in electronic format at the time the database was developed (2010); it does not include sediment quality data that was only available from hard copy sources. In addition, URS did not conduct an independent review of data quality before incorporating the data into its database.

Table B-1 lists all of the data sets incorporated into the URS/DuPont database. This list was provided to the NJDEP by URS in April 2010 in a document titled "Table 2 – Working Draft of Physical, Chemical, and Biological Datasets – Delaware Estuary Database – Phase 2: Delaware River Study" (undated). Queries of the URS database have been run for sediment data for each of the general types of contaminants listed in Table B-1. The query results were edited to remove unneeded content and exported into the Delaware Estuary RSMP Sediment Quality Database. Any samples in the URS/DuPont database that were (a) not located in the Delaware Estuary or its watershed, and (b) collected prior to 1990, were not included in the Delaware Estuary RSMP Sediment Quality Database. Some sample data were reported in two of the data sets that were compiled into the URS/DuPont database; to avoid duplication, the samples from only one of these data sets were used in the Delaware Estuary RSMP Sediment Quality Database.

Table B-1: Electronic Sources of Sediment Quality Data Compiled into the "Delaware River Estuary RSMP Sediment Quality Database".

Study	Contaminants Measured	Year(s) Collected	Electronic Data Source
DEBI2009	PCBs – PCDD/Fs	2008	URS/Dupont Database & DRBC files
DRBC – Delaware Estuary Upload (1991)	Metals	1991	URS/Dupont Database
DRBC - PCB Sediment Data (2001)	PCBs - Pesticides	2001	URS/Dupont Database
NOAA - NS&T: Bioeffects (1997)	PCBs - Pesticides PAHs - Metals	1997	URS/Dupont Database
Rutgers – Hg (2002)	PCBs – DDE - Hg	2002	URS/Dupont Database
USACE High Resolution PCBs (1996)	PCBs	2000-2001	URS/Dupont Database
USEPA - National Coastal Assessment (1990-2001)	PCBs - Pesticides PAHs - Metals	EMAP: 1990, 1991, 1992, 1993, 1997, 2000, 2001	URS/Dupont Database
USEPA - STORET	PCBs - Pesticides PAHs - Metals	1998, 2000	URS/Dupont Database
USGS - NAWQA (1991-2007)	PCBs - Pesticides PAHs - Metals	1998, 1999, 2000	URS/Dupont Database
USEPA-National Coastal Assessment	PCBs - Pesticides PAHs - Metals	2002	http://www.epa.gov/emap/nca/html/data/index.html

Given the number of data sets compiled into the URS/DuPont database (54) and the number of potential analyte categories of interest (14), a total of 756 separate queries of the database would have to be run to completely verify that the list in Table B-1 provided by URS contains all of the sediment data in the database. Given the limited resources and time available to complete this white paper, this was not done, and the Sediment Quality Committee relied on the list of sediment data sets provided by URS in Table B-1.

In addition to those data sets compiled into the URS/DuPont database, a number of additional available electronic data sets were identified by the Sediment Quality Committee and incorporated into the Delaware Estuary RSMP Sediment Quality Database; these data sources are also identified in Table B-1.

Data Compilation – Hard Copy Sources of Sediment Data

Sediment quality data for the COCs available only from hard copy sources were obtained and incorporated into the Delaware Estuary RSMP Sediment Quality Database. Given the limited available time and resources, the hard copy sources used were largely limited to studies conducted by the USACE in support of navigation dredging projects. Table B-2 lists all such studies from which sediment quality data were obtained.

Table B-2: Hard Copy Sources of Sediment Quality Data Compiled into the "Delaware River Estuary RSMP Sediment Quality Database".

Study	Contaminants Measured	Year(s) Collected	Hard Copy Data Source
Philadelphia Naval Shipyard	PCBs - Pesticides PAHs - Metals	2009	Versar (2009). FY 2008, Pier 4 Chemical Analysis of Sediment Samples. Apr 2009. 38 pp + App
USACE Philadelphia to Trenton	PCBs - Pesticides PAHs - Metals	2009	Versar (2009). FY 2008 Philadelphia to Trenton Chemical Analysis of Sediment Samples. June 2009. 72 pp + App
Philadelphia Naval Shipyard	PCBs - Pesticides PAHs - Metals	2007	Versar (2007). FY 2007 Pier 4 Chemical Analysis of Sediment Samples. Nov 2007. 38 pp + App
USACE Schuylkill River	PCBs - Pesticides PAHs - Metals	2007	Versar (2007). Schuylkill River Chemical Analysis of Sediment Samples. July 2007. 23 pp + App
USACE Fairless Turning Basin	PCBs - Pesticides PAHs - Metals	2007	Versar (2008). FY 2007 Fairless Turning Basin Chemical Analysis of Sediment Samples. Jan 2007. 36 pp + App
USACE Maintenance Dredging	PCBs - Pesticides PAHs - Metals	2005	Versar (2005), Delaware River, Philadelphia, Pennsylvania to New Castle, Delaware – Chemical Analysis of Dredged River Sediments, Nov 2005, 319 pp.
NOAA Athos I Preassessment	PAHs	2004	NOAA (2006), Final Preassessment Data Report *M/T Athos I,* Oil Spill Delaware River, June 2006, 36 pp + App
USACE Maintenance Dredging	PCBs - Pesticides PAHs - Metals	2003	Versar (2003), Chemical Analysis of Maintenance Dredge Material from the Marcus Hook, Deepwater Point, and New Castle Navigational Ranges, Oct 2003, 50 pp.
USACE Philadelphia to Trenton	Pesticides PAHs - Metals	2003	Versar (2003), Chemical Analysis of Maintenance Dredge Material from the Marcus Hook, Deepwater Point, and New Castle Navigational Ranges, Oct 2003, 50 pp.
USACE Philadelphia to Trenton	Pesticides PAHs - Metals	2001	Versar (2003). Delaware River, Philadelphia, Pennsylvania to Trenton, New Jersey Chemical Analysis of Dredged River Sediments. Jul 2003. 34 pp + App
USACE Schuylkill River	PCBs - Pesticides PAHs - Metals	1997	Versar (2001). Delaware River, Philadelphia, Pennsylvania to Trenton, New Jersey Chemical Analysis of Dredged River Sediments. Jun 2001. 18 pp + App
USACE Main Channel Deepening	PCBs - Pesticides PAHs - Metals	1994	Greely-Polhemus Group (1995), Delaware River – Philadelphia to the Sea Chemical Analysis of Sediments, May 1995, 113 pp + App.
USACE Main Channel Deepening	PCBs - Pesticides PAHs - Metals	1992	Greely-Polhemus Group (1993), Delaware River Comprehensive Navigation Study Chemical Analysis of Sediments, Feb 1993, 19 pp + App

Appendix C

Selected Database Analyses

Appendix C: Selected Database Analyses

Effects of Using One-Half the Detection Limit for Non-detected Contaminant Concentrations

A value of one-half the detection limit was used in the Delaware Estuary RSMP Sediment Quality Database as the sample concentration for those contaminants of concern (COCs) that were non-detects. Table C-1 shows the percentage of non-detects for each COC, as well as how the one-half detection limit concentrations are related to the sediment quality thresholds established by the Sediment Quality Committee. Concentrations of all of the organic COCs, mercury, and cadmium, were frequently not detected in the sediment samples. Thus, the results of the white paper threshold analyses for these COCs could be affected to varying degrees by non-detected sample concentrations and the use of one-half the detection limit.

Table C-1: For selected COCs, percentages of all sample concentrations that were non-detect, and percentages of the non-detect samples relative to the White Paper sediment quality thresholds.

% of Non-Detect Sample Concentrations that are:	<ERL/TEL	> ERL/TEL	> ERM/PEL	> LRT	> HNRT	% of Sample COC Concentrations that are ND
Mercury	93%	7%	0.6%	-	-	20%
Cadmium	99%	1%	0%	-	-	9%
4,4'-DDT	48%	52%	31%	-	-	64.5%
4,4'-DDD	39%	61%	51%	-	-	42.5%
4,4'-DDE	39%	61%	57%	-	-	34.3%
Chlordane	36%	64%	43%	1%	-	54.7%
Dieldrin	16%	84%	38%	0%	-	62%
Benzo(a)pyrene	24%	76%	0%	73%	-	41%
Total PCBs	15%	85%	60%	58%	1.5%	23%
LRT = Lowest "Residential" Threshold, HNRT = Highest "Non-residential" Threshold						

Very few samples (0-1.8% of the total collected) were non-detect for arsenic, cobalt, copper, and lead, and only 4.2% of the samples were non-detect for PCDD/Fs (including 2,3,7,8-TCDD; data for these COCs are not shown in Table C-1). The results of the white paper threshold analyses for arsenic, cobalt, copper, lead, and PCDD/Fs will be affected very little by non-detected sample concentrations and the use one-half the detection limit.

Further analysis showed that conclusions regarding the sediment data will be little effected by using one-half the detection limit for non-detected mercury and cadmium sample concentrations. One-half the detection limit for almost all of the non-detect mercury and cadmium samples were less than the ERL/TEL, and none of these samples had non-detected concentrations that exceeded the Lowest "Residential" Threshold (Table C-1).

For the pesticides 4,4'-DDT, 4,4'-DDD, 4,4'-DDE, and dieldrin, one-half the detection limit concentrations were less than the Lowest "Residential" Threshold in all of the non-detect samples. Only 1% of the non-detect total chlordane samples had one-half detection limit concentrations greater than this threshold. The upland beneficial use component of the *Sediment Quality White Paper* threshold analysis would not be affected for these contaminants.

Approximately 31% to 57% of the non-detects for 4,4'-DDT, 4,4'-DDD, 4,4'-DDE, dieldrin, and total chlordane would have concentrations greater than the ERM/PEL using one-half the detection limit. In addition, 52-84% of the non-detects for these pesticides would exceed the ERL/TEL. This could result in a significant number of false exceedances of the aquatic habitat restoration suitability concentrations in the threshold analysis. In addition, the Sediment Quality Committee noted a number of analytical Quality Assurance concerns that typically occur with sediment pesticide data. Therefore, it was determined that those non-detect samples in which one-half the detection limits for 4,4'-DDT, 4,4'-DDD, 4,4'-DDE, dieldrin, or total Chlordane exceeded their respective ERL/TEL would be deleted from the database (for these parameters only) used in the Aquatic Habitat Restoration Suitability Threshold Analysis.

An analysis of the samples with non-detected concentrations of dieldrin, 4,4'-DDT, 4,4'-DDD, 4,4'-DDE, and total chlordane was conducted to determine the potential impact on the results of the Aquatic Habitat Restoration Suitability Threshold Analysis of omitting the sample data with one-half detection limit values greater than the ERL/TEL. Combined, a total of 23 additional samples may have exceeded an ERL/TEL value: three of these samples were in DRBC Zone 3, 13 in DRBC Zone 6, and 10 in various tributaries. An additional 50 samples with non-detected concentrations of these pesticides may have exceeded an ERM/PEL: one of these samples was in DRBC Zone 3, 34 were in DRBC Zone 4 and were collected in support of the Main Channel Deepening Project, one sample was from DRBC Zone 5, 12 were from DRBC Zone 6, and there were two tributary samples.

For benzo(a) pyrene, approximately 76% and 73%, respectively of the non-detect samples in the Aquatic Habitat Restoration Suitability Threshold Analysis and upland beneficial use analysis could be affected by the use of one-half the detection limit (Table C-2). Most of these samples were collected in 1992, 1994, or 1997. Benzo(a)pyrene non-detects would have no or small impacts on both of the threshold analyses in DRBC Zone 2 and Zone 3, and in the Delaware River watershed tributaries. However, potential false exceedances of both the aquatic habitat restoration suitability and upland beneficial use thresholds could occur in a substantial percentage of the samples in DRBC Zone 4, Zone 5, and Zone 6 (Table C-2).

Table C-2: Number of benzo(s)pyrene non-detect samples in each DRBC Zone greater than the ERL/TEL and Lowest "Residential" standard (LRT).

Total # Non-detects = 135	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
> ERL/TEL	0	16	23	40	19	7
> LUS	0	15	23	40	19	3
Total # Samples	10	84	49	74	60	51

The Sediment Quality Committee also noted (a) that a number of recent dredging projects have had elevated sediment benzo(a)pyrene concentrations greater than the Lowest "Residential" Threshold, and (b) there was a significant oil spill in the Delaware River (M/V Athos I) in 2004. The committee decided to take a conservative approach and include all of the samples that were non-detect for benzo(a)pyrene in both the aquatic habitat restoration suitability and upland beneficial use components of the *Sediment Quality White Paper* threshold analysis.

Approximately 80% of the non-detect total PCB samples in the Aquatic Habitat Restoration Suitability Threshold Analysis, and approximately 58% of the non-detect samples in the upland beneficial use analysis, could be affected (Table C-3). About 65% of the non-detect PCB samples were collected in 2001 or earlier (mostly in 1992, 1994, or 1997), with the remaining 35% of the samples collected in 2002, 2003, and 2005. Samples that were non-detect for PCBs would have no or small impacts on both of the threshold analyses in DRBC Zone 2 and Zone 6. The non-detects may have impacted the aquatic habitat restoration suitability threshold results in DRBC Zone 3, Zone 4, and Zone 5, and in the Delaware River watershed tributaries. Potential false exceedances of the upland beneficial use threshold could occur in a substantial percentage of the samples in DRBC Zone 3 and Zone 5.

Table C-3: Total PCBs - Total number of non-detect samples and number of non-detect samples in each DRBC Zone compared to the various contamination thresholds used in the White Paper.

PCBs	# Samples	# Non-Detects	< ERL	>ERL	>ERM	> LUS	>HUS
Zone 2	25	0	-	-	-	-	-
Zone 3	73	22	1	21	16	16	0
Zone 4	57	16	1	15	7	5	0
Zone 5	165	48	1	47	44	43	2
Zone 6	143	11	11	0	0	0	0
Tributaries	128	36	6	30	13	13	0
Overall	592	133	20	113	80	77	2

An initial spatial analysis of the total PCB non-detect samples using a draft version of the Delaware Estuary RSMP Sediment Quality Database was conducted by DRBC Zone. Those non-detect samples in each DRBC Zone that had one-half the detection limit total PCB concentrations significantly different from those samples in which PCBs were detected were deleted from the final database (46 samples).

Given that DRBC has established a Total Maximum Daily Load (TMDL) for PCBs in the Delaware River, the committee decided to take a conservative approach and include all of the remaining samples that were non-detect for total PCBs in both the aquatic habitat restoration suitability and upland beneficial use components of the *Sediment Quality White Paper* threshold analysis.

Year of Sample Collection

The Delaware Estuary RSMP Sediment Quality Database includes sediment samples collected in the Delaware Estuary from 1990 to 2009. Table C-4 lists the percentage of the available sediment sample data for each COC that were collected in 1990-2001 and 2002-2009. Samples analyzed for metals (except cobalt) and benzo(a)pyrene (i.e. PAHs) were collected about evenly during these two time periods. Most of the samples analyzed for PCBs and pesticides were collected in 1990-2001, and thus most of the data are at least ten years old. All of the available dioxin/furan data are from samples collected in 2008.

Table C-4: Percentage of sediment samples in the Database for each COC collected from 1990-2001 and 2002-2009.

Contaminant of Concern (COC)	1990-2001	2002-2009
Mercury Arsenic Cadmium Copper Lead	~55% Varies slightly with each COC	~45% Varies slightly with each COC
Cobalt	29%	71%
Total PCBs	71%	29%
Total Dioxin/Furan TEQ	-	100%
4,4'-DDT	82%	18%
4,4'-DDD	75%	25%
4.4'-DDE	74%	26%
Chlordane	77%	23%
Dieldrin	75%	25%
Benzo(a)pyrene	52%	48%

DRBC Zone 5 Aquatic Habitat Restoration Suitability Threshold Analysis

A total of 231 sediment samples were collected in DRBC Zone 5 (180 grab samples, 48 core samples, and 3 composite samples). Twenty-three percent (23%) of the DRBC Zone 5 samples did not exceed an ERL/TEL for any COC, 42% of the samples exceeded at least one ERL/TEL, and 35% of the samples exceeded at least one ERM/PEL (Appendix E). While 94% of the core samples exceeded at least one ERM/PEL, only 18% of the grab samples did so.

Most of the samples in DRBC Zone 5 collected downstream of the Christina River that exceeded an ERM/PEL were core samples. As discussed below, many of these may be false exceedances due to using one-half the detection limit for non-detect total PCBs. A number of samples collected downstream of the Christina River, but closer to the shorelines and outside of the main navigation channel, were contaminated with mercury, arsenic, and/or lead at concentrations greater than the ERM/PEL.

In contrast, most of the samples in DRBC Zone 5 collected near the mouth of the Christina River, and upstream in the Delaware River, that exceeded an ERM/PEL value were grab samples with detected COC concentrations.

Core Samples

The 48 DRBC Zone 5 core samples were collected during three U.S. Army Corps of Engineers (USACE) studies in support of navigational dredging activities:

- Main Channel Maintenance (2005) – 11 samples (11 locations)
- Main Channel Deepening (1994) – 16 samples (8 locations, 2 sections each)
- Main Channel Deepening/Bends (1992) – 21 samples (10 locations/1 section each; 1 location/6 sections; 1 location/5 sections).

Thirty-seven (37) of the samples were collected over 15 years ago, with the most recent core samples over five years old.

Three of the core samples did not exceed any ERM/PEL. PCBs were not detected in any of the remaining 45 samples, so one-half the detection limits were used for the analysis. These values were greater than the total PCB ERM/PEL of 189 ug/kg, and may be false exceedances of the ERM/PEL.

Only nine of the core samples had a detected COC concentration greater than the ERM/PEL (Table C-5 and Figure C-1). None of the core samples exceeded the ERM/PEL for benzo(a)pyrene, dieldrin, chlordane, and copper; the samples were not analyzed for PCDD/Fs.

Table C-5: DRBC Zone 5 Core Samples – Detected Exceedances of Contaminants of Concern ERM/PELs.

Sample	Mercury	Arsenic	Cadmium	Lead	4,4'-DDT	4,4'-DDD 4,4'-DDE
DRV-21	X	X	X	X	X	
DRV-23						X
DRV-24	X	X		X	X	X
DRV-25						X
DRV-09-94 (deep section)		X	X			
DRV-10-94 (surface section)		X	X	X		
DRV-10-94 (deep section)			X			
DRV-15-94 (surface section)				X		X
DRV-15-94 (deep section)			X			

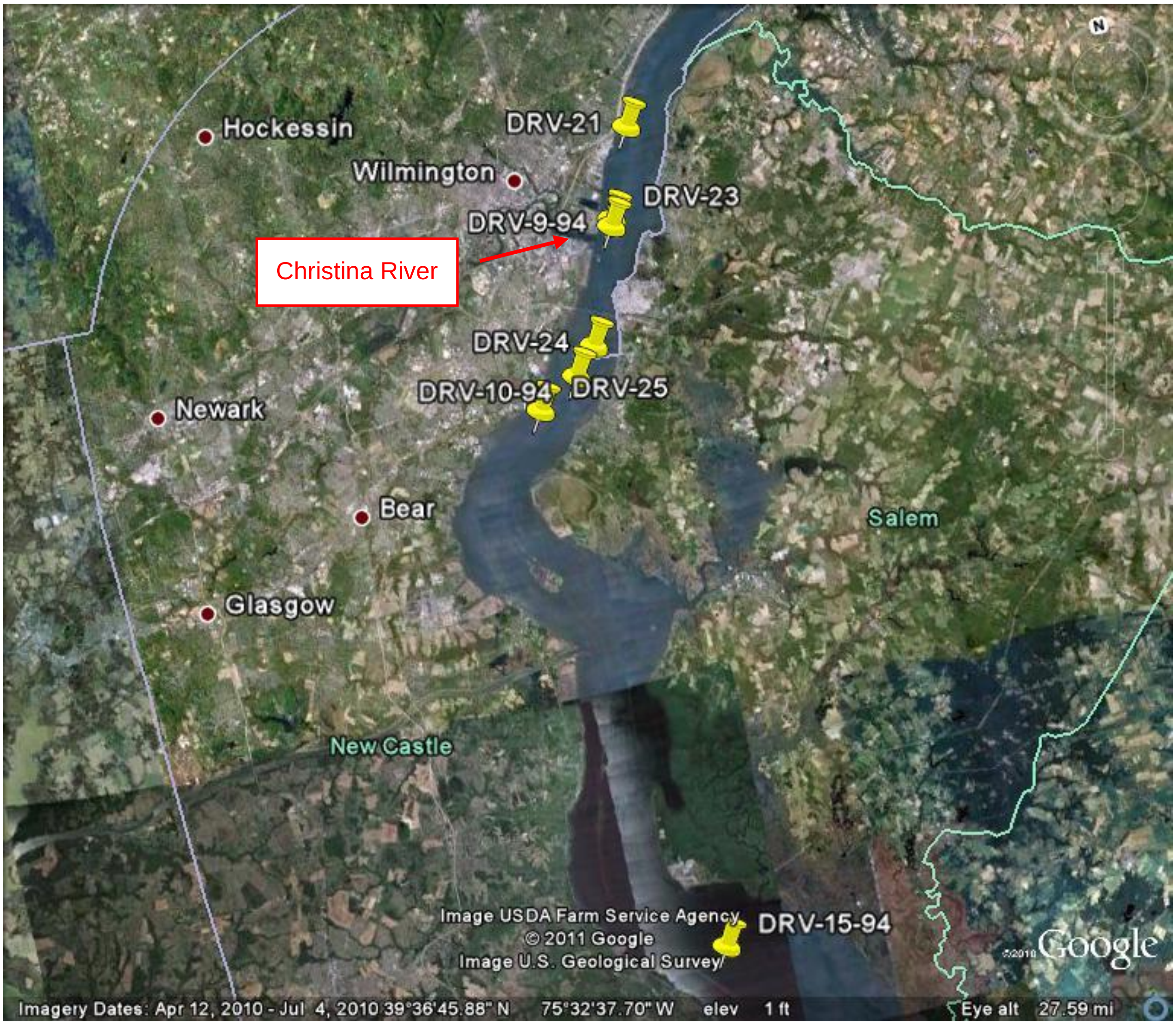


Figure C-1: DRBC Zone 5 Core Samples Location

Grab Samples

Thirty-three (33) of the 180 DRBC Zone 5 sediment grab samples exceeded the ERM/PEL for one or more detected COC, as follows:

- Mercury – 15 samples
- Arsenic – 21 samples
- Copper – 3 samples
- Cadmium – 2 samples
- Lead – 15 samples
- PCDD/Fs TEQ – 1 sample
- Total PCBs – 6 samples
- 4,4'-DDT – 5 samples
- 4,4'-DDD – 9 samples
- 4,4'-DDE – 9 samples

> Chlordane – 2 samples

None of the grab samples exceeded the ERM/PEL for benzo(a)pyrene and dieldrin.

Ten (10) grab samples exceeded the ERM/PEL for at least four of the COCs (Table C-6 and Figure C-2).

Table C-6: DRBC Zone 5 Grab Samples with Detected Concentrations Greater than the ERM/PELs for Four or More COCs.

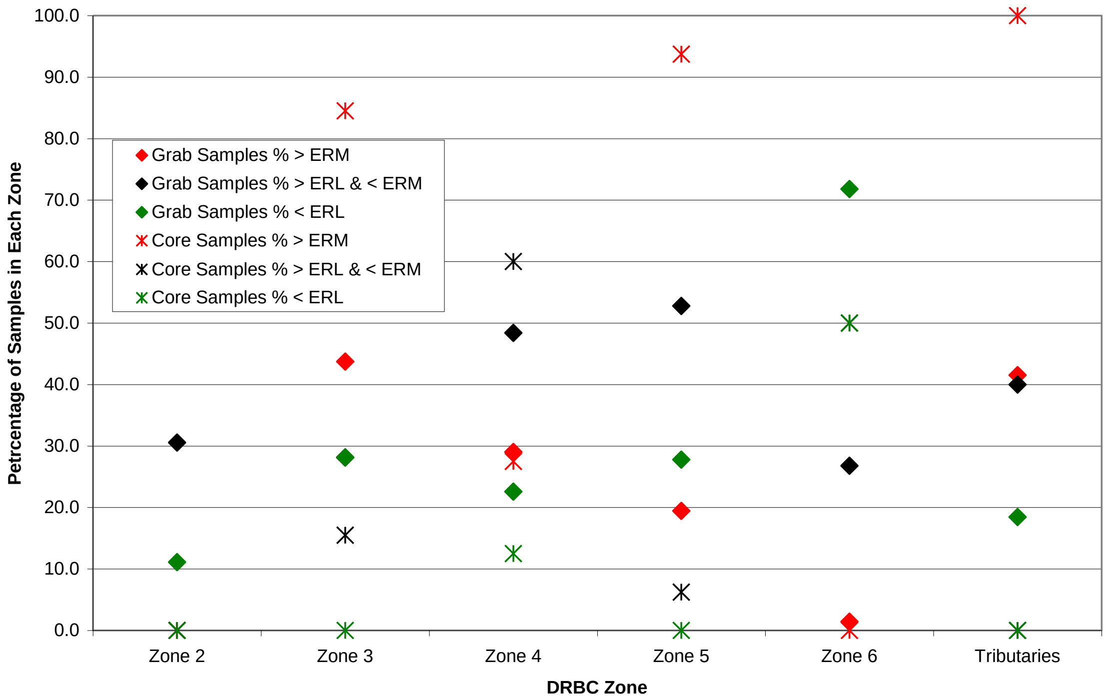
Sample:	NST 1997 DEB-19	NST 1997 DEB-20	NST 1997 DEB-21	DE-00-0047A	MA97-0422	MA97-0423	MA97-0424	DE08-0542	DE08-0548	DE08-0556
Mercury		X		X		X		X	X	X
Arsenic		X	X	X		X	X	X	X	X
Copper		X		X					X	
Cadmium								X	X	
Lead		X		X		X		X	X	X
PCDD/F TEQ								X		
Total PCBs		X				X		X	X	X
4,4'-DDT	X		X	X	X		X			
4,4'-DDD	X		X	X	X		X			
4,4'-DDE	X		X	X	X		X			
Chlordane	X				X					

Figure C-2: DRBC Zone 5 Grab Samples with Exceedances of Four or More COC ERM/PELs.

Aquatic Habitat Restoration Suitability Threshold Analysis – Effect of Sample Type

Figure C-3 shows the percentage of sediment samples (grab or core) in each DRBC Zone that fell into each of the three Aquatic Habitat Restoration Suitability Threshold Analysis categories. No core sample data are available from DRBC Zone 2.

Figure C-3: Aquatic Habitat Suitability Analysis Results Gab and Core Samples in Each DRBC Zone



In DRBC Zone 3, Zone 5, and the tributaries (all but two of the tributary core samples were collected in the Schuylkill River), the percentage of the core samples with a COC greater than the ERM/PEL (84.5% to 100%) was much greater than in the grab samples (19% to 28%). Most of these core samples were collected in association with USACE dredging projects, while most of the grab samples were collected in shallower waters closer to the shoreline, which suggests that sediment in the navigation channels (or berthing areas) in DRBC Zone 3, Zone 5, and the Schuylkill River may be more contaminated than sediment from other locations in these areas.

> DRBC Zone 3 – of the 60 core samples that had a COC concentration greater than the ERM/PEL, only eight (13%) were non-detects (total PCBs and pesticides). The COCs were detected in all 14 of the grab samples that had a COC concentration greater than the ERM/PEL. This suggests that in DRBC Zone 3, sample type had only a minimal effect on its Aquatic Habitat Restoration Suitability Threshold Analysis category.

> DRBC Zone 5 – 45 of the core samples had a COC concentration greater than the ERM/PEL. In all but one of these samples, these exceedances were due to the use of one-half the detection limit for non-detected PCBs and/or pesticides. Thirty-five (35) grab samples had a COC concentration greater than the ERM/PEL; these exceedances were largely due to detected concentrations of arsenic, lead, mercury, and/or pesticides. This suggests that in DRBC Zone 5, sample type had a significant effect on its Aquatic Habitat Restoration Suitability Threshold Analysis category.

> Tributaries - 24 core samples, all but two of which were collected in the Schuylkill River, had a detected COC concentration greater than the ERM/PEL. Similarly, 54 of the grab samples had a detected COC concentration greater than the ERM/PEL. This suggests that in the Schuylkill River,

sample type had only a minimal effect on its Aquatic Habitat Restoration Suitability Threshold Analysis category.

In DRBC Zone 4, the percentage of core samples that had a COC concentration greater than the ERM/PEL (27.5%) was similar to that for grab samples (29%). None of the DRBC Zone 6 core samples, and only 1.4% of the grab samples (for arsenic or cadmium), had a COC concentration greater than the ERM/PEL.

With the exception of DRBC Zone 5, the higher percentages of the core samples with a COC concentration greater than ERM/PEL (Figure C-3) are not an artifact of the types of sample collected.

Appendix D

Statistical Summaries of the Sediment Data Compiled in the Delaware Estuary RSMP Sediment Quality Database for Each Contaminant of Concern

Appendix D: Statistical Summaries of the Sediment Data Compiled in the Delaware Estuary RSMP Sediment Quality Database for Each Contaminant of Concern

Arsenic Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
795	601	193	1	786	9
% of Total:	75.6%	24.3%	0.1%	98.9%	1.1%
	Mean (mg/kg)	**Standard Deviation**	**Median (mg/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	5.56	4.84	4.13	36	0
1991	6.51	7.43	4.09	36	0
1992	7.19	3.33	7.20	48	0
1993	10.58	8.55	8.01	11	0
1994	4.97	5.30	3.28	44	0
1997	10.96	10.69	9.40	165	0
1998	18.61	15.52	11.55	10	0
1999	14.59	14.63	8.80	13	0
2000	7.93	5.41	7.09	39	1
2001	10.31	10.06	8.00	37	1
2002	6.61	4.76	5.00	32	4
2003	11.90	3.90	12.75	22	0
2005	8.47	10.86	5.86	28	2
2007	23.47	31.36	9.95	18	0
2008	7.40	22.57	4.60	226	1
2009	6.62	3.11	5.80	21	0
Overall	8.81	15.00	6.00		
Total # Samples	**# Samples <= ERL**	**# Samples > ERL**	**# Samples > ERM**	**# Samples > LUS**	**# Samples > HUS**
795	395	400	64	143	8
% of Total	49.7%	50.3%	8.1%	18.0%	1.0%
Note: 46 (5.8%) of the samples > NJ Non-residential Soil Remediation Standard (19 mg/kg)					

The following samples/locations > HNRT:

1. USGS01467150 (Cooper River at Haddonfield, NJ - 1999)
2. NJ01-0090-A (Maurice River – 2001)
3. DE08-0542 (Delaware River Zone 5 – 2008)
4. DE08-0548 (Delaware River Zone 5 – 2008)
5. FY2007 SR4 (Schuylkill River – 2007)
6. FY2007 SR5 (Schuylkill River – 2007)
7. FY2007 SR7 (Schuylkill River – 2007)
8. 1997 SR5Lower (Schuylkill River – 1997)

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	22	89	92	195	265	132
% of Total	2.8%	11.2%	11.6%	24.5%	33.3%	16.6%
% Detects	100%	100%	97.8%	100%	98.5%	97.7%
Mean (mg/kg)	9.54	7.40	7.11	11.93	4.70	14.47
Standard Dev (mg/kg)	4.92	4.92	6.18	24.81	3.27	17.30
Median (mg/kg)	10.40	6.50	5.72	7.81	3.84	9.25

Benzo(a)pyrene Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
328	135	193	0	193	135
% of Total:	41.2%	58.8%	0%	58.8%	41.2%
	Mean (mg/kg)	**Standard Deviation**	**Median (mg/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	-	-	-	-	-
1991	-	-	-	-	-
1992*	0.2714	0.0518	0.2650	0	36
1993	-	-	-	-	-
1994*	0.2469	0.0818	0.2310	0	44
1997	0.3300	0.4996	0.1200	78	5
1998	-	-	-	-	-
1999	-	-	-	-	-
2000	-	-	-	-	-
2001*	0.1306	0.0923	0.1075	1	7
2002*	0.1000	0.1626	0.0100	15	21
2003	0.4729	1.1764	0.1900	19	3
2004	0.2411	0.2469	0.1890	27	0
2005*	0.1454	0.2611	0.0280	15	18
2007	0.6878	0.9117	0.2150	18	0
2008	-	-	-	-	-
2009	0.3312	0.2201	0.2500	20	1
Overall	0.2857	0.4817	0.2000		

*Greater than 50% of the sample data were non-detect – used ½ detection limits

Total # Samples	# Samples <= ERL	# Samples > ERL	# Samples > ERM	# Samples > LUS	# Samples > HUS
328	73	255	22	227	0
% of Total	22.3%	77.7%	6.7%	69.2%	0%
# Non-detects at ½ DL	33	102	0	98	0
% of samples	45.2%	40.0%	0%	43.2%	0%

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	10	84	49	74	60	51
% of Total	3.0%	25.6%	14.9%	22.6%	18.3%	15.5%
% Detects	100%	73.8%	34.7%	37.8%	53.3%	86.3%
Mean (mg/kg)	0.2801	0.2428	0.3167	0.1998	0.0929	0.6791
Standard Dev (mg/kg)	0.2694	0.2176	0.7954	0.1319	0.1142	0.7483
Median (mg/kg)	0.2029	0.1980	0.2300	0.2007	0.0249	0.4300

Cadmium Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
793	599	193	1	723	70
% of Total	75.5%	24.3%	0.1%	91.2%	8.8%
	Mean (mg/kg)	**Standard Deviation**	**Median (mg/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	0.578	1.242	0.208	36	0
1991	1.610	2.405	0.566	34	2
1992	0.507	1.440	0.206	11	37
1993	1.935	2.686	0.592	10	1
1994	1.911	1.350	1.465	42	2
1997	0.766	0.918	0.426	162	3
1998	1.785	1.622	1.120	8	0
1999	1.353	0.768	1.100	13	0
2000	0.491	0.746	0.220	39	1
2001	1.376	1.939	0.370	36	2
2002	0.697	0.893	0.325	33	3
2003	1.552	1.149	1.080	22	0
2005	0.740	1.417	0.229	16	14
2007	2.853	1.831	2.200	18	0
2008	0.450	0.532	0.300	222	5
2009	1.933	0.640	2.200	21	0
Overall	0.901	1.298	0.400		
Total # Samples	**# Samples <= ERL**	**# Samples > ERL**	**# Samples > ERM**	**# Samples > LUS**	**# Samples > HUS**
793	503	290	39	30	0
% of Total	63.4%	36.6%	4.9%	3.8%	0%

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	22	89	92	195	265	130
% of Total	2.8%	11.2%	11.6%	24.6%	33.4%	16.4%
% Detects	100%	96.6%	75.0%	86.2%	95.8%	95.4%
Mean (mg/kg)	3.027	2.042	0.766	0.735	0.307	1.311
Standard Dev (mg/kg)	2.547	1.644	1.001	0.973	0.383	1.547
Median (mg/kg)	2.072	1.900	0.359	0.400	0.200	0.701

Chlordane (total) Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
540	361	179	0	244	296
% of Total	66.9%	33.1%	0	45.2%	54.8%
	Mean (ug/kg)	**Standard Deviation**	**Median (ug/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	-	-	-	-	-
1991*	0.71	0.87	0.26	4	10
1992*	103.64	69.42	120.00	4	44
1993	2.19	2.18	1.46	7	4
1994*	116.23	24.86	112.50	0	44
1997	2.07	5.90	0.26	120	31
1998	3.57	1.01	3.45	4	2
1999*	22.35	27.99	4.00	6	7
2000	3.21	8.49	0.31	25	14
2001	11.78	28.96	0.81	63	24
2002*	4.04	4.98	0.18	1	35
2003*	4.77	0.97	4.90	0	22
2004	-	-	-	-	-
2005*	5.87	4.04	4.80	0	30
2007	8.02	8.30	6.28	5	13
2008	-	-	-	-	-
2009	7.07	8.40	1.70	5	16
Overall	23.37	46.90	1.70		
*Greater than 50% of the sample data were non-detect – used ½ detection limits					

Total # Samples	# Samples <= ERL	# Samples > ERL	# Samples > ERM	# Samples > LUS	# Samples > HUS
540	202	338	166	3	0
% of Total	37.4%	62.6%	30.7%	0.6%	0%
# Non-detects at ½ DL	106	190	126	3	-
% of samples	52.5%	56.2%	75.9%	100.0%	-

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	24	88	73	126	120	109
% of Total	4.4%	16.3%	13.5%	23.3%	22.2%	20.2%
% Detects	100.0%	27.3%	38.3%	43.7%	42.5%	56.9%
Mean (ug/kg)	6.03	25.09	42.21	41.26	10.69	6.43
Standard Dev (ug/kg)	4.00	38.39	60.16	65.50	31.16	13.79
Median (ug/kg)	5.06	5.15	4.50	1.40	0.16	1.83

Cobalt Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
97	28	69	0	97	0
% of Total	28.9%	71.1%	0%	100%	0%
Total # Samples	**# Samples <= ERL**	**# Samples > ERL**	**# Samples > ERM**	**# Samples > LUS**	**# Samples > HUS**
97	NA	NA	NA	80	0
% of Total	NA	NA	NA	82.5%	0%
Note: none of the samples > NJ Non-residential Soil Remediation Standard (590 mg/kg)					

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	0	38	12	11	0	36
% of Total	-	39.2%	12.4%	11.3%	-	37.1%
% Detects	-	100%	100%	100%	-	100%
Mean (mg/kg)	-	12.9	8.2	9.9	-	28.8
Standard Dev (mg/kg)	-	4.8	4.7	5.1	-	32.4
Median (mg/kg)	-	13.1	9.0	11.2	-	20.0

Year	Mean (mg/kg)	Standard Deviation (mg/kg)	Median (mg/kg)
Over All Years	17.9	21.7	15.0

Copper Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
794	599	193	2	780	14
% of Total	75.4%	24.3%	0.3%	98.2%	1.8%
	Mean (mg/kg)	**Standard Deviation**	**Median (mg/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	11.52	15.43	4.62	36	0
1991	41.46	47.68	25.70	36	0
1992	11.21	14.91	8.36	47	1
1993	45.18	61.90	15.30	10	1
1994	7.80	10.02	4.10	43	1
1997	32.28	36.14	18.28	165	0
1998	43.66	52.79	31.90	15	0
1999	65.77	26.11	60.00	13	0
2000	24.16	23.71	17.00	39	1
2001	25.31	25.23	17.50	38	0
2002	10.14	15.35	6.00	21	9
2003	38.94	14.50	36.40	22	0
2005	22.51	30.30	9.13	30	0
2007	116.17	104.15	66.75	18	0
2008	13.70	17.38	8.30	226	1
2009	40.94	18.96	38.30	21	0
Overall	25.12	35.85	11.70		
Total # Samples	**# Samples <= ERL**	**# Samples > ERL**	**# Samples > ERM**	**# Samples > LUS**	**# Samples > HUS**
794	498	296	21	3	0
% of Total	62.7%	37.3%	2.6%	0.4%	0%

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	22	87	91	193	265	136
% of Total	2.8%	11.0%	11.5%	24.3%	33.4%	17.1%
% Detects	100%	100%	100%	99.0%	96.6%	97.8%
Mean (mg/kg)	54.34	42.80	18.71	22.16	6.36	54.15
Standard Dev (mg/kg)	18.53	36.84	20.79	23.25	5.87	59.89
Median (mg/kg)	53.87	38.30	9.97	13.10	4.10	36.84

4,4'-DDT Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
520	327	193	0	185	335
% of Total	62.9%	37.1%	0	35.5%	64.5%
	Mean (ug/kg)	**Standard Deviation**	**Median (ug/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	-	-	-	-	-
1991*	2.98	8.83	0.13	6	8
1992*	10.64	6.66	12.00	2	46
1993*	1.74	3.27	0.13	2	9
1994*	11.67	2.52	11.25	0	44
1997*	6.58	16.75	0.03	68	97
1998*	2.32	3.23	1.00	1	5
1999	6.82	11.85	2.00	9	4
2000	8.65	38.81	0.43	23	16
2001	3.72	8.98	0.50	47	41
2002	1.9	-	1.9	1	0
2003*	14.15	39.97	3.45	4	18
2004	-	-	-	-	-
2005*	2.06	2.12	1.40	3	27
2007*	8.97	10.21	4.35	6	12
2008	-	-	-	-	-
2009	31.96	69.06	8.20	13	8
Overall	7.97	22.56	1.21		
*Greater than 50% of the sample data were non-detect – used ½ detection limits					

Total # Samples	# Samples <= ERL	# Samples > ERL	# Samples > ERM	# Samples > LUS	# Samples > HUS
520	254	266	170	0	0
% of Total	48.8%	51.2%	32.7%	0%	0%
# Non-detects at ½ DL	171	164	109	-	-
% of samples	67.3%	61.7%	64.1%	-	-

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	25	86	71	123	106	108
% of Total	4.8%	16.5%	13.7%	23.7%	20.4%	20.8%
% Detects	92.0%	38.4%	25.4%	36.6%	19.8%	41.7%
Mean (ug/kg)	11.06	18.79	6.09	7.78	1.26	6.77
Standard Dev (ug/kg)	14.85	43.38	7.53	22.97	3.27	11.39
Median (ug/kg)	3.85	6.90	2.00	0.81	0.05	1.10

4,4'-DDD Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
504	311	193	0	290	214
% of Total	61.7%	38.3%	0	57.5%	42.5%
	Mean (ug/kg)	**Standard Deviation**	**Median (ug/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	-	-	-	-	-
1991	2.63	5.17	0.71	8	6
1992*	19.13	56.19	12.00	6	42
1993	5.03	3.79	5.66	8	2
1994*	11.76	3.66	11.25	1	43
1997	9.65	18.82	2.09	141	24
1998*	2.62	4.62	0.50	2	4
1999	8.17	12.81	2.40	12	1
2000	4.56	15.07	0.76	34	5
2001	4.09	5.06	1.50	24	13
2002*	1.07	2.81	0.11	7	29
2003*	16.18	17.16	6.25	8	14
2004	-	-	-	-	-
2005	3.58	4.86	1.40	7	23
2007	14.84	8.84	11.50	18	0
2008	-	-	-	-	-
2009	6.75	4.44	6.90	14	7
Overall	8.90	21.91	3.20		

*Greater than 50% of the sample data were non-detect – used ½ detection limits

Total # Samples	# Samples <= ERL	# Samples > ERL	# Samples > ERM	# Samples > LUS	# Samples > HUS
504	184	320	186	0	0
% of Total	36.5%	63.5%	36.9%	0%	0%
# Non-detects at ½ DL	72	142	109	-	-
% of samples	39.1%	44.4%	58.6%	-	-

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	16	82	63	100	119	123
% of Total	3.2%	16.3%	12.5%	19.8%	23.6%	24.4%
% Detects	100.0%	46.3%	42.9%	52.0%	61.3%	68.3%
Mean (ug/kg)	27.9	10.4	10.5	12.7	1.4	8.7
Standard Dev (ug/kg)	42.3	10.6	10.9	40.5	3.1	12.7
Median (ug/kg)	9.0	9.5	9.5	6.3	0.1	2.2

4,4'-DDE Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
496	311	185	0	326	170
% of Total	62.7%	37.3%	0	65.7%	34.3%
	Mean (ug/kg)	**Standard Deviation**	**Median (ug/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	-	-	-	-	-
1991	4.10	8.55	1.04	10	4
1992*	11.55	6.10	12.00	8	40
1993	6.00	8.76	1.25	6	5
1994*	12.39	5.65	11.25	1	43
1997	13.83	34.20	2.75	150	15
1998	4.88	5.39	4.00	4	2
1999	5.99	6.73	4.10	12	1
2000	5.23	19.20	0.99	38	1
2001	3.59	6.00	1.50	28	1
2002*	0.36	0.75	0.09	8	28
2003	21.29	18.24	17.00	19	3
2004	-	-	-	-	-
2005	25.96	89.98	1.60	11	19
2007	49.54	44.65	37.00	18	0
2008	-	-	-	-	-
2009	6.21	5.69	4.80	13	8
Overall	12.51	32.84	3.40		

*Greater than 50% of the sample data were non-detect – used ½ detection limits

Total # Samples	# Samples <= ERL	# Samples > ERL	# Samples > ERM	# Samples > LUS	# Samples > HUS
496	192	304	206	0	0
% of Total	38.7%	61.3%	41.5%	0%	0%
# Non-detects at ½ DL	65	105	97	-	-
% of samples	33.9%	34.5%	47.1%	-	-

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	16	74	63	100	120	123
% of Total	3.2%	14.9%	12.7%	20.2%	24.2%	24.8%
% Detects	93.8%	68.9%	47.6%	51.0%	71.7%	68.3%
Mean (ug/kg)	23.4	23.2	20.9	8.8	1.6	13.9
Standard Dev (ug/kg)	15.4	58.0	48.3	13.5	3.1	27.2
Median (ug/kg)	23.0	11.1	11.3	6.2	0.2	3.3

Dieldrin Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
504	311	193	0	192	312
% of Total	61.7%	38.3%	0	38.1%	61.9%
	Mean (ug/kg)	**Standard Deviation**	**Median (ug/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	-	-	-	-	-
1991*	0.222	0.236	0.130	2	12
1992*	10.432	6.841	12.00	5	43
1993*	0.423	0.397	0.250	5	6
1994*	11.614	2.495	11.250	0	44
1997	3.268	8.669	0.180	106	59
1998*	1.083	1.160	0.500	2	4
1999*	10.231	18.797	1.000	6	7
2000	1.207	2.874	0.240	29	10
2001	2.500	4.063	0.190	26	11
2002*	0.101	0.081	0.085	0	36
2003*	3.382	0.718	3.400	0	22
2004	-	-	-	-	-
2005*	2.754	4.678	1.400	0	30
2007	27.678	48.545	9.500	11	7
2008	-	-	-	-	-
2009*	3.533	4.304	0.900	0	21
Overall	5.101	12.375	0.709		
*Greater than 50% of the sample data were non-detect – used ½ detection limits					
Total # Samples	**# Samples <= ERL**	**# Samples > ERL**	**# Samples > ERM**	**# Samples > LUS**	**# Samples > HUS**
504	61	443	134	4	0
% of Total	12.1%	87.9%	26.6%	0.8%	0%
# Non-detects at ½ DL	49	263	118	0	0
% of samples	80.3%	59.4%	88.1%	0%	0%

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	16	82	63	100	120	123
% of Total	3.2%	16.3%	12.5%	19.8%	23.8%	24.4
% Detects	87.5%	14.6%	33.3%	40.0%	32.5%	53.7%
Mean (ug/kg)	1.128	5.184	5.462	5.596	1.113	8.866
Standard Dev (ug/kg)	1.197	4.706	5.889	6.732	3.091	22.814
Median (ug/kg)	0.711	3.400	1.750	1.646	0.052	0.500

Mercury Database Summary Statistics

Note: these summary statistics only consider the surface section of the sediment core samples collected in 2002 at Oldmans and Woodbury Creeks.

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
799	602	195	2	638	161
% of Total:	75.3%	24.4%	0.3%	79.8%	20.2%
	Mean (mg/kg)	**Standard Deviation**	**Median (mg/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	0.082	0.130	0.042	29	7
1991	0.135	0.135	0.100	20	16
1992	0.095	0.084	0.087	12	36
1993	0.184	0.177	0.118	10	1
1994	0.093	0.082	0.070	3	41
1997	0.187	0.262	0.115	155	10
1998	0.110	0.099	0.070	11	0
1999	0.226	0.148	0.150	13	0
2000	0.122	0.192	0.080	38	3
2001	0.137	0.177	0.085	35	3
2002	0.099	0.149	0.033	32	6
2003	0.173	0.062	0.178	22	0
2005	0.110	0.213	0.020	20	10
2007	0.526	0.558	0.315	18	0
2008	0.103	0.187	0.050	199	28
2009	0.170	0.095	0.150	21	0
Overall	0.130	0.212	0.075		
Total # Samples	**# Samples <= ERL**	**# Samples > ERL**	**# Samples > ERM**	**# Samples > LUS**	**# Samples > HUS**
799	559	238	40	0	0
% of Total	70.0%	29.8%	5.0%	0%	0%

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	22	89	92	195	265	136
% of Total	2.8%	11.1%	11.5%	24.4%	33.2%	17.0%
% Detects	81.8%	84.3%	65.2%	76.9%	81.5%	87.5%
Mean (mg/kg)	0.184	0.155	0.105	0.183	0.052	0.250
Standard Dev (mg/kg)	0.114	0.098	0.122	0.291	0.048	0.301
Median (mg/kg)	0.166	0.148	0.077	0.091	0.040	0.180

Lead Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
799	604	193	2	791	8
% of Total:	75.6%	24.2%	0.2%	99.0%	1.0%
	Mean (mg/kg)	**Standard Deviation**	**Median (mg/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	22.12	20.14	15.35	35	1
1991	71.86	82.94	37.65	36	0
1992	18.08	22.51	12.30	41	7
1993	54.01	56.43	23.10	11	0
1994	22.13	22.53	14.75	44	0
1997	51.87	53.56	34.88	165	0
1998	421.49	1586.30	47.40	19	0
1999	123.08	92.21	80.00	13	0
2000	39.77	44.61	26.90	41	0
2001	38.24	33.90	29.35	38	0
2002	20.70	28.77	12.40	30	0
2003	51.00	16.31	51.15	22	0
2005	30.93	45.12	9.42	30	0
2007	144.00	118.80	83.15	18	0
2008	22.81	32.78	14.00	227	0
2009	51.04	20.61	47.00	21	0
Overall	48.29	250.54	20.40		
Total # Samples	**# Samples <= ERL**	**# Samples > ERL**	**# Samples > ERM**	**# Samples > LUS**	**# Samples > HUS**
799	497	302	81	1	1
% of Total	62.2%	37.8%	10.1%	0.1%	0.1%

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	22	87	91	193	265	141
% of Total	2.8%	10.9%	11.4%	24.2%	33.2%	17.6%
% Detects	100%	100%	95.6%	98.4%	99.6%	100%
Mean (mg/kg)	72.88	58.10	28.55	38.50	13.42	130.08
Standard Dev (mg/kg)	25.31	50.74	32.65	42.28	8.48	585.90
Median (mg/kg)	81.45	51.40	15.80	23.30	12.10	55.00

Total PCB Database Summary Statistics

Total # Samples	# Grab Samples	# Core Samples	# Composite Samples	# Detected Concentrations	# Non-Detections
592	441	144	7	459	133
% of Total	74.5%	24.3%	1.7	77.5%	22.5%
	Mean (ug/kg)	**Standard Deviation**	**Median (ug/kg)**	**# Detected Concentrations**	**# Non-Detections**
1990	-	-	-	-	-
1991	20.22	33.96	3.45	10	4
1992*	422.20	345.20	517.50	8	26
1993	25.98	36.76	21.24	9	2
1994	545.13	138.31	510.00	1	22
1996	41.10	53.82	14.13	7	0
1997	72.78	144.49	11.00	151	14
1998*	58.23	54.01	25.00	2	4
1999	69.46	44.53	50.00	7	6
2000	30.35	50.55	8.54	32	7
2001	49.47	93.27	13.80	79	0
2001 (?)	7.66	12.72	3.33	28	0
2002	14.61	47.74	1.52	29	9
2003*	371.73	67.53	361.00	2	13
2005*	319.14	477.77	181.00	2	26-
2007	1104.50	1735.55	305.50	18	0
2008	95.04	450.13	9.67	52	0
2009	112.80	94.66	62.06	21	0
Overall	150.16	422.29	18.12		
*Greater than 50% of the sample data were non-detect – used ½ detection limits					
Total # Samples	**# Samples <= ERL**	**# Samples > ERL**	**# Samples > ERM**	**# Samples > LUS**	**# Samples > HUS**
592	308	284	128	124	10
% of Total	52.0%	48.0%	21.6%	20.9%	1.7%
# Non-detects at ½ DL	20	113	80	77	2
% of samples	6.5%	39.8%	62.5%	62.1%	20.0%

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Tributaries
# Samples	25	73	57	165	143	128
% of Total	4.2%	12.3%	9.6%	27.9%	24.2%	21.6%
% Detects	100%	69.9%	71.9%	70.9%	92.3%	71.9%
Mean (ug/kg)	74.37	242.09	102.25	204.38	3.89	228.55
Standard Dev (ug/kg)	45.99	329.88	121.75	361.00	4.63	742.70
Median (ug/kg)	82.31	165.00	36.44	23.74	1.82	18.12

PCDD/F TEQ Database Summary Statistics

Total # Samples	# Samples <= ERL	# Samples > ERL	# Samples > ERM	# Samples > LUS	# Samples > HUS
24	6	18	1	0	0
% of Total	25.0%	75%	4.2%	0%	0%

Year	Mean (ug/kg)	Standard Deviation	Median
All Data - 2008	0.00482	0.00608	0.00342

	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
# Samples	0	0	2	12	10
% of Total	0%	0%	8.3%	50.0%	41.7%

Appendix E

Detailed Maps Showing the Results of the Aquatic Habitat Restoration and Suitability and Upland Beneficial Use Threshold Analyses

Appendix E: Detailed Maps Showing the Results of the Aquatic Habitat Restoration Suitability and Upland Beneficial Use Threshold Analyses