ARCADIS Design & Consultancy for natural and built assets

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

REMEDIAL INVESTIGATION REPORT

Newark Bay Study Area
Newark, New Jersey

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ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
95LCL	95% lower confidence limit
95UCL	95% upper confidence limit
ABS	Aquatic Biological Survey
ANCOVA	analysis of covariance
ANOVA	analysis of variance
AOC	Administrative Order on Consent
Arcadis	Arcadis U.S., Inc
ATSDR	Agency for Toxic Substances and Disease Registry
AVS	acid volatile sulfide
BAF	bioaccumulation factor
Bay	Newark Bay
BAZ	biologically active zone
Be-7	beryllium-7
BEHP	bis(2-ethylhexyl)phthalate
BERA	baseline ecological risk assessment
BHC	hexachlorocyclohexane
BHHRA	baseline human health risk assessment
B-IBI	benthic index of biotic integrity
BIC	benthic invertebrate community
bss	below sediment surface
CAD	confined aquatic disposal
CARP	Contaminant Assessment Reduction Project
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cfs	cubic feet per second
CFR	Code of Federal Regulations
CFT	contaminant fate and transport
CI	confidence interval

cm	centimeter
cm/yr	centimeters per year
COPC	constituents of potential concern
COPEC	constituents of potential *ecological* concern
CPG	Cooperating Parties Group
Cs-137	cesium-137
CSM	Conceptual Site Model
CSO	combined sewer overflow
CTE	central tendency exposure
cy	cubic yards
DASS	Diamond Alkali Superfund Site
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEAR	Data Evaluation and Analysis Report
DEHP	bis(2-ethylhexyl)phthalate
DL	dioxin-like
DPZ	differential pressure piezometers
DV	Darcy velocity
EFH	essential fish habitat
EPC	exposure point concentration
ETM	estuarine turbidity maximum
FCM	food chain multiplier
FFS	Focused Feasibility Study
FOD	frequency of detection
FDR	Field and Data Report
fps	feet per second
FS	Feasibility Study
g/day	grams per day
g/yr	grams per year
GLEC	Great Lakes Environmental Center

GSH	Glenn Springs Holdings, Inc.
HDP	Harbor Deepening Project
HI	hazard index
HMW	high molecular weight
HQ	hazard quotient
HVCWCM	High Volume Chemical Water Column Monitoring
HydroQual	HydroQual, Inc.
kg/m^2/year	kilograms per square meter per year
kg/yr	kilograms per year
kHz	kilohertz
KM	Kaplan-Meier
Kow	octanol-water partitioning coefficient
LMW	low molecular weight
LOAEL	lowest-observed-adverse-effect level
LOE	line of evidence
LPR	Lower Passaic River
LPRSA	Lower Passaic River Study Area
mg/kg	milligrams per kilogram
mi^2	square miles
MLLW	mean lower low water
MLW	mean low water
mm	millimeter
MPA	mass per unit area
MPI	Malcolm Pirnie, Inc.
msl	mean sea level
MT	metric ton
MT/yr	metric tons per year
NAVD88	North American Vertical Datum of 1988
NBSA	Newark Bay Study Area
NCA	National Coastal Assessment
NCP	National Contingency Plan

ng/kg	nanograms per kilogram
ng/L	nanograms per liter
NGVD29	National Geodetic Vertical Datum of 1929
NJ	New Jersey
N.J.A.C.	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect level
NY	New York
NYSDEC	New York State Department of Environmental Conservation
OC	organic carbon
OCC	Occidental Chemical Corporation
OSI	Ocean Surveys, Inc.
OU	operable unit
OU1	Operable Unit 1
OU2	Operable Unit 2
OU3	Operable Unit 3
OU4	Operable Unit 4
PAH	polycyclic aromatic hydrocarbon
PBDEs	polybrominated diphenyl ethers
PC	principal components
PCNs	polychlorinated naphthalenes
PCA	principal component analysis
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxin
PCDF	polychlorinated dibenzofuran
pCi/g	picocuries per gram
PE	polyethylene
pg/g	picograms per gram
pg/L	picograms per liter
POM	polyoxymethylene

POTW	publicly owned treatment works
ppth	parts per thousand
PRC	performance reference compound
PRSA	Passaic River Study Area
psu	practical salinity unit
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RAOs	remedial action objectives
REMAP	Regional Environmental Monitoring and Assessment Program
RI	remedial investigation
RIWP	Remedial Investigation Work Plan
RME	reasonable maximum exposure
ROD	Record of Decision
RPD	relative percent difference
SEDFlume	Sediment Erosion at Depth Flume
SEM	simultaneously extractable metals
SF_6	sulfur hexafluoride
SIU	significant industrial user
SLERA	Screening-Level Ecological Risk Assessment Report
SOW	Statement of Work
SQT	sediment quality triad
SSC	suspended sediment concentration
SUF	site use factor
SVCWCM	Small Volume Chemical Water Column Monitoring
SVOC	semivolatile organic compound
SWQC	Surface Water Quality Criteria
SWO	stormwater outfall
TEPH	total extractable petroleum hydrocarbon
TEQ	toxic equivalents
Tierra	Tierra Solutions, Inc.

TOC	total organic carbon
total DDx (4,4')	sum of 4,4'-DDE, 4,4-DDD, and 4,4'-DDT
total DDx (2,2' & 4,4')	sum of 2,4'-DDE, 4,4'-DDE, 2,4'-DDD, 4,4'-DDD, 2,4'-DDT, and 4,4'-DDT
TPH	total petroleum hydrocarbons
TRV	toxicity reference value
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VHG	vertical hydraulic gradient
VOC	volatile organic compound
WOE	weight of evidence
WQC	water quality criteria
°F	degrees Fahrenheit
%	percent
µg/kg	micrograms per kilogram
µm	micrometer
µmol/g-oc	micromoles per gram OC



Remedial Investigation Report Summary
Newark Bay Study Area
Newark, New Jersey

Introduction

Newark Bay (Bay) is part of the Newark Bay Study Area (NBSA), which includes portions of three connected waterways and is Operable Unit 3 of the Diamond Alkali Superfund Site (DASS or Superfund Site). The DASS was added to the Superfund National Priorities List on September 21, 1984 because of the presence of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) at the site and in the sediments of the Lower Passaic River (LPR). The initial Superfund investigations also identified a number of other contaminants in the sediments of the LPR. Due to the tidal nature of the LPR and the associated transport of contaminated sediment, the areal extent of contamination from the LPR extends into the Bay. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process has proceeded on separate schedules for each of the four operable units of the Superfund Site. Pursuant to the CERCLA Administrative Order on Consent (AOC) (Index 02-2004-2010; United States Environmental Protection Agency [USEPA] 2004), Glenn Springs Holdings, Inc. (GSH), on behalf of Occidental Chemical Corporation (the successor to Diamond Shamrock Chemicals Company [formerly known as Diamond Alkali Company]) has conducted a Remedial Investigation (RI) for the NBSA. This report presents activities and findings of the RI that began in 2004. Specifically, this report describes the nature and extent of contamination in the NBSA and findings concerning fate and transport and human health and ecological risk.

Site Background and History

The Bay is a 6.3-square-mile enclosed embayment located on the western side of the New York/New Jersey (NY/NJ) Harbor Estuary in one of the most urbanized and industrialized areas in the United States. It is bounded on the west, east and north by mainland New Jersey and on the south by Staten Island, New York. The Bay is adjacent to four large cities (Newark, Elizabeth, Bayonne, and Jersey City) and is surrounded by an urban/industrial complex. It is fringed on its western side by deep water port facilities, industrial facilities, and the Newark Liberty International Airport. On its northern side, the Hackensack and Passaic Rivers flow into the Bay, with federally authorized shipping channels extending into both rivers. On the southern side, the Bay is connected to NY Harbor (NY) and Raritan Bay (NJ) through two tidal straits: the Kill Van Kull and Arthur Kill, respectively, both with shipping channels running through them. The Kill Van Kull was deepened to 50-foot channels along with the Bay's main port channels, with dredging completed in 2016. The United States Army Corps of Engineers (USACE) has proposed an additional phase of channel construction to deepen and widen the channel to accommodate larger shipping vessels (USACE 2020).



Newark Bay is central to one of the most urbanized and industrialized areas in the United States.

In the mid-1800s, construction of railways and industrial development began to alter the Newark Region that was previously characterized by small towns surrounded by undeveloped land and tidal wetlands. By 1900, Newark was the largest industrial-based city in the United States. Throughout the 1900s, development continued as industrial operations replaced agriculture and large numbers of people moved to the area. As the area's population and industrialization grew, transportation needs increased, and a large network of roads, bridges, airports, and port facilities was constructed. Today, Newark – the largest city in New Jersey – is a major trade and transportation center and the Bay is a highly modified, deep water shipping port. The transformation of the Newark region required extensive shoreline filling and reshaping, channel development, and installation of water diversion structures (e.g., stormwater and combined sewer outfalls, dams) along the larger regional tributaries (Passaic and Hackensack Rivers), in addition to inland construction of roads, parking lots, and other structures. The Bay has become deeper due to channel and port construction while its surface area has become smaller due to filling activities. Between 1845 and 1989, water volume in the Bay increased by 15 percent (%) from dredging activities, while its surface area decreased by 26% from shoreline filling projects (Steinberg et al. 2004). These changes have reshaped the natural shoreline, filled tidal wetlands, and altered regional hydrology, sediment loading, and depositional patterns. These changes have significantly reduced the availability of ecological habitat, and present-day fate and transport of contaminated sediment is highly altered from conditions that existed earlier in the Bay's industrial history.



The Bay and portions of the Hackensack River, Arthur Kill, and Kill Van Kull make up the NBSA. The NBSA has seven distinct geomorphic areas: subtidal flats, historically disturbed subtidal flats (areas altered by anthropogenic activities that were later filled by natural sedimentation, resulting in estimated sediment deposition of 5 feet or greater over time), transitional slopes, navigational channels, port channels, intertidal areas, and industrial waterfront. The Bay has complex hydrodynamics and sediment transport processes. Hydrodynamics of the Bay are externally forced by: 1) freshwater tributary flows from the Passaic and

Hackensack Rivers; 2) astronomical (tidal) forcing entering through the Arthur Kill and Kill Van Kull; 3) local and regional meteorological events, which produce waves, periods of high freshwater discharge, and storm surge; and 4) gravitational forcing including density-driven circulation (Herrington et al. 2002; Wakeman 2006), also referred to as estuarine circulation in the literature. The history of industrial/urban inputs to the Bay is the source of contamination, while the complex hydrodynamic and sediment transport processes have given rise to the current nature and extent of contamination in the NBSA. Numerous contemporary and historical releases of contaminants have impacted and may continue to impact the Bay, including industrial discharges; discharges from combined sewer overflows, stormwater outfalls, and publicly owned treatment works; releases from ships; tributary inflows; and resuspension of existing contaminants in the sediment bed, among others. However, given the municipal infrastructure to control stormwater and treat wastewater, it is unlikely that these sources are presently important contributors to contamination in the Bay.

Remedial Investigation Process

The RI activities in the NBSA reported here were completed pursuant to the AOC and focused on three RI-related goals.

Remedial Investigation Goals

1. **Nature and Extent of Sediment Contamination:** Determine the horizontal and vertical distribution and concentrations of PCDDs, PCDFs, PCBs, PAHs, pesticides, and metals for NBSA sediments.
2. **Risk Assessment:** Determine the primary human and ecological receptors (endpoints) of PCDD-, PCDF-, PCB-, PAH-, pesticide-, and metals-contaminated sediments in the NBSA to identify human health and ecological risks and establish appropriate action levels.
3. **Source Identification:** Determine the significant direct and indirect continuing sources of PCDDs, PCDFs, PCBs, PAHs, pesticides, and metals to the sediments in the NBSA.

PAHs – polycyclic aromatic hydrocarbons;
PCBs – polychlorinated biphenyls;
PCDDs – polychlorinated dibenzo-p-dioxins;
PCDFs – polychlorinated dibenzofurans

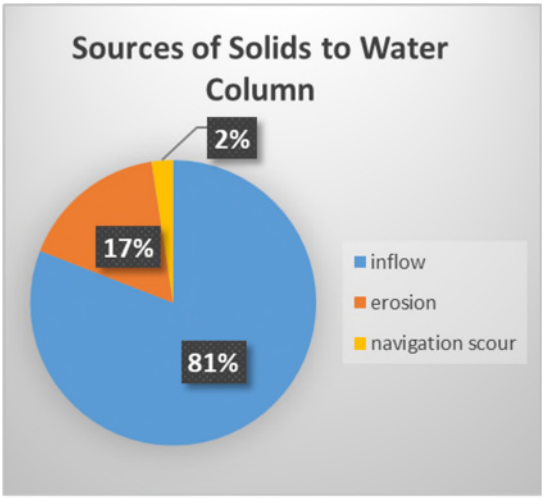
Beginning in 2005, RI work has proceeded in three separate phases, with each phase building on the previous to achieve the RI goals (Section 3). Phase I consisted of sediment core collection and analyses, biologically active zone investigations, bathymetry surveys, and an investigation of sources of pollutants and contaminants. Phase II was conducted in 2007 as an extension of the Phase I investigation and was specifically designed to address RI goals 1 and 3. Phase II also provided information pertaining to the Bay's overall contaminant loading history (Tierra 2007), and targeted collection of sediment cores in areas of potentially high historical sediment deposition. Phase III activities included collection of sediment and surface water samples, bathymetry surveys, and information necessary to complete baseline human health and ecological risk assessments, including survey of shoreline types, habitats, collection of clam, crab, and fish samples, and completion of a sediment quality triad and porewater sampling program. Work has included several focused investigations to provide the necessary data and information to conduct a Baseline Human Health Risk Assessment (BHHRA) and Baseline Ecological Risk Assessment (BERA) for the NBSA. Further, in parallel to the investigation process, a model system simulating the hydrodynamics, sediment transport, organic carbon transport, and contaminant fate and transport has been adapted for use in the NBSA and is designed to provide insight into the long-term fate and transport of contaminants in the system (Section 5). The model does not account for site-specific direct discharges of contaminants to the Bay estuary system and USEPA is not aware of any significant, direct discharges of contaminants that are not accounted for in the model. Contaminant fate and transport model results were linked to a bioaccumulation model to predict biota tissue concentrations of bioaccumulative chemicals.

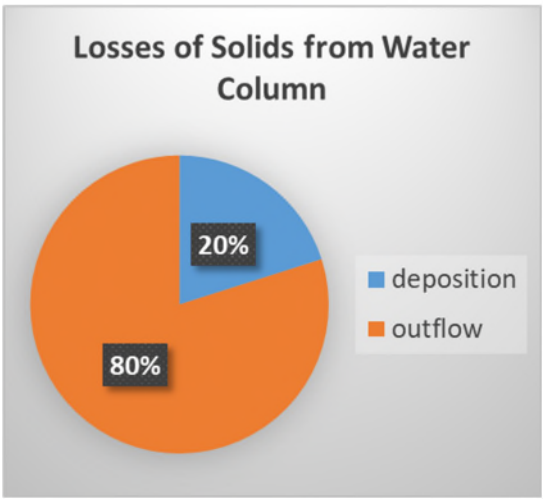
As part of the Phase I, Phase II, and/or Phase III investigations, sediment (surface and subsurface), biota (clam, crab, and fish), surface water, and porewater were sampled and analyzed for over 600 individual chemical compounds (Section 4). The data were evaluated to identify the contaminants in sediments for which risks to human health and ecological receptors/communities exceed acceptable levels set by the USEPA and are therefore likely to drive remedial decision-making in the NBSA (Section 6). The cumulative analyses presented in this RI report support key findings that will inform the feasibility study (FS) as the next step in the CERCLA process. The key

findings presented below are discussed in more detail, along with supporting information and data, in the various sections and appendices of this RI report.

Key Findings

- *Available data and modeling analyses indicate contaminants associated with human and ecological risks in the NBSA are primarily bound to sediment particles; therefore, the fate and transport of fine-grained sediments in the NBSA governs the movement of these contaminants.* Broad relatively shallow areas – including both subtidal and historically disturbed subtidal flats – comprising approximately 49% of the NBSA and the channels comprising approximately 31% of the NBSA are the dominant environments. Fate and transport processes differ between these environments. The channels are more depositional and are subject to periodic maintenance dredging and experience heavy ship traffic. The subtidal flats are subject to comparatively slower rates of sedimentation or no appreciable deposition. Wind-wave and tidal forces may cause erosion on the subtidal flats. However, the Sediment Erosion at Depth Flume, or SEDFlume, study (Section 5) found that erosive forces are unlikely to impact sediments below the depth of the biologically active zone. Critical shear stress data indicate that sediments are the most resistant to erosion in the subtidal flats, particularly in the southeast and southwest areas of the Bay. The depth of sediment containing contaminants in the Bay (based on sampling depths) ranges from approximately 3 feet or less in undisturbed areas to up to 30 feet in historically disturbed areas that were subsequently abandoned and allowed to refill with sediment. Historically disturbed areas of the subtidal flats experienced higher rates of historical deposition as they filled in (e.g., during the 1940s to 1980s) and contain elevated contaminant concentrations at depth and thicker deposits of contaminated sediment compared to other areas of the subtidal flats (Section 5). Where the historically disturbed areas have filled in and reached an elevation consistent with the surrounding subtidal flats, they are likely experiencing similar rates of sediment deposition to the surrounding undisturbed areas. Measured critical shear stress values are highest in the southeast and southwest subtidal flats that contain relatively elevated surface sediment concentrations of DDx and mercury in historically disturbed areas.





- *Large volumes of water and associated suspended solids are exchanged between the Bay and connecting waterways, namely the LPR, Hackensack River, Arthur Kill, and Kill Van Kull.* In deeper areas of the Bay, the exchange of water and suspended solids between the Bay and its tributaries is governed primarily by differences in density between freshwater and seawater, twice-daily (diurnal) tidal fluctuations, and the amount (higher or lower than normal) of discharge from the LPR. In shallower areas, including the subtidal flats, local and regional flows are dominated by a combination of wind driven circulation, wind generated waves, and to a lesser extent, twice-daily (diurnal) tidal fluctuations. Based on the USEPA contaminant fate and transport (CFT) model results for the calibration period in years 1996 through 2013, the majority of suspended solids coming into the water column of the Bay are from inflows from connecting waterways (~ 81%), followed by resuspension of sediment by wind waves on the shallow subtidal flats and by tidal currents and ship movement in the

channels (~19%). The Kill Van Kull is the largest net source of solids into the Bay (average annual flux in non-hurricane years of ~173,400 metric tons per year), followed by the Passaic River (~13,450 metric tons per year in non-hurricane years). In the shallow subtidal flats, sediment-water exchanges of contaminants are dominated by wind-generated waves that resuspend bottom sediments. Redistribution of these suspended sediments is controlled by a combination of tidal and wind-driven circulation patterns in the Bay (Sections 3 and 5); however, sources and sinks for suspended solids are not necessarily indicative of the net transport of individual contaminants. Instead, the net mass exchange of contaminants at the boundaries of the NBSA determine contaminant concentrations in the sediments in the Bay. Specifically, the concentrations of COCs on incoming solids combined with the local and spatially varying deposition rates control sediment concentrations in the Bay.

- *Concentrations of contaminants on suspended sediment in the water column of the NBSA and tributaries suggest the potential for future declines in surface sediment concentrations due to the deposition of particles with lower contaminant concentrations, but also suggest the potential for ongoing sources of contaminants to the NBSA.* Based on USEPA's modeling results for the 1996 through 2013 period, the direction of net transport (the difference in the flood and ebb-tide transport) for specific chemicals varies across each of the waterway boundaries within the NBSA and varies among contaminants. Some waterways are net sources of some, but not other contaminants; however, increases in modeled mass inventory of constituents of potential concern (COPCs) indicate the fate of mass inventory retained in the Bay is net deposition. On an annual basis, the net transport can vary such that some waterways are a net source to the Bay during some years and are a net exporter from the Bay during other years. Particulate contaminant concentrations (including 2,3,7,8-TCDD, mercury, PCBs, and DDx [sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane], and other contaminants) on suspended sediments from the Passaic River are expected to be reduced by implementation of the remedy selected by USEPA for the Lower 8.3 miles of the LPR (Operable Unit 2 of the DASS). Except for PCBs, sediment loads on the incoming tides from the Kill Van Kull are providing a major source of comparatively less contaminated particulates that promote continued reductions in surface sediment concentrations. Particulate concentrations of PCBs on sediments from the Kill Van Kull are greater than current average surface sediment concentrations in the NBSA (Section 5). The Arthur Kill is a net exporter of most contaminants and suspended sediments from the NBSA; however, the Arthur Kill is shown to be an ongoing source of the pesticide 4,4'-dichlorodiphenyltrichloroethane and its related isomers (DDx) to the NBSA (Sections 5 and 7). An additional source of mercury is Pierson's Creek, a Superfund site, that empties into the Port Newark Channel. The difference between particulate contaminant concentrations in the water column compared to waterways flowing into the NBSA and contaminant concentrations in surface sediments of the NBSA, as well as spatial deposition patterns within the NBSA, will play a role in determining how quickly concentrations of the risk drivers decline, and ultimately, the extent to which background levels limit declines.
- *The Bay is a net depositional environment, and the rate of deposition varies among shallow and deep areas of the Bay.* Modeling analysis quantified the loss of suspended solids from the NBSA water column, with channels capturing 80% (about 176,000 metric tons per year). Available radioisotope data and model results indicate that recent deposition has occurred at varying rates across most of the Bay, with recent sediment deposition primarily occurring in and near channel areas, with low rates of sediment accumulation on the subtidal flats. A historical dike was constructed in 1923 that bordered the navigation channel at the southern end of the southwestern subtidal flat. Based on a review of National Oceanic and Atmospheric Administration charts, sediment deposition increased on the southwest subtidal flat after dike construction and deposition rates may have reached equilibrium by the 1940s. The dike had deteriorated by 1964 and was reconstructed. By 1984, it had deteriorated again, and upon inspection it was found that sediment had accumulated north of the structure. This accumulation may lower rates of future deposition in the vicinity of the historical structure, although this specific effect has not been evaluated empirically or via modeling analysis for purposes of the RI Report. The periodic removal of sediments and associated contaminant inventory in the channels via maintenance dredging

on an as-needed basis is the most important factor affecting sediments in the channels. Maintenance dredging may also promote long-term reduction of sediment contaminant levels in non-dredged areas in the Bay and water column quality by reducing the COPC mass available for resuspension and redeposition within the NBSA (Sections 5 and 8). The USACE is currently proposing deepening and widening of the navigation channel and this project may alter sediment inventories and sediment transport processes in the Bay. Potential effects of this project will be further evaluated in the FS.

- *The subtidal flats are of key importance to management of sediment COPC concentrations due to their large area. Natural recovery processes in these large shallow areas include deposition and bioturbation, which add sediment and organic carbon to the sediment bed.* Sediment burial in the subtidal flats occurs at relatively slow rates and in some areas no appreciable net accumulation of sediment has been observed. However, where net accumulation does occur, it gradually buries and sequesters historical contamination out of the biologically active, or exposure, zone. Where net accumulation is not occurring, deposition is in balance with resuspension over time. As external and internal sources to the NBSA are reduced, deposited sediment will contain lower concentrations of contaminants and mixing of these less contaminated sediments into the bed by bioturbation will lower surface sediment concentrations. Long-term burial associated with thin accumulated layers of sediment may sequester contaminants below feeding depths of benthic organisms. This may be the most important process governing the reduction of contaminant concentrations in the biologically active zone of the subtidal flats (Sections 5 and 7).

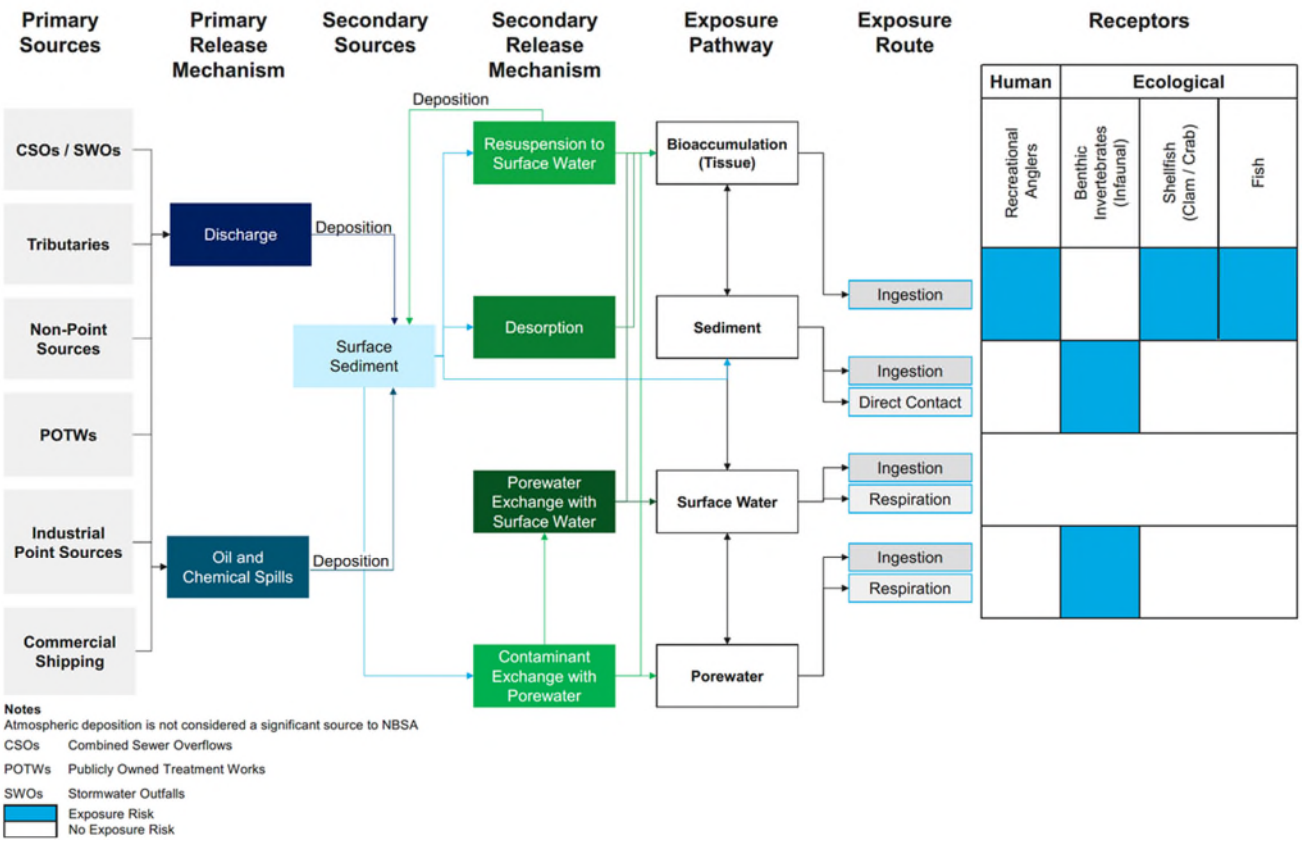
- *The complex interaction of oceanographic and hydrologic processes during episodic storm events can influence the rate of sediment loading to the Bay (via inflows), the stability of the sediments in the NBSA (due to higher bed stresses associated with winds, river discharge flows and storm surges), and surface sediment contaminant concentrations in the Bay.* Events such as Hurricane Irene (2011) or Hurricane Sandy (2012) have the propensity to deliver large sediment and associated contaminant loadings to the Bay, but high freshwater discharge from the LPR and Hackensack can also increase flushing of the Bay. High winds that can also occur during these storms have the potential to cause erosion. The competing influences with respect to storm-driven exchange of water and suspended solids between the Bay and connected waterways may affect the rate of reduction of contaminant concentrations in surface sediments. Modeling analyses indicate the LPR was a notable source of contaminants to the NBSA during Hurricane Irene (2011), and USEPA's modeling results show surface sediment contaminant concentrations of 2,3,7,8-TCDD and tetra-PCBs increased in response to this storm event (depending on the exposure area, concentration increases ranged from 18% to 225% for 2,3,7,8-TCDD and 1% to 24% for tetra-PCBs). Similarly, surface sediment contaminant concentrations of total DDx and mercury increased in response to Hurricane Irene (depending on the exposure area, concentration increases ranged from 2% to 10% for total DDx and from 1% to 11% for mercury). This illustrates the importance of source control to reduce inputs to the Bay and promote and sustain reductions in surface sediment concentrations. LPR inputs to NBSA in 2011 including Hurricane Irene were larger than all prior years combined for the period examined by the USEPA model (2004 to 2013). Despite the occurrence of Hurricane Irene, the model results show that reductions in surface sediment concentrations resumed after the event (Section 5). The greatest decreases were noted for 2,3,7,8-TCDD and tetra-PCB; depending on exposure area, concentrations decreased over the period January 1, 2012 to September 30, 2016 from 7% to 57% for 2,3,7,8-TCDD and from 4% to 26% for tetra-PCB. Decreases in surface sediment concentrations of total DDx (4,4') and mercury also occurred, ranging from 3% to 9% and 4% to 20%, respectively, depending upon exposure area.

- *Of the 23 contaminants evaluated, concentrations in surface sediments for 18 of these have declined 20% to 40% from 2005 to 2016 (based on comparison of Phase I/II and Phase III co-located samples), continuing historical declines evident over the period between 1980 and 2016 that ranged from 2% to 5% annually however future rates of change are uncertain.* These findings reflect deposition of comparatively less contaminated particulates and a reduction in sources. As discussed in Section 4, while demonstrable trends can be detected in these evaluations, they are subject to uncertainty because while the Phase I/II sample

locations were distributed spatially throughout the NBSA, they were not randomly located in the strict sense and rates of decline may not be predictive of future conditions. At a few locations, an increase in COPC concentrations between 2005 and 2016 was noted, suggesting that the average rate of decline may not apply in all areas of the Bay, particularly where deposition rates are very low or where particulate concentrations suggest ongoing inputs of COPCs. More recent rates of sediment burial appear slower; however, it is unknown if rates would continue to be slower due to rising bed elevations coming into dynamic equilibrium with erosive stresses (e.g., wind waves and tidal flows) or if sea level rise may offset these such that similar rates occur going forward. Further, the deepening and widening of the navigation channel currently proposed by USACE may alter sediment inventories and sediment transport processes in the Bay. Implementation of a long-term monitoring program would provide a basis for understanding ongoing rates and persistence of declines in surface sediment concentrations in the Bay.

- *There are statistically significant differences in surface sediment contaminant concentrations between various areas of Newark Bay.* These differences are primarily attributed to differences in depositional history, as opposed to local sources (Sections 4 and 5).
- *The BHHRA and BERA have identified four primary Bay-wide risk drivers associated with cancer and noncancer risks to human health, and with bioaccumulation-based ecological risks: 2,3,7,8-TCDD, PCBs, DDx, and mercury/methylmercury*[1]. *Arsenic, lead, and nickel also pose bioaccumulative risks to softshell clam.* Risks associated with 4,4'-dichlorodiphenyldichloroethane (DDD) and methylmercury are specific to human health. The BERA also identified localized risk of toxicity to benthic (infaunal) invertebrate communities from direct exposure in sediments to a variety of contaminants. The primary risk drivers for this pathway (i.e., direct exposure to invertebrates) were identified through the sediment quality triad assessment within the BERA to include: PCBs, DDx, PAHs, and arsenic. While the BHHRA and BERA identified major risk drivers, other COPCs that contribute to the overall risk will be evaluated by USEPA to ensure that the overall remedy is protective, including whether other COPCs are co-located with the major risk drivers. An overview of the conceptual site model for NBSA risk drivers is illustrated on the following page (Sections 6 and 7).
- *For most organic contaminants, shellfish (clam and crab) and fish tissue concentrations increase with sediment concentrations, although there is variability in the relationship.* For higher trophic level shellfish, fish, and wildlife that utilize the Bay, the food web exposure pathways are the primary influence on bioaccumulation. 2,3,7,8-TCDD, total PCBs, total DDx, and mercury are associated with ongoing Bay-wide human health risks in the NBSA associated with consumption of fish and blue crab, and pose ecological risks to softshell clam, blue crab, and fish.

[1] The BHHRA also identified copper as contributing to an unacceptable noncancer hazard from blue crab consumption. Due to the toxicity value and uncertainty factors used to estimate the noncancer hazards associated with copper, and considering that copper is an essential nutrient, USEPA determined that a preliminary remedial goal does not need to be calculated for copper.



Conceptual Site Model for NBSA Risk Drivers

Primary Conclusions of the RI

When the results from the investigation work conducted between 2005 and 2016 are considered along with the contaminant fate and transport information provided by the model system available for the NBSA, several important conclusions can be drawn, including:

1. **Declines in surface sediment COPC concentrations and improvements in benthic community health are occurring in the Bay.**

   Sediment data show surface sediment COPC concentrations in the Bay are declining, but ongoing contaminant sources exist. The rate of reduction in surface sediment contaminant concentrations varies considerably by location due to varying deposition rates. The rates and persistence of these declines are not fully understood at this time. Some sediment core profiles, particularly in historically disturbed areas, exhibit burial of older, legacy-contaminated sediments by deposition of sediment with lower contaminant concentrations. Where historical deposition rates are low, mainly in undisturbed areas of the subtidal flats, contaminants occur primarily in the surface sediment layer (0 to 0.5 feet) and the shallow core profiles from those areas are not interpretable with respect to trends. However, while the rate of decline may vary, evaluation of temporally co-located surface sediment samples suggests they are Bay-wide for many COPCs. Source reductions and attendant reductions in surface sediment contaminant concentrations are evident in the benthic invertebrate community where a reduction in acute toxicity has been observed over time along with increases in diversity and abundance. Source reductions further result in reduced risks to human health (Section 8). Further source control to be achieved by the remedial action currently in design for the lower 8 miles of the LPR, and other planned and potential remediation in the connected waterways will further support continued reductions in surface sediment COPC concentrations. Periodic removal of sediments by the U.S. Army Corps of Engineers through the ongoing maintenance dredging program of the channels will remove inventories of contaminants in recently-deposited sediments, which will facilitate risk reduction by reducing the potential for redistribution in and export

from the Bay. Outside of the channels in the subtidal flats, where little recent deposition has occurred, the processes of sediment mixing, sediment burial, and sediment-water transfer and dispersion within and exported from the Bay may continue to drive declines in surface sediment concentrations.

2. **The NBSA both contributes and receives contaminant loads from connected waterways.**

   Analysis of sediment and mass fluxes of risk-driving contaminants between the NBSA and connected waterways show that, due to bi-directional tidal currents, large tidal fluxes of sediments and contaminants are exchanged with connected waterways. All connected waterways are sources of sediments and risk-driving contaminants to the Bay, and the Bay is a source of sediments and risk-driving contaminants to connected waterways; however, the direction of net transfer varies among the individual compounds and waterway interfaces. The difference between water column particulate concentrations of contaminants driving risk and sediment surface concentrations of those contaminants in the Bay will play a role in determining how quickly concentrations of the risk drivers decline (assuming contaminant sources to the Bay remain at or below current inputs), and ultimately, what background levels may be limiting declines. Based on USEPA's contaminant fate and transport modeling results, the LPR is a source of several risk-driving contaminants (including 2,3,7,8-TCDD, mercury, PCBs, and DDx) to the NBSA due to higher sediment concentrations in the LPR. Planned remedial efforts for the lower 8 miles of the Passaic River will reduce inputs of risk-driving contaminants to the NBSA, promoting future declines in surface sediment contamination in the NBSA. Particulate contaminant concentrations in Kill Van Kull inflows indicate fluxes of sediment from the Kill Van Kull are promoting reductions in surface sediment contaminant concentrations with the exception of PCBs (Section 5). Particulate concentrations and contaminant fate and transport modeling show the Kill Van Kull to be an ongoing source of PCBs to the Bay, while the Arthur Kill is an ongoing source of DDx to sediments in the Bay. These have the potential to lengthen rates of future reductions of surface sediment contaminant concentrations of these risk drivers in the NBSA.

3. **Bioaccumulation risks to human and ecological receptors remain.**

   Despite decreases in recent years, 2,3,7,8-TCDD, total PCBs, total DDx, and mercury are still associated with Bay-wide human health risks in the NBSA associated with consumption of fish and blue crab, and pose ecological risks to softshell clam, blue crab, and fish (GSH 2019, 2020). In addition, arsenic, lead, and nickel are associated with bioaccumulative risk to softshell clam.

4. **Localized risks for direct exposure/toxicity risks for the benthic (infaunal) community remain.**

   PCBs, DDx, PAHs, and arsenic are associated with direct sediment toxicity risk to benthic (infaunal) invertebrates in localized areas of the NBSA – particularly in the southwest subtidal flats and near the Interstate-78 bridge crossing in the northern Bay. Other contaminants may also contribute to toxicity in the system, but their likelihood as toxicological drivers in sediments is substantially less. Water column particulate concentrations of total DDx (4,4') at the Arthur Kill station are lower on average (131,000 µg/kg) than the average concentration in surface sediments on the southwest subtidal flat (205,000 µg/kg) but are elevated compared to water column particulate concentrations measured at other NBSA stations and in comparison to average surface sediment concentrations elsewhere in the Bay. Model results provided by USEPA suggest that some proportion of contaminants entering the Bay from the Arthur Kill are exported via the Kill Van Kull; however, the Arthur Kill is a net source of DDx to the Bay and reduction of DDx source(s) from the Arthur Kill may be needed to ultimately achieve risk-based toxicity levels in the southwest subtidal flats.

The next phase of the Superfund process in the Bay will be the development of the FS Report, which is an evaluation of possible remedial alternatives for the NBSA. As part of the FS, the USEPA CFT model and the linked bioaccumulation model will be used to evaluate a range of remedial alternatives under projected future conditions, including the channel widening and deepening project proposed by USACE, and to estimate tissue concentrations of bioaccumulative chemicals in fish and blue crab. The model output will also be examined regarding predictions of the likelihood and magnitude of future sediment deposition.

Guide to the Newark Bay Study Area Remedial Investigation Report

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Section 2:	Newark Bay Study Area Investigations
Section 3:	Newark Bay Study Area Physical Characteristics
Section 4:	Nature and Extent of Contamination
Section 5:	Fate and Transport of Constituents of Potential Concern
Section 6:	Risk Assessment Summary
Section 7:	Conceptual Site Model
Section 8:	Summary and Conclusions

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1 INTRODUCTION

The Diamond Alkali Superfund Site (DASS) was added to the Superfund National Priorities List on September 21, 1984 because of contaminants present at the site (Figure 1-1). Four different operable units (OUs) are associated with the site (Figure 1-1): the former manufacturing plant and surrounding properties at 80 and 120 Lister Avenue (Operable Unit 1 [OU1]), the lower 8.3 miles of the Passaic River (Operable Unit 2 [OU2]), the Newark Bay Study Area (NBSA; Operable Unit 3 [OU3]), and the lower 17 miles of the Passaic River (Operable Unit 4 [OU4]; Lower Passaic River Study Area [LPRSA]; U.S. Environmental Protection Agency [USEPA] 2016c).

Pursuant to the Administrative Order on Consent (AOC) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; Index 02-2004-2010; USEPA 2004a), Glenn Springs Holdings, Inc., (GSH), on behalf of Occidental Chemical Corporation (OCC; the successor to Diamond Shamrock Chemicals Company [formerly known as Diamond Alkali Company]), has conducted a Remedial Investigation (RI) for the NBSA.

The findings of the NBSA RI are the subject of this RI Report.

1.1 Site Setting and Study Area Description

1.1.1 Newark Bay Study Area

Newark Bay (Bay) is a 6.3-square-mile enclosed embayment on the western side of the New York/New Jersey (NY/NJ) Harbor Estuary. The Bay is adjacent to four large cities (Newark, Elizabeth, Bayonne, and Jersey City), and is fringed on its western side by port facilities, industrial facilities, and the Newark Liberty International Airport. On its northern side, the Hackensack and Passaic Rivers flow into the Bay, while on the southern side, the Bay is connected to NY Harbor (NY) and Raritan Bay (NJ) through two tidal straits: the Kill Van Kull and Arthur Kill, respectively. The NBSA has been defined as the Bay and portions of key tributaries, including the Hackensack River, Arthur Kill, and Kill Van Kull. The Bayonne and Goethals Bridges are not the OU3 boundaries themselves (Figure 1-2); however, these bridges were identified as convenient ‘landmarks’ for the planned extent of the NBSA RI sampling programs described in this RI Report. The Passaic River is not part of the NBSA. It is being addressed via separate OUs (OU2 and OU4 are in the Lower Passaic River [LPR] that is part of the NBSA tidewater). Investigation of the NBSA OU is being conducted in a comparable manner and with consideration of the linkages between OUs for the purposes of CERCLA management decision-making and broader environmental management considerations. In April 2020, USEPA made a minor revision to the boundary between OU2 and OU3 to include all of the Kearny Point submerged bar and adjoining intertidal mudflats in OU2 (USEPA 2020).

The Bay is a partially mixed estuary, meaning that there is some density stratification of saline and fresh water (Suszkowski 1978; U.S. Army Corps of Engineers [USACE] 2007a). Salinity in the Bay ranges from approximately 14 to 24 parts per thousand (ppth), with an average annual salinity of approximately 20 ppth (USACE 2007a). Estuaries can have a wide range in salinity from freshwater to marine environments (0.5 to 30 ppth; USACE 2007a). The tides in the Bay area are semi-diurnal, with a mean tide range of 5.1 feet and a spring tide range of 6.1 feet. The mean tide level is 0.27 feet below North American Vertical Datum of 1988 (NAVD88; USACE 1997). Tidal currents are the primary mechanism of water flow within

the Bay and are strongest (both ebb and flood) in the Kill Van Kull. The dominant freshwater contributions to the Bay are from the Passaic and Hackensack Rivers at the northern end of the Bay, while other freshwater sources to the Bay include smaller tributaries like the Elizabeth River, Peripheral Ditch, and Pierson's Creek, among others (Figure 1-1). The Passaic River is the single largest contributor to freshwater discharges to the Bay, as discussed further in Section 3.4; however, the Hackensack River has a larger tidal exchange volume. Annual flow computations by Blumberg et al. (1999) show that approximately 60 percent (%) of annual flows into the Bay come from the Kill Van Kull and 34% come from the Hackensack and Passaic Rivers combined, while net discharge to the Raritan Bay occurs through the Arthur Kill. Tributary inflows to the Bay are discussed in detail in Section 3.4.1. Salinity is highest and density stratification is weakest in the Kill Van Kull due to high volume exchange with NY Harbor (Suszkowski 1978).

The Newark Basin, in which the NBSA is located, is underlain by sedimentary rocks (sandstones, shales, limy shales, and conglomerates), igneous rocks (basalt and diabase), and metamorphic rocks (schists and gneiss). Sediments found on the bottom or just below the bottom of the Bay are mostly fine-grained within the range of silt and clay-sized particles (USACE 1997). The pattern of sediment types (sand/gravels versus silt/clays) is indicative of fluvial sediment input at the northern end of the Bay and tidal exchange sedimentation at the southern end. The physiography and geology of the NBSA is discussed in further detail in Section 3.1.

Hydrodynamics within the Bay are influenced primarily by four inter-related physical forces: 1) freshwater tributary flows from multiple rivers, creeks, combined sewer outfalls (CSOs), and stormwater outfalls (SWOs); 2) astronomical (tidal) forcing that induces flow through the Arthur Kill and Kill Van Kull; 3) local and regional meteorological events, which produce waves, circulation, and storm surge; and 4) gravitational forcing (density-driven) that induces circulation (Chant 2006; Herrington et al. 2002; Wakeman 2006). These primary influences are responsible for the variations in hydrodynamic and sediment transport characteristics within the system (Herrington et al. 2002). Hydrodynamics of the NBSA are described in further detail in Section 3.4.

1.1.2 Environmental History, Development, and Use of the Newark Bay Study Area

The Bay is central to one of the most urbanized and industrialized areas in the United States. It has experienced more than 2 centuries of environmental degradation attributable to many factors, including shoreline and land development (USACE 2006a), wetlands/habitat loss, garbage and sewage disposal, dredging and dredged material disposal, and releases of contaminants from a variety of sources and locations (Iannuzzi et al. 2002).

The environmental history of Newark Bay parallels the development of the New York City metropolitan area. Most shipping and economic development in the 19th century clustered around Manhattan and Brooklyn, but as the pace of development quickened in the first half of the 20th century, the Bay eventually supplanted Manhattan as the primary port by the middle of the 20th century. Over that period of development, approximately 80 to 90% of the pre-existing shoreline of the Bay was developed and ecological habitats correspondingly diminished (Iannuzzi et al. 2002; USACE 2009a).

Newark and Elizabeth (known in its early history as Elizabethtown and Elizabethport), much like surrounding communities, started as small towns surrounded by farms, forest, and wetlands (Hassler

1844). By the 1840s, railways bisected wetlands and connected Newark to Jersey City and Elizabeth, setting the pre-conditions for future industrial development. Newark was home to several chemical companies producing various chemical products and raw materials by 1850 (Cunningham 1954; Zdepski 1992). By 1900, Newark was the largest industrial-based city in the United States, with well-established industries, including petroleum refining; shipping; tanneries; creosote wood preservers; metal recyclers; and manufacturers of materials, including rubber, rope, textiles, paints and dyes, pharmaceuticals, raw chemicals, leather, and paper products (Meyers 1945; Cunningham 1954, 1966; Brydon 1974; Halle 1984; MacRae's 1986; Galishoff 1988). By the early 20th century, housing developments covered most of the Bayonne peninsula, and the cities of Newark and Elizabeth on the west side were greatly expanded as the growing industrial manufacturing complex in the Newark region replaced agriculture and large numbers of people moved to the area. Commercial use of local waterways expanded between 1920 and 1950, driven by demands associated with World Wars I and II (Squires 1981). The Bay continued to evolve into what is now a highly modified, major shipping port.

The development of the Bay port system required extensive land development, achieved through "reclamation" of the meadowlands (wetlands) along the Bay and the Hackensack River during the 20th century. As the area's population and industrial development grew, transportation needs increased, and a large network of roads, bridges, airports, and port facilities was constructed. Today, Newark – the largest city in New Jersey – is a trade and transportation center. One of Newark's important functions as a transportation center is the transfer of goods from cargo vessels in the Bay ports to the many railroad and truck lines that serve the region and beyond. Land use along the northern, western, and southern shoreline of the Bay is high-density commercial and industrial/commercial development. A highly developed network of highways, combined sewer overflows, storm sewer outfalls, and publicly owned treatment works also exist within the Bay and its watershed (Mueller et al. 1982).

Industrialization of the Bay was facilitated by development of navigational channels in the NY/NJ Harbor Estuary starting in the mid-1800s through channel deepening and widening by the USACE New York District (see Figure 1-2 for current navigation channel system). Table 1-1 presents the Bay's history of dredging, navigation channel widening, and wetlands alteration. Bathymetry surveys have been conducted since the early 1900s by the National Oceanic and Atmospheric Administration (NOAA) and USACE, and historical nautical charts prepared by the NOAA illustrate the shaping of the Bay. Bathymetry surveys are discussed in further detail in Section 2.2.4.

The depth and width of the navigational channels have grown continually since the early 1900s (USACE 2006a), although channels in some adjacent water bodies (e.g., the LPR and Hackensack River) are no longer maintained to their previously authorized depths. The navigation channel in the Bay north of the port channels is not maintained to previously authorized depths, even though it is still subject to large vessel traffic (e.g., wastewater treatment sludge barges). Substantial maintenance dredging of the existing channels is required. During maintenance dredging in 2016, approximately 285,000 cubic yards (cy) of material were removed from critically shoaled areas of the Port Newark approach channels (USACE 2018a). The most recent maintenance dredging contract was awarded in June 2020 (Marine Log 2020). USACE is currently evaluating the feasibility of another construction project to deepen and widen the channel to accommodate larger shipping vessels (USACE 2020).

It is important to distinguish annual maintenance dredging from construction dredging, which may be considerably larger but occurs only once for any given project modification and typically removes parent

bed material, whereas maintenance dredging removes newly accumulated material. In 2018, the USACE completed the Harbor Deepening Project (HDP). It included deepening in the Kill Van Kull, Arthur Kill, Elizabeth Channel, and the southern portion and middle reaches of the Bay (Figure 1-3) to accommodate large post-Panamax ships, which have drafts of 48 feet or more. Note that the HDP contract areas are separate from the reach boundaries presented on Figure 1-2. With the completion of the project, 50 feet of water access is available in the major channels in NY Harbor and the Bay, including the channels leading to the terminals in the NBSA (USACE 2016). The estimated total volume of dredged material removed as a result of the entire project (including NY Harbor and the NBSA), was 52,000,000 cy. Dredged material was placed at the Historic Area Remediation Site (located offshore in the Atlantic Ocean adjacent to the NY/NJ Harbor Estuary) or was beneficially reused for grading/closure materials, marsh restorations, and artificial reef development (USACE 2004a, 2013).

A present land use map of the NBSA is presented on Figure 1-4. Human use of the NBSA is primarily industrial and commercial. Recreational use is limited due to access limitations from the shoreline types (i.e., bulkhead, bridges, sheet piling, and mudflats) and surrounding urban/industrial/commercial land use. Access for recreation is through available public access areas and pleasure boating (i.e., from marinas inside and outside of the NBSA). Human use and associated exposure pathways are discussed in Section 6.1.

Ecological use is limited, particularly for nesting and foraging birds and mammals, due to historical wetland and tributary losses, the limited amount of intertidal habitats present in the Bay, and the fact that much of the shoreline is hardened by bulkheads, riprap, buildings, and impervious surfaces (i.e., pavement and concrete) (Iannuzzi et al. 2002). However, a variety of aquatic organisms, including both resident and migratory fish and shellfish species, are present throughout the Bay. The habitat areas in the Bay include subtidal flats, deepwater areas (including the maintained navigational channels and side slopes), and to a lesser extent intertidal mudflats and vegetated wetlands (Figure 1-4). Degraded structures and pilings offer some habitat for aquatic species. Shooters Island offers some forested and wetland habitat for birds. North and south of the NBSA are extensive tidal wetlands associated with the Hackensack River and the Arthur Kill that provide wildlife habitat for birds and mammals. Despite the changing habitat conditions in the ecosystem during the 20th century, the Bay acts as a spawning ground, migratory pathway, and a nursery/foraging area for a variety of aquatic organisms. Ecological use and exposure pathways are discussed in Section 6.2.

1.2 Superfund Site History and Participation

The NBSA is part of the DASS, which was added to the Superfund National Priorities List on September 21, 1984 because of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) present at the site and in the sediments of the LPR. USEPA's response began at the former facility located at 80 and 120 Lister Avenue in Newark, New Jersey (OU1). 2,3,7,8-TCDD was a by-product of one of the manufacturing processes at the former Lister Avenue facility and was detected onsite and in adjacent river sediments (USEPA 2016c). Due to the tidal nature of the LPR and the associated transport of contaminated sediment, the areal extent of contamination from the LPR extends into the Bay.

Four different OUs are associated with the DASS today (Figure 1-1):

- OU1: 80 and 120 Lister Avenue

- OU2: Lower 8.3 miles of the Passaic River
- OU3: NBSA
- OU4: Lower 17 miles of the Passaic River.

In 1990, a Consent Decree was entered into by the USEPA/State of New Jersey and OCC to implement and maintain an interim remedy, documented in a 1987 Record of Decision (ROD), at 80 and 120 Lister Avenue for OU1 (United States District Court 1990). The primary contaminants of concern identified in the ROD for OU2 are polychlorinated dibenzo-p-dioxins and furans (dioxins and furans), polychlorinated biphenyls (PCBs), mercury, dichlorodiphenyltrichloroethane and its primary breakdown products, dichlorodiphenyldichloroethane and dichlorodiphenyldichloroethylene (referred to as Total DDx), copper, dieldrin, and polycyclic aromatic hydrocarbons (PAHs).

In 2007, an AOC was signed by the USEPA and the Cooperating Parties Group (CPG; USEPA 2007a) to conduct an RI/Feasibility Study (FS) for OU4 (and OU2). The primary contaminants of concern identified for the DASS in the 2007 AOC include polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), PCBs, PAHs, pesticides, and metals.

In 2004, the USEPA and OCC signed an AOC under CERCLA (Index 02-2004-2010; USEPA 2004a) in which OCC agreed to conduct an RI/FS for the NBSA (USEPA 2004a). This work was formerly implemented, through April 2017, by Tierra Solutions, Inc. (Tierra) on behalf of OCC. GSH is currently performing the work on OCC's behalf. The USEPA sent General Notice Letters to provide notice of potential liability in the NBSA to additional companies in 2006, 2007, 2009, and 2012 as shown in Table 1-2.

Cleanup activities performed or planned to date at the DASS include the following:

- On September 30, 1987, the ROD for OU1 was finalized. The USEPA-selected interim remedy, which was completed by 2001, included constructing slurry and flood walls, capping the properties, and pumping and treating of groundwater to reduce its migration.
- In June 2008, the USEPA and OCC signed an agreement to remove 200,000 cy of contaminated sediment from the river adjacent to OU1. Phase I was completed in 2012 and included dredging, dewatering, and offsite disposal of 40,000 cy. Phase II was intended to include removal of the remaining 160,000 cy with disposal in a confined disposal facility (CDF). Remediation of the Phase II area is being integrated with the OU2 remedy.
- In June 2012, the USEPA and CPG signed an agreement to address contaminants found at the surface of a mudflat on the east bank of the Passaic River at River mile 10.9 in Lyndhurst, New Jersey. In 2013 and 2014, surface sediment was dredged and a cap was constructed.
- On March 3, 2016, the ROD for OU2 was finalized. The selected remedy consists of capping with sediment dredging to accommodate cap construction. The design of the OU2 remedy is underway (USEPA 2018).

The NBSA, which is the subject of this RI Report, is presently in the RI/FS process. In addition to this RI, baseline human health and ecological risk assessments (baseline human health risk assessment [BHHRA] and baseline ecological risk assessment [BERA], respectively) have been conducted for the NBSA (GSH 2019b, 2020), and the FS will follow.

1.3 Remedial Investigations

All investigation work was carried out in accordance with the USEPA-approved RI documents developed in accordance with Section B of the Statement of Work (SOW) attached to the RI/FS AOC, including the Health and Safety/Contingency Plan and the Investigation Work Plan (IWP)/Sampling and Analysis Plan (SAP)/Site Management Plan (SMP)/Quality Assurance Project Plan (QAPP) (Tierra 2005a, 2005b, respectively). The RI work is described in Section 2.

GSH has completed all investigation work needed to prepare an FS and support remedial decision-making in the NBSA. The efforts described in the USEPA-approved work plans have been completed.

This RI Report was developed based on the requirements described in Paragraph E (Scope) of the SOW attached to the RI/FS AOC, as well as USEPA guidance on the development of RIs under CERCLA (USEPA 1988). All relevant data for the various media in the NBSA that represent current conditions are included in the discussions of nature and extent (Section 4) and fate and transport (Section 5). Concurrent with USEPA review of this RI Report, GSH will prepare an FS Report.

1.3.1 Remedial Investigation Objectives

The RIs in the NBSA, designed and conducted according to the requirements specified in the RI/FS AOC and associated SOW, were developed to generate additional data that will be used to produce this RI Report, an FS Report, and ultimately support the development of a ROD for the NBSA. The NBSA AOC defined three RI-related goals that are addressed in this RI Report:

1. **Nature and Extent of Sediment Contamination:** Determine the horizontal and vertical distribution and concentrations of PCDDs, PCDFs, PCBs, PAHs, pesticides, and metals for NBSA sediments.
2. **Risk Assessment:** Determine the primary human and ecological receptors (endpoints) of PCDD-, PCDF-, PCB-, PAH-, pesticide-, and metals-contaminated sediments in the NBSA to identify human health and ecological risks and establish appropriate action levels.
3. **Source Identification:** Determine the significant direct and indirect continuing sources of PCDDs, PCDFs, PCBs, PAHs, pesticides, and metals to the sediments in the NBSA (USEPA 2004a).

As described in the RI/FS Phase I Investigation Work Plan (Phase I RIWP; Tierra 2005b) and Phase II Remedial Investigation Work Plan (Phase II RIWP; Tierra 2007), sediment and related investigation activities were carried out in two initial phases. On September 9, 2015, the USEPA submitted a memorandum to Tierra that described a need to characterize subunits of the Bay at an appropriate scale for RI/FS decision-making because the existing data only allowed for Bay-wide decision making (USEPA 2015b). A Phase III surface sediment investigation was designed and implemented in 2016 as described in the Newark Bay Study Area Phase III Sediment Investigation Quality Assurance Project Plan Amendment (Phase III QAPP; Tierra 2016). Sampling was conducted in a systematic, stratified manner to collect sufficient data to characterize and statistically compare surface sediment data in the various geomorphic zones and defined subunits of the Bay, and a number of previous Phase I/II locations were resampled to provide data for recent (i.e., previous decade) trend analyses. This program was also designed/intended to provide a baseline surface sediment sampling grid for the NBSA to utilize for future sampling events to conduct long-term trend analyses.

In addition to the RI investigations, a number of focused investigations were conducted to provide the necessary data and information to conduct a BHHRA and BERA for the NBSA. These included a reconnaissance survey (Tierra 2013d), sediment quality triad (SQT) and porewater sampling and analysis (Tierra 2015a), crab and clam sampling and analysis (Tierra 2014a), and fish sampling and analysis (Tierra 2014b). A determination of risks for the NBSA will be included within the BHHRA and BERA.

All work for this RI was carried out in accordance with USEPA-approved sampling plans. Section 2 of this RI Report describes the various RI phases and investigations, and the complete dataset for the NBSA is presented in Section 4. The BHHRA and BERA are summarized in Section 6, and the full reports are attached as Appendices A and B.

1.4 Report Organization

Together with this introductory section, this RI Report is organized as follows:

- Section 2 – Newark Bay Study Area Investigations
- Section 3 – Newark Bay Study Area Physical Characteristics
- Section 4 – Nature and Extent of Contamination
- Section 5 – Fate and Transport of Constituents of Potential Concern
- Section 6 – Risk Assessment
- Section 7 – Conceptual Site Model
- Section 8 – Summary and Findings
- Section 9 – References

2 NEWARK BAY STUDY AREA INVESTIGATIONS

The RI activities in the NBSA involved sampling to characterize the nature and extent of contamination in the NBSA, support BHHRA and BERA activities, and complete source identification. RI sampling activities were conducted according to the approach laid out in USEPA-approved QAPP and work plans for each phase of work.

The Bay RI field and sampling activities described in Section 2.1, and summarized in Table 2-1, include Phase I, II, III, and risk assessment investigations. Data collected by others outside of the RI process, but located within the NBSA, is referred to as secondary data and is discussed in Section 2.2. Modeling activities to support the RI/FS process are discussed briefly in Section 2.3. The data collected during these activities are synthesized in Sections 4 and 5 of this RI Report.

2.1 Investigations Conducted under the Remedial Investigation/ Feasibility Study Program

2.1.1 Phase I Site Investigation

The Phase I site investigation, which was implemented in 2005, was the initial effort to characterize the nature and extent of contamination in the NBSA. It consisted of sediment core collection and analyses, biologically active zone (BAZ) investigations, bathymetry surveys, and an investigation of sources of pollutants and contaminants. However, the investigation pertaining to sources of pollutants and contaminants was not reviewed or approved by the USEPA. The Phase I investigation was designed to address the RI goals by meeting the specific objectives listed in Table 2-2.

2.1.1.1 Phase I Sediment Sampling

The Phase I sediment sampling included collection of sediment cores from seven geomorphic areas (Figure 2-1) of the NBSA for chemical and radiological analyses. Sediment samples were analyzed for the parameter groups listed in Table 2-3. Sediment cores were collected using vibracoring techniques by Ocean Surveys, Inc. (OSI) from 69 locations between October 30 and December 12, 2005. At 51 of the 69 coring locations, two cores (referred to as primary and secondary) were collected to provide adequate sample volume for both chemistry and radiochemistry analyses. At the remaining 18 locations, only a primary core was collected for chemical analyses. Sediment core collection depths ranged from 0.5 to 11 feet below sediment surface (bss), with 0.5 to 2-foot sample intervals. In addition, one Ponar dredge grab sample was collected at each of the 69 locations for beryllium-7 (Be-7) analysis to determine whether recent sedimentation had occurred at the core location. Grain size analyses were performed on a subset of samples from each core to screen for general patterns in sediment texture (Tierra 2008b, 2014c). The locations of sediment samples collected during Phase I sampling are shown on Figure 2-1. During Phase I core processing, sample segment lengths were adjusted based on percent differences between core penetration and length of recovered sediment, as discussed in the Field and Data Report (FDR; Tierra 2008b).

Core radiochemistry data were collected and evaluated during Phase I primarily to establish the approximate depth of the 1940 horizon. Characterizing NBSA sediments to a depth corresponding to the year 1940 is a requirement of the NBSA AOC (USEPA 2004a) and was originally negotiated as part of the 1994 Passaic River Study Area (PRSA) AOC to confirm that the vertical extent of contamination in the LPR would be captured during the PRSA sediment investigation. Radiochemistry analyses included lead-210, Be-7, and cesium-137 (Cs-137) (Tierra 2005b, 2011).

The Phase I investigation characterized the spatial distribution and concentrations of contaminants in sediments. Details of the field and analytical activities for the Phase I site investigation are provided in the IWP/SAP/SMP/QAPP (Tierra 2005a, 2005b), and the FDR (Tierra 2008b). Field, laboratory, data quality assurance/quality control (QA/QC) procedures, and data validation were also implemented, as specified in the QAPP (Tierra 2005b).

2.1.1.2 Evaluation of the Biologically Active Zone

The purpose of the BAZ evaluation was to estimate the depth of the BAZ in the Bay (Tierra 2008a). The sampling event involved installation of a sediment profile camera system at each location followed by collection of three grab samples, for a total of 14 locations. For this evaluation, the BAZ was divided into two zones – an upper zone extending from the sediment surface to the average depth of active burrow structures and a lower zone extending from the average depth of active burrows to the maximum depth of active feeding voids. The results of the BAZ evaluation were summarized in the Estimation of the Biologically Active Zone, Newark Bay New Jersey (Diaz and Arcadis U.S., Inc. [Arcadis] 2008) report. From this work, for the purposes of the RI, the depth of the BAZ is defined as 0 to 6 inches, as described in Tierra 2008a.

2.1.1.3 2005 Bathymetric Survey

As part of the Phase I site investigation, a single-beam bathymetric survey was completed in 2005. The survey was performed by OSI between October 7 and October 20, 2005. The primary purpose of the Phase I bathymetry survey was to verify geomorphic areas and to ensure that transitional slope cores were collected at approximately mid-slope. The survey results led to several adjustments of the Phase I geomorphic regions, which are described in detail in the Phase II RIWP (Tierra 2007). The findings did not result in changes to proposed coring locations.

During the survey, simultaneous dual-frequency (200 kilohertz [kHz] and 24 kHz) soundings were obtained along a survey line plan composed of approximately 180 transects. These transects were generally spaced at 0.25-mile intervals oriented perpendicular to the Bay, with more closely spaced, shorter tracklines near shoreline structures, bridge crossings, and sharp breaks in slope (e.g., navigational channel). In anticipation of USACE-conducted bathymetric surveys to support ongoing navigation channel dredging in the southern region of the Bay (conducted as part of the 50-foot NY/NJ HDP), the survey transects crossing the southern navigation channel were eliminated from the original bathymetry survey plan. OSI provided bathymetry data referenced to NAVD88 and horizontal coordinates referenced to the New Jersey State Plane Coordinate System, North American Datum of 1983. The results of the bathymetry survey are included in the Phase II RIWP (Tierra 2007).

2.1.1.4 Investigation of Sources of Pollutants and Contaminants

A source investigation program compiled and developed information on potential sources and associated contaminants impacting the NBSA, including three major tributaries (Hackensack River, Kill Van Kull, and Arthur Kill) and smaller direct and indirect tributaries. The investigation program was organized into four components:

- Identification of potential contaminant sources to the NBSA from review of publicly available records
- Investigation of publicly owned treatment works (POTWs), CSOs, and storm sewer outfalls in the NBSA
- Investigation of waterfront-located sources in the NBSA
- Investigation of tributary sources in the NBSA (Tierra 2006).

Publicly available documentation regarding sources impacting the NBSA was reviewed, and results of this investigation are provided in the Report on Investigation of Sources of Pollutants and Contaminants (Tierra 2006). Note that this source investigation program was not reviewed or approved by the USEPA.

2.1.2 Phase II Site Investigation

The Phase II site investigation, which was conducted in 2007 as an extension of the Phase I site investigation, was implemented pursuant to the Phase II RIWP (Tierra 2007). The Phase II RIWP, based on preliminary review of the Phase I analytical data, determined that all but one of the nine established Phase I data quality objectives were met. The Phase I goal for nature and extent of contamination was to better understand broad constituent patterns in both the surface and subsurface, but not to investigate nature and extent to a level of detail adequate to complete the RI (Tierra 2005b). Specifically, the data suggested that certain Phase I sediment cores did not extend sufficiently to capture the depth of the 1940 sediment horizon as called for in the NBSA AOC. Consequently, Tierra proposed to return to those locations during Phase II in an attempt to penetrate to the 1940 horizon depth (Tierra 2007, 2014c). In addition, Tierra targeted other potentially high historical deposition rate areas shown in the USACE's report Geomorphological/ Geophysical Characterization of the Nature and Dynamics of Sedimentation and Sediment Transport in Newark Bay Focusing on the Effects Related to Continued and Future Federal Navigation Channel Deepening and Maintenance (USACE 2006a). Investigations into these isolated areas provided information pertaining to the Bay's overall contaminant loading history (Tierra 2007).

The Phase II investigation was designed to address RI goals 1 and 3 by meeting the specific objectives listed in Table 2-2.

2.1.2.1 Phase II Sediment Sampling

The Phase II sediment sampling included collection of sediment cores from 50 locations within the NBSA and its tributaries (Table 2-4). Twenty-nine of these were deep cores (target penetration down to approximately 30 feet bss) collected for both chemical and radiochemical parameters, and 21 were shallow cores (target penetration down to 0.5 foot bss) collected for chemical parameters only (Tierra 2008b, 2014c). Target depths for the 29 deep cores were estimated to capture the depth of the 1940 horizon based on results of the Phase I analyses and the analysis of the USACE (2006a). The deep cores

were intended to address project quality objectives to characterize sediments to the 1940 horizon in select areas found to be accreting sediments at a relatively high rate and to understand matrix heterogeneity. Both shallow and deep cores were collected to address project quality objectives to characterize sediments to further the understanding of broad spatial patterns in contaminant distribution in the channels and other geomorphic areas, as well as to characterize surface and subsurface sediments in select areas found to be potentially impacted by upland sources (Tierra 2007). Sediment grab samples were also collected adjacent to each of the 50 Phase II sediment core locations; the top 1-inch of sediment was retained for Be-7 analysis to determine whether recent sedimentation had occurred at the core location (Tierra 2008b, 2014c). Of the 25 Phase II cores that were co-located with Phase I cores, 12 were deep and 13 were shallow. Seven of the deep cores and three of the shallow cores were advanced in historical net depositional areas identified by USACE-NY while conducting long-term channel maintenance (Tierra 2008b, 2014c). Similar to Phase I, sample segment lengths were adjusted in Phase II based on percent differences between core penetration and length of recovered sediment, as discussed in the FDR (Tierra 2008b).

Table 2-4. Phase II Sediment Samples

Sampling Phase	Depth of Sediment Cores	
	Deep[1]	Shallow[2]
Phase II Cores	29	21
Phase I/II Co-located Cores	12	13
Phase I/II Co-located Cores in High Net Depositional Areas	7	3

Notes:
1. Deep cores were collected down to a depth of approximately 30 feet bss.
2. Shallow cores were collected down to a depth of approximately 0.5 foot bss.

Grain size was measured in five segments in each of the 29 deep cores: one from the top of the core, three from the middle of the core, and one from the bottom of the core. One grain size sample was collected from each of the 21 shallow cores. The Phase I and Phase II Data Evaluation and Analysis Report (DEAR) provides additional sediment sampling details (Tierra 2014c).

The locations of sediment samples collected during Phase II sampling are shown on Figure 2-1.

Chemical analyses are provided in Table 2-3. Geotechnical parameters included grain size and specific gravity (Tierra 2007). The FDR provides tables that summarize the physical, chemical, and radiochemical samples collected at each Phase II location (Tierra 2008b).

Details of the field and analytical activities for the Phase II site investigation are provided in the Phase II RIWP (Tierra 2007) and the FDR (Tierra 2008b). Field, laboratory, data QA/QC procedures, and data validation were also implemented, as specified in the QAPP elements of the Phase II RIWP (Tierra 2007).

2.1.3 Phase III and Risk Assessment Site Investigations

A Phase III site investigation, and several additional sampling programs to collect the data necessary to conduct the BHHRA and BERA, were conducted between 2012 and 2016. Together with the Phase I and

II investigations, these investigations provide the necessary data to complete this RI, as discussed in the Conceptual Site Model (CSM; GSH 2019a). These investigations are discussed in sequence of performance below.

2.1.3.1 2012/2013 Multi-Beam and Single-Beam Survey

OSI conducted a bathymetry survey between December 4, 2012 and February 19, 2013 in the main body of Newark Bay (including Port Newark Channel, Elizabeth Channel, and South Elizabeth Channel), southern portions of the Hackensack and Passaic Rivers, and the confluence of the Bay, the Arthur Kill, and Kill Van Kull (including South of Shooters Island Reach and a portion of the Elizabeth River). The purposes of the 2012/2013 survey were to:

- Generate a current dataset to represent sediment bed elevations within the NBSA and mouth of the Passaic River to support hydrodynamic and sediment transport modeling
- Develop empirical data to support the NBSA CSM (Tierra 2013c; Revision 2, GSH 2019a)
- Characterize changes in bathymetry since the 2005 survey (Tierra 2013b).

Multi-beam technology was used for surveying deeper areas, while single-beam technology was used in shallower areas. In general, multi-beam data acquisition was accomplished within the survey area up to elevation -8 feet relative to National Geodetic Vertical Datum of 1929 (NGVD29). Single-beam data were acquired inshore of the -8-foot NGVD29 elevation contour up to the shallowest practical depth, with a target water depth of 3 feet at the time of the survey. Planned multi-beam survey lines were constructed in advance of the field program and were supplemented where needed based on actual depth/tide conditions encountered. Planned lines were generally oriented parallel to the major contours of the water body (bay, river, or kill) and spaced at an interval that would result in overlap of the outer limits of the multi-beam echosounder swath equal to at least 10% of the width of the swath. In practice, the swath overlap percentage varied widely based on the actual water depth, undulating bottom depths, slope, sea conditions, tide, etc. The multi-beam echosounder was operated in geographic “blocks” that were generally less than approximately 3,500 feet in length. The single-beam trackline plan consisted of nominally 100-foot spaced lines oriented roughly perpendicular to the shoreline or major contours in each area (Tierra 2013b). The results of the 2012/2013 bathymetry survey are shown on figures included in the Multi-beam and Single-beam Bathymetric Survey Final Report (Tierra 2013b). The bathymetric survey was performed in accordance with the QAPP (Tierra 2012b).

2.1.3.2 Shoreline/Habitat Survey

The Shoreline/Habitat Reconnaissance Survey for the NBSA was conducted in 2013 as part of the BHHRA and BERA activities for the RI/FS. Tasks for this work were completed as per the Reconnaissance Survey Work Plan (Tierra 2013d), with some minor deviations. The survey was completed by boat and video, and still cameras were used to record various shoreline/habitat data, including:

- Shoreline/habitat characterization information
- Characterization of human use of shoreline areas

- Identification of sampling areas and evaluation of sampling approaches.

Where feasible, the field biologists surveyed, on foot, the shoreline areas identified as habitat looking for bird nests and signs of mammal use (e.g., scat, tracks) and documented such findings. Survey findings, including a photograph log and a shoreline characterization video, are provided in the Newark Bay Study Reconnaissance Survey Report (Tierra 2015b). Figure 1-4 shows the shoreline habitat characterization. Figure 2-2 shows the shoreline human use characterization.

2.1.3.3 Crab and Clam Sampling Program

As part of the BHHRA and BERA investigations, blue crab (*Callinectes sapidus*), softshell clam (*Mya arenaria*), and co-located surface sediment sampling (for softshell clam only) were conducted in late summer/early fall 2014. This work was performed in accordance with the Crab and Clam Sampling and Analysis Quality Assurance Project Plan (Tierra 2014a). These data were collected to support the objectives of the NBSA BHHRA and BERA listed in Table 2-2.

Crab tissue samples collected as part of this program included hepatopancreas, edible muscle, and carcass samples. A total of 37 samples of each crab tissue type were collected, and 18 clam samples were collected. Tissue samples were analyzed for the parameter groups listed in Table 2-3. Additionally, 18 co-located surface sediment samples were collected from the softshell clam locations in intertidal areas by compositing the sediment associated with each clam burrow from which clams were collected at a location. Sediment samples were analyzed for the parameter groups listed in Table 2-3. Crab and clam and surface sediment sample locations are shown on Figure 2-3.

Details of the field program are provided in the Newark Bay Study Area Environmental Sample Collection Report (Normandeau Associates, Inc. 2017). Results for the crab and clam sampling program are provided in the Crab and Clam Data Report (GSH 2017a). Field, laboratory, data QA/QC procedures, and data validation were also implemented, as specified in the QAPP (Tierra 2014a).

2.1.3.4 Fish Sampling Program

A fish sampling program was conducted as part of the BHHRA and BERA activities, which included a community survey, fish tissue sampling, and a fish health study. These activities were conducted in accordance with the Fish Sampling and Analysis Quality Assurance Project Plan (Tierra 2014b) to support the BHHRA and BERA objectives listed in Table 2-2.

A total of 43 distinct fish species were collected over sampling events conducted in three phases (fall 2014, spring/summer 2015, and spring 2016) (Normandeau Associates, Inc. 2017). This combined fish sampling program resulted in a total of 12,826 specimens. The fish collection effort in 2014 included a total of 31 fish species represented by 6,454 individuals. For all sampling efforts, various combinations of eel pots, minnow traps, seine hauls, trawls, and gillnet sets were used. Species counts were collected to supplement existing NBSA fish community data. The 2015 sampling effort yielded a total of 24 fish species represented by 2,551 individuals. The targeted species in this event were: American eel, flounder/hake, white perch, striped bass, and bluefish. The sampling effort in 2016 resulted in a total of 25 fish species represented by 3,821 individuals, although white perch was the only targeted species for 2016.

Fish tissue samples were analyzed for the parameter groups shown in Table 2-3. Information regarding fish species collected and analytical results are reported in the Fish Data Report (Tierra 2017). Fish were collected from various locations along the subtidal flats, transitional slopes, and navigational channel throughout each of the three zones (north, south, central) to provide spatial coverage across the NBSA. Sample locations for 2014, 2015, and 2016 are shown on Figures 2-4, 2-5, and 2-6, respectively.

Additional data were also collected to provide qualitative information about the health of fish in the NBSA. During fish tissue sampling, non-forage fish were externally examined, and any gross physical abnormalities, lesions, or anomalies were documented. A subset of individual forage fish collected were externally examined. Additionally, a representative sample of individual non-forage fish were subjected to internal pathological examination in 2014 and 2015. The fish pathology evaluations included overall morphology, gonad condition, presence of lesions, gonadosomatic index, and internal physical conditions/abnormalities.

Information regarding the fish health results, as well as details of the analytical program, are reported in the Fish Data Report (Tierra 2017). Field, laboratory, data QA/QC procedures, and data validation were also implemented, as specified in the QAPP (Tierra 2014b).

2.1.3.5 Sediment Quality Triad and Porewater Sampling Program

An SQT and porewater sampling program was conducted in September 2015. The SQT and porewater program was conducted in support of the BHHRA and BERA and in accordance with the Sediment Quality Triad and Porewater Sampling and Analysis Quality Assurance Project Plan (Tierra 2015a). This program was implemented to meet the objectives identified in Table 2-2.

Sediment grab samples were collected from 43 locations over 13 days. The SQT analyses (i.e., sediment chemistry, toxicity testing, and benthic invertebrate community analysis) and porewater chemistry analyses were conducted at 30 of these locations. Samples from the remaining 13 locations were evaluated only for sediment chemistry for the purposes of quantifying contaminant levels in shoreline/nearshore areas where potential human exposure may occur (Figure 2-7). Sediment samples were analyzed for the parameter groups listed in Table 2-3.

An ex-situ laboratory porewater passive sampling program was conducted on field-collected sediments by researchers at the University of Maryland Baltimore County, in coordination with Arcadis and Tierra. Passive samplers for select organic compounds included polyoxymethylene for PCDDs/PCDFs and polyethylene for PCB congeners, pesticides, and PAHs via select ion monitoring. Strips of these samplers were deployed in sediments to extract compounds from the porewater fraction of the sediment. The organic compounds were then extracted from the samplers and the resulting data were used to estimate concentrations of these compounds in the porewater. The estimation procedures are summarized in Appendix B of the Sediment Quality Triad and Porewater Data Report (GSH 2017d). The calculations rely on the use of a poly-water partition constant (K_{PS}), which is estimated from other studies. Therefore, organic compound porewater concentrations are subject to uncertainty. Large-volume (0.5 liter) diffusion bags were used to capture porewater for direct analysis of metals and other inorganics (i.e., mercury, methylmercury, dissolved organic carbon (OC), ammonia, and total sulfide). A total of 30 porewater samples were analyzed using these methods.

Sediment samples collected from the 30 SQT locations were subject to two toxicity tests using the amphipod *Leptocheirus plumulosus*. These included a short-term 10-day exposure for survival and a longer-term 28-day exposure for survival, growth, and reproduction (GSH 2017d) hereinafter referred to as “acute” and “chronic” exposures, respectively. Statistically significant effects for acute exposures were defined as amphipod survival in test sediments that were significantly different than the laboratory control result.

Bioaccumulation tests (laboratory exposures of polychaete worms using field-collected sediments) were conducted at a subset of eight locations. Polychaete tissue samples were analyzed for the parameter groups listed in Table 2-3.

Details of the field program are provided in the Sediment Quality Triad and Porewater Field Report (GSH 2017e). Results for the sediment quality triad and porewater sampling program are provided in the Sediment Quality Triad and Porewater Data Report (GSH 2017d). Field, laboratory, data QA/QC procedures, and data validation were also implemented, as specified in the Sediment Quality Triad and Porewater Sampling and Analysis Quality Assurance Project Plan (Tierra 2015a).

2.1.3.6 Surface Sediment Sampling Program

The Phase III sediment investigation program was conducted in fall 2016, pursuant to the Phase III QAPP (Tierra 2016). This program was implemented to meet the objectives identified in Table 2-2.

Sediment samples were collected using vibracore and PONAR grab samplers. A total of 173 discrete vibracore surface sediment samples and 47 grab samples were collected in the NBSA under this program (Figures 2-8, 2-9a, 2-9b, and 2-9c). The vibracore samples and 10 of the grab samples were analyzed as discrete samples, while the remaining grab samples were combined into 10 composite samples representative of navigation and port channels. Sediment samples were analyzed for the parameter groups listed in Table 2-3.

Details of the field program and analytical results are provided in the Phase III Sediment Investigation Field Report (GSH 2017b) and in the CSM (GSH 2019a). Field, laboratory, data QA/QC procedures, and data validation were also implemented, as specified in the Phase III QAPP (Tierra 2016).

2.1.3.7 Surface Water Sampling Program

A comprehensive surface water sampling program was conducted by the CPG within the LPR and the NBSA (2010 to 2013) as part of the fate and transport modeling work being conducted by the CPG for the LPRSA and NBSA (AECOM 2010, 2011, 2019b). These surface water data have been deemed sufficient by the USEPA for use in conducting the RI, BHHRA, and BERA for the NBSA (Arcadis 2015).

Surface water samples were analysed for the parameter groups listed in Table 2-3. In discussion with the USEPA, it was agreed that the data from this program were suitable to characterize the nature and extent of contaminants in surface water in the NBSA.

The sampling program included six stations (NNE, NBN, NNW, NBE, NBS, and ARK) within the NBSA (Figure 2-10). Other locations outside the NBSA that were also sampled under this program included stations within the LPR and its tributaries, the Hackensack River, and the Kill Van Kull (Figure 2-10). The physical water column monitoring program was conducted from March through November 2010.

Five routine small volume chemical water column monitoring events were conducted in 2011 and 2012 under normal flow conditions (i.e., 400 to 3,000 cubic feet per second [cfs] at Dundee Dam):

- Event 1 was conducted from August 15 to 17, 2011, during average tide (median flow at Dundee Dam was 2,650 cfs)
- Event 2 was conducted from February 20 to 21, 2012, during spring tide (median flow at Dundee Dam was 699 cfs)
- Event 3 was conducted from March 26 to 27, 2012, during neap tide (median flow at Dundee Dam was 392 cfs)
- Event 4 was conducted from June 4 to 5, 2012, during spring tide (median flow at Dundee Dam was 1,389 cfs)
- Event 5 was conducted from December 10 to 11, 2012, during average tide (median flow at Dundee Dam was 664 cfs).

A single low-flow (i.e., less than 400 cfs at Dundee Dam) water column monitoring event was conducted on the LPR only in August 2012 during spring tide (median flow at Dundee Dam was 253 cfs).

Two high-flow events (i.e., greater than 3,000 cfs at Dundee Dam) were conducted in 2013:

- Event 1 was conducted from February to March 2013
- Event 2 was conducted in June 2013.

At each location and event, grab samples were collected from two depths in the water column: 3 feet (0.9 meter) above the bottom and 3 feet (0.9 meter) below the surface. Samples were collected at four intervals (i.e., high water slack tide, low water slack tide, maximum ebb tide, and maximum flood tide) at each location and depth.

A high volume chemical water column monitoring program was conducted over two sampling events: from December 2012 – January 2013 and June 2013 (AECOM 2019a). Large volumes of water were collected over a period of hours and then filtered in a three-step process. The objective of the program was to characterize the dissolved and particulate phase concentrations of PCDDs/PCDFs and PCBs in surface water and to achieve lower detection limits than was possible for the small volume program. Samples were collected from a subset of the sampling stations (Figure 2-10) in the NBSA, LPR and Kill Van Kull.

2.1.3.8 Combined Sewer Overflow and Stormwater Outfall Characterization

Information data gaps from the source investigation conducted by Tierra (2006), which was not reviewed or approved by the USEPA, were addressed by subsequent work carried out in accordance with the Combined Sewer Overflow and Stormwater Outfall Characterization – Phase I: Reconnaissance Work Plan – Information Gathering (GSH 2017c). The objective of this reconnaissance study was to develop an inventory of CSO outfalls, SWOs, emergency relief points, POTW outfalls, and outfall points for permitted industrial facilities that discharge to the NBSA, including location, history, operational status, and construction details, when available. Specifically, the following information was sought from public agencies or public databases to address data gaps remaining after the publication of the Report on Investigation of Sources of Pollutants and Contaminants (Tierra 2006):

- The locations of SWOs in Newark, Kearny (southern section), Jersey City, Bayonne, and Elizabeth, NJ, and Staten Island (Port Richmond), NY
- A listing of the names of significant industrial user dischargers located within the NBSA that were cited for violations of applicable permit conditions and a description of related permit violations
- More robust technical information related to the sewer systems, including reports and mapping to help identify additional mechanisms for sources of contaminants to enter into the NBSA from the POTWs identified above (GSH 2017c).

The results of the reconnaissance study are included in the Combined Sewer Overflow and Stormwater Outfall Characterization – Phase I: Reconnaissance Report – Information Gathering (GSH 2018). The report concluded additional characterization of the CSOs and SWOs that discharge to the NBSA was not warranted based on the information gathered; therefore, proposed sampling was not implemented.

2.2 Secondary Data

The NBSA has been studied by numerous agencies, institutions, and industry consultants over the last several decades. These studies are reported in several different publications, including government reports, university reports and theses, and scientific journal articles. A comprehensive search and summary of available data for the NBSA was undertaken by Tierra during development of the RIWP. The historical data collected up until that time are detailed in the Newark Bay Study Area RIWP, Sediment Sampling and Source Identification Program, Volume 1a of 3, Inventory and Overview Report of Historical Data (Tierra 2004).

Additional secondary data were identified in cooperation with the USEPA during development of the DEAR. At the time, a process was developed to classify secondary data for usability in the characterization of the NBSA. That process was detailed in the memorandum entitled Updating the Inventory Report Bibliography Database (Tierra 2004) and Performing a Secondary Data Evaluation for the Newark Bay Study Area Remedial Investigation (Tierra 2012a) and further described in Section 2.2.1.

During the preparation of the Final Newark Bay Study Area Problem Formulation (Tierra 2013a), a comprehensive review of secondary biological data in the NBSA was conducted and summarized. The purpose of the review was to provide the information necessary to develop ecological sampling programs for the NBSA. These data are summarized in Sections 2.2.3, 2.2.4, and 2.2.5.

The characterization of current conditions in the NBSA for this RI Report relies solely on the data collected under the RI/FS program described in Section 2.1. Secondary data were used to provide historical perspectives and comparisons only. The following section describes historical secondary data and its usability for this RI.

2.2.1 Sediment

During preparation of the DEAR (Tierra 2014c), a search was conducted to identify appropriate secondary sediment data that could potentially supplement the Phase I and Phase II characterization of the NBSA. The data evaluation presented in the DEAR included data collected within the NBSA, as well within adjacent tributaries extending 2 miles from the boundaries of the NBSA. The search focused on data collected from the year 2000 onward (some older data were evaluated), a timeframe considered

comparable to that of the combined Phase I/Phase II dataset that comprised the whole RI dataset at that time. Secondary data were reviewed for applicability to the project quality objectives of the Phase I and Phase II sediment investigations and evaluated for data quality comparability to the Phase I/Phase II dataset using an evaluation process developed with the USEPA (Tierra 2014c) to assign one of three usability levels:

- Level 1 (Qualitative): Datasets with Level 1 usability were collected without documented work plans and/or a QAPP or other project planning. Such data could be utilized in a qualitative manner (i.e., referenced or cited) but not included in quantitative analyses of the NBSA.
- Level 2 (Semi-Quantitative): Datasets with Level 2 usability were those that were collected under work plans, a QAPP, or other project planning, but that lacked post-collection quality activities (e.g., comparable validation procedures to the Phase I/Phase II dataset). Level 2 data could be summarized statistically and displayed on figures, but not combined with the RI data in quantitative analyses of the NBSA.
- Level 3 (Quantitative): Datasets with Level 3 usability had undergone similar QA/QC procedures consistent with the Phase I/Phase II dataset, including work plans, a QAPP, or other project planning, as well as post-collection validation. These Level 3 data, with comparable quality procedures, could be used in the same manner as Level 2 data. In addition, they could be combined with the RI data in quantitative analyses of the NBSA, where appropriate.

A complete description of these datasets is found in the DEAR. Most of the secondary sediment data evaluated for the DEAR were collected from locations outside the boundary of the NBSA and were within the adjacent tributaries. In addition, the age of much of the secondary sediment data make it useful only for historical context and not current characterization of the NBSA. Current characterization of NBSA sediment for this RI relies solely on the sediment data collected under the RI/FS program described in Section 2.1. Secondary sediment data that were used for historical perspective and for describing urban reference in this RI Report are described below.

1993 – 2013 USEPA Regional Environmental Monitoring and Assessment Program (REMAP) and National Coastal Assessment (NCA) Program: The USEPA conducted sampling of the NY/NJ Harbor Estuary to characterize sediment quality (USEPA 2003a). Twenty-eight locations were sampled in 1993-1994 and again in 1998 within the Bay sub-basin, which, under REMAP, included the LPR, Arthur Kill, and Kill Van Kull. Twelve of these locations were located within the NBSA (USEPA 2003a). Each location was sampled for sediment chemistry, sediment toxicity (i.e., 10-day *Ampelisca abdita* survival), and benthic invertebrate community characterization. These sediment data were not considered in the characterization in the DEAR because they were collected prior to 2000. However, they were evaluated for usability and determined to be of Level 3 quality. Similar sampling was conducted in 2003 under this program. The USEPA did not provide a published report for this dataset; however, it is available online (USEPA 2016b). REMAP sampling continued in 2008 and 2013 as part of the National Coastal Assessment Program and the data are available online at the National Water Quality Monitoring website (https://www.waterqualitydata.us). In addition, other samples collected in Jamaica Bay under the National Coastal Assessment Program are included as secondary data for urban reference. The REMAP data are useful for describing historical trends within the NBSA due to the random sample design and because many of the locations were re-sampled over time (Figure 2-11). All REMAP sediment sampling consisted of collecting the top 2 centimeters (cm) of sediment for evaluation.

2013 Post-Hurricane Sandy Sediment Quality Sampling: With multi-agency coordination, sediment quality sampling was conducted in 2013 in coastal areas of NY and NJ that were inundated during flooding that occurred in October 2012 during Hurricane Sandy (U.S. Geological Survey [USGS] 2015). Sediment samples from the top 2 cm were collected from 23 locations within the NBSA and were analyzed for multiple chemicals, including 2,3,7,8-TCDD, which are the only available analytical results made available to the public to date. Some sampling locations were co-located with REMAP locations making these data useful for describing historical trends within the NBSA.

2.2.1.1 Summary of Secondary Sediment Data

The locations of Level 3 data in the NBSA used in this RI are depicted on Figure 2-11 and include REMAP and post-Hurricane Sandy sediment data. These secondary data are used to evaluate historical trends within the NBSA. The locations of Level 3 data collected in Jamaica Bay and used to describe urban reference are shown on Figure 2-12. The following criteria were required for a Jamaica Bay sampling location to be used in defining reference conditions in the SQT evaluation presented in the BERA: SQT Triad (i.e., chemistry, 10-day laboratory toxicity, and community taxonomy) must be complete, greater than 80% *Ampelisca abdita* survival, no effects range-median exceedances in the sediment, and no more than three effects range low exceedances in the sediment.

2.2.2 Tissue

Secondary chemistry data for fish and other biota tissue are limited for the NBSA. During the 1980s, the New Jersey Department of Environmental Protection (NJDEP) captured and analyzed fish for PCBs and pesticides in edible fillet samples (NJDEP 1982, 1983, 1985). Also, during the 1980s, Brown et al. (1994) and Rappe et al. (1991) collected PCDD/PCDF data from various fish and shellfish tissue in the Bay. More recently, under the Contaminant Assessment Reduction Project (CARP), investigators captured and analyzed tissue data from one location in the center of the Bay (New York State Department of Environmental Conservation [NYSDEC] 2004a, 2004b, 2004c, 2005, 2006) from the following species: American eel, mummichog, ribbed mussel, sevenspine bay shrimp, striped bass, and white perch. Additional data are available for polychaetes and zooplankton greater than 64 microns. All tissue data were analyzed for metals, PAHs, PCBs, pesticides, PCDDs, and PCDFs.

A study by Parsons (2003), also conducted under the CARP program, analyzed samples of double-crested cormorant eggs, blood, and feathers for various chemical parameters (metals, PAHs, pesticides, PCBs, PCDDs/PCDFs) from three islands throughout the NY/NJ Harbor Estuary to determine if concentrations of contaminants were present in the birds at levels of concern, and to determine if there was any correlation between the concentrations of the contaminants and reproductive success in the population.

Additional studies (e.g., Cooper and Buchanan 2007; Bugel 2009; Bugel et al. 2011; Gale et al. 2000) have collected biomarker data, such as external examinations; blood smears; hematocrit; total and organ weights; histopathology; biochemical endpoints, including endocrine disruption (e.g., ethoxyresorufin-O-deethylase induction); and fluorescent activity. These data attempt to document potential changes in fish at the molecular level; however, it is difficult to scientifically link alterations in biomarkers to particular constituents.

Secondary tissue data are used for historical perspective only and as secondary lines of evidence for risk assessment as described in the BERA. Only data collected under the RI/FS program discussed in Section 2.1 are used to characterize chemical concentrations in biota in the NBSA.

2.2.3 Sediment Toxicity Data

More than a dozen historical laboratory studies have documented sediment toxicity within the Bay and its tributaries (Tierra 2004). Various organisms were used to measure survival and growth, including amphipods (*Ampelisca abdita* and *Rhepoxynius abronius*), polychaetes (*Armandia brevis*), mysids (*Mysidopsis bahia*), bivalves (*Mulina lateralis*), and sand dollars (*Dendraster excentricus*) (Tierra 2013a).

There are 10 published studies that include the results of *A. abdita* survival, the largest of which were conducted by the NOAA (1995) and USEPA (2003a). Additional unpublished REMAP *A. abdita* survival data collected in 2003, 2008, and 2013 by the USEPA and under the NCA Program were accessed online (USEPA 2016b; https://www.waterqualitydata.us). Both the REMAP and NOAA studies used a stratified random design to estimate the areal extent of toxicity. The REMAP and NOAA toxicity data are used to describe historical characterizations of toxicity in the NBSA. The description of current sediment quality with respect to toxicity rely solely on the data collected under the RI/FS program described in Section 2.1. The REMAP and NCA toxicity data collected in Jamaica Bay are used as an urban reference data set. For the NBSA SQT evaluation, Jamaica Bay reference data were screened as described in Section 2.2.1.1 and as detailed in the BERA.

2.2.4 Non-Remedial Investigation Bathymetric Surveys

Bathymetry surveys have been conducted since the early 1900s by the NOAA and USACE (GSH 2019a). The NY District of the USACE periodically surveys channels that are their responsibility. The main channel of the NBSA was most recently surveyed in February 2018, and the results are included in Appendix C (USACE 2018a).

In addition to bathymetry surveys, NOAA has prepared nautical charts since the mid-1800s. A selection of historical NOAA nautical charts from 1844 through 2020 are presented in Appendix C (NOAA 1844, 1917, 1925, 1935, 1940, 1967, 1978, 1986, 1994, 2010, 2020).

2.2.5 Biological Community Data

Benthic community data were collected under the REMAP programs described in Section 2.2.1 (USEPA 2003a, 2016b) and will be used to provide historical perspective. The characterization of current conditions of the benthic invertebrate community (BIC) will rely solely on the BIC data collected under the RI/FS program described in Section 2.1. Benthic community data collected under the REMAP and NCA programs in Jamaica Bay were screened as described in Section 2.2.1.1 and in the BERA and used as an urban reference data set.

From 1998 to 2010, the USACE collected fish community data from various stations within the NBSA with a 30-foot otter trawl as part of the NY/NJ HDP to establish use of the channel and non-channel areas within the harbor from year to year. These sampling data are used to describe the annual variability, seasonal movement patterns, and relative species abundance in the NBSA over the sampling period (1998-2010). The data are reported in annual Aquatic Biological Survey Reports (USACE 2003, 2004c,

2005, 2006b, 2007b, 2008, 2009b, 2010, 2011) and a Migratory Finfish Summary Report (USACE 2015). These data are used to help describe the fish community and to estimate residence times for the species sampled in the NBSA. The most recent of these reports, including data collected in the fish sampling program described in Section 2.1.3 are used to characterize current conditions of the fish community in the NBSA for this RI Report in lieu of additional sampling of other communities, including ichthyoplankton.

2.3 Hydrodynamic, Sediment Transport, and Modeling Studies

Numerical modeling of the LPR and the Bay system is being performed by USEPA's contractor HDR, Inc. (HDR 2021b). The model simulates hydrodynamics, sediment transport, OC transport, and contaminant fate and transport. The contaminant fate and transport model results are linked to a Newark Bay bioaccumulation model (Warren Pinnacle Consulting, Inc. 2020) as well. The application of these models is described further in Section 5.

In addition, Sea Engineering, Inc., on behalf of the USEPA, completed a Sediment Erosion at Depth Flume (SEDFlume) study to characterize the spatial variation in erosion rates and physical properties of the bed sediments in the NBSA. The findings of this analysis are discussed in Section 5.4.6 (Sea Engineering, Inc. 2013).

3 NEWARK BAY STUDY AREA PHYSICAL CHARACTERISTICS

3.1 Physiography and Geology

Newark Bay is situated within the Newark Basin portion of the Piedmont physiographic province, which itself is located between the Atlantic Coastal Province and the Appalachian Province (Suszkowski 1978). The Newark Basin is underlain by sedimentary rocks (sandstones, shales, limy shales, and conglomerates), igneous rocks (basalt and diabase), and metamorphic rocks (schists and gneiss). These rocks are from the mid-Triassic to early Jurassic periods. Bedrock underlying the Bay consists of the Lockatong Formation (light to dark gray silty argillite and laminated mudstone that has been thermally metamorphosed to hornfels where intruded by diabase), Passaic Formation (interbedded red-brown sandstones and shales), and Jurassic diabase (dark gray to black, moderately fractured igneous rock [the Palisades]) (Nichols 1968; Olsen et al. 1984; Drake et al. 1996). Figure 3-1 presents a cross-sectional view of the geology of the NBSA.

During the Pleistocene period of glaciations, the ancestral channels of the Hudson, Raritan, Hackensack, and Passaic Rivers were established in the glacial outwash plain along the Atlantic coast and became submerged as the sea level rose. The rise in sea level reduced flow velocities and created long-term permanent depositional environments in the coastal plain estuaries (Roman et al. 2000). The materials that were deposited above the red clay, commonly referred to as black silt, represent more recent (post-Pleistocene) estuarine deposits of sand, silt, and organic matter. The red brown Pleistocene clay layer represents an interval of native material in the NBSA deposited before the industrial period. The red brown Pleistocene clay layer was tested by the USACE and USEPA and was determined to be essentially free of contaminants and suitable for placement at the Historic Area Remediation Site (USACE 2007b). The black silts deposited above this clay layer were used to estimate deposition rates in the Phase I and Phase II cores (Tierra Solutions, Inc. [Tierra] 2011).

A combination of extensive shoreline filling and reshaping, channel development (dredging and dredged material disposal), and water diversion structures (e.g., stormwater and combined sewer outfalls, dams) built along the larger regional tributaries (Passaic and Hackensack Rivers) have reshaped the natural shoreline and altered regional hydrology and sediment input patterns. Growth and inland development have also transformed the region and resulted in roads, parking lots, and other structures that have modified the immediate watershed and runoff. First River, for example, no longer exists as a surface feature (Iannuzzi et al. 2002). The urban land use in the surrounding area is shown on Figure 1-4; approximately 20-25% of historical tidal wetlands remain in the area, while most of the freshwater wetlands which existed historically have been lost (Steinberg et al. 2004). Dredging in the NBSA (and the NY/NJ Harbor Estuary in general) has also substantially influenced the geomorphology of the Bay since the mid-19th century (see Section 1.1.2). The Bay has become deeper due to channel and port construction while its surface area has become smaller due to filling activities. Between 1845 and 1989, water volume in the Bay increased by 15% from dredging activities, while its surface area decreased by 26% from shoreline filling projects (Steinberg et al. 2004). These changes in volume and surface area produced an estimated 55% increase in mean depth for the Bay. Historical nautical charts prepared by

NOAA and presented in Appendix C-2 illustrate these changes. The 1844 nautical chart shows the historical shoreline and bathymetry of the Bay, and wetlands that were present; comparison of the 1844 chart against the most recent charts in Appendix C-2 highlights anthropogenic changes that have occurred over time. The changing shape and depth of the Bay, in addition to the changing characteristics of the watershed and tributaries, have influenced the hydrodynamics of the region over the past century. Changes to such hydrodynamic characteristics of a system can change tidal velocities, as well as sedimentation patterns and rates (Pence 2004). Table 1-1 presents a history of dredging activities within the Bay.

3.2 Meteorology

In the New Jersey Climate Division 1, which includes Essex County, the mean annual maximum temperature is 60.2 degrees Fahrenheit (°F), and the mean annual minimum temperature is 39.2°F. The mean average annual temperature is 49.7°F. The annual mean precipitation (rainfall) is 46.92 inches. July typically has the heaviest precipitation, while February has the lightest precipitation (Office of the New Jersey State Climatologist 2018[1]).

For the City of Newark, the average annual maximum temperature is 63.3°F, and the average annual minimum temperature is 46.5°F. The average annual temperature is 54.9°F. July is typically the hottest month, while January is the coldest. Average annual precipitation (rainfall) is 46.01 inches. July typically has the heaviest precipitation, while February has the lightest precipitation (U.S. Climate Data 2018[2]).

3.3 Geomorphology

Anthropogenic activities have had a significant influence on the evolution and geomorphology of the NBSA since the mid-1800s, resulting in its current shape. Geomorphic areas are defined based on comparable bathymetry and slopes, natural (e.g., mudflats or wetlands) and man-made (e.g., Navigation and Port Channels) features, water depth, hydrodynamic conditions, and historical influences. The NBSA, as described in Section 1.1.1, can be divided into seven distinct geomorphic areas (previously shown on Figure 2-7), which include the following:

- Subtidal Flats -- Broad, shallow, and located outside of the navigation channels, these flats cover approximately 42% of the NBSA. Water depth in the subtidal flats averages approximately 9 feet NAVD88 (Tierra 2013c), and water flow in these areas is largely driven by tidal influence and local winds.
- Historically Disturbed Subtidal Flats – These include specific areas within the subtidal flats that were likely altered by anthropogenic activities, such as dredging or construction. As detailed in the Deposition Report, these zones were characterized by USACE (2006a) as areas of “potential high net deposition” which were also located within the subtidal flats. These altered areas were confirmed through review of historical NOAA bathymetric maps; no other altered areas were identified (Tierra 2011). Intermittent natural sedimentation and lack of maintenance has since filled the former

[1] The period of record for New Jersey Climate Division 1 is 1895 to 2018.

[2] The period of record for City of Newark is 1981 to 2010.

depressions to a sediment bed elevation that is comparable with the surrounding subtidal flats. These zones encompass areas where the estimated sediment deposition is 5 feet or greater over time (1934 to 2006). Therefore, the surficial features and habitats of the historically disturbed subtidal flats, which cover approximately 6% of the NBSA, are similar to the surrounding subtidal flats; only the subsurface sediment characterization differs.

- Transitional Slopes -- These slopes are located between the deeper dredged channels and the subtidal flats and cover approximately 10% of the NBSA, with average water depths of approximately 25 feet NAVD88. The slopes are generally 3 to 1 based on observations from available NOAA bathymetric charts and consistent with the results of the bathymetric survey conducted as part of the Phase I site investigation (Tierra 2005a).
- Navigation Channels -- These areas are characterized by deeper depths and anthropogenic effects (currents) from deep-draft ocean-going ships and tugs. The HDP was completed in the navigation channels and port channels in 2016, resulting in an estimated depth of the navigation channels of approximately 50 feet NAVD88 (USACE 2018b). Navigation channels cover approximately 25% of the NBSA.
- Port Channels -- The port channels are located at Port Newark, Elizabeth, and South Elizabeth. Within these ports, large marine vessels maneuver and dock for cargo exchanges, then exit from the piers. The port channels account for approximately 6.2% of the NBSA, with average water depths of approximately 50 feet NAVD88 after completion of the HDP. Maintenance dredging occurs on a regular basis within the established port channels and associated berths for container ships at the larger terminals. Berths associated with privately owned properties along the shoreline of the NBSA are also periodically maintained.
- Intertidal Areas -- These areas (approximately 0.6% of the NBSA) are characterized by two main features: wetlands and mudflats (or sand/cobble flats) that are typically exposed during low tide. The wetlands are typically characterized by the presence of emergent vegetation, such as common reeds (*Phragmites australis*) and/or saltmarsh cordgrass (*Spartina alterniflora*), as well as soft muddy or organic substrates. Mudflats, sand, and cobble flats are characterized by unvegetated expanses of mud, fine sand, or clay.
- Industrial Waterfront Areas -- This geomorphic area includes shoreline areas along the NBSA within 100 feet of the entire shoreline, excluding intertidal areas. This area covers approximately 8% of the NBSA with average water depths of 17 feet NAVD88, not including upland areas. The Newark Bay shoreline has been significantly modified by human activities over time. The large number of constructed pier and shipping facilities along the waterfront is evidence of extensive historical removal, reworking, and disturbance of sediments. These facilities also present numerous physical obstructions to water currents and may cause highly localized variation in sedimentation patterns.

The geomorphic areas were originally presented in the Phase I Remedial Investigation Work Plan (Tierra 2005a) and refined for Phase II using the 2005 OSI bathymetric data and information from USACE (2006a). Most notably, results from USACE (2006a) allowed for a new geomorphic area to be identified within the NBSA, “Historically Disturbed Subtidal Flats” (Tierra 2011). These geomorphic features are important in understanding and predicting key processes affecting contaminant fate and transport in the Bay. Table 3-1 presents a summary of the surface area, mean depth, and the percentage of the NBSA

covered by each geomorphic area as recorded in the 2012/2013 bathymetric survey (Tierra 2013b). Additional details regarding geomorphic area identification and delineation is provided in the Data Evaluation and Analysis Report (Tierra 2014c).

A CDF (Cell 1S) was constructed within the Bay in 1997 over an area of approximately 27 acres, as shown on Figure 1-2. It is not a designated geomorphic area but is an area of importance in the Bay. The CDF was originally constructed to a depth of -70 mean low water (MLW). In August 2000, the surface of the dredged material within the CDF was measured by bathymetric survey to be approximately -35 to -40 MLW, which was approximately 30 to 35 feet above the facility bottom (Matthews et al. 2002). The CDF is nested within a subtidal flat in the central portion of the Bay, between the Port Newark and Elizabeth Channels. This facility has been utilized to accept dredge and other materials that were unacceptable for disposal at other sites. The CDF footprint comprises less than 1% of the NBSA. The CDF was closed in June 2012, and a final cap consisting of 3 feet of sand was applied to the site (Port Authority of New York and New Jersey 2012; Newark Bay Study Area Coordination Team 2012). Table 3-1 presents a summary of the surface area, mean depth, and the percentage of the NBSA covered by the CDF.

3.3.1 Shorelines in the NBSA

The NBSA shoreline is primarily comprised of bulkhead, mixed intertidal, riprap, and vegetation habitats and is characterized as follows:

- Bulkhead – Extent of shoreline where majority of vertical face consists of wood timbers, metal sheet pile, or large stone/cement blocks; approximately 40% of the NBSA shoreline is classified as bulkheads.
- Mixed Intertidal – Extent of shoreline where a combination of riprap, sand, and/or emergent vegetation is present. Mixed intertidal shorelines comprise approximately 10% of the NBSA shoreline.
- Riprap – Extent of shoreline dominated by sloped banks that are covered by cobble to boulder sized stones and/or concrete rubble. Riprap covers approximately 30% of the NBSA shoreline.
- Vegetation – Extent of shoreline with greater than 50% emergent vegetation. Approximately 20% of the NBSA shoreline is classified as vegetation habitat.

Human use of the NBSA upland areas is primarily industrial and commercial. Recreational use is limited due to access limitations of the shoreline types and surrounding land use. Buildings and other impervious surfaces are also found throughout the NBSA. The shoreline is characterized by the following human use categories:

- Disturbed Uplands – Open space areas abandoned and overgrown with terrestrial vegetation (e.g., trees, scrub/shrub)
- Undisturbed Uplands or Habitat – Areas consisting of natural vegetation providing habitat for wildlife species (not including landscaped vegetation)
- Industrial/Commercial – Areas consisting of industrial/commercial use, including manufacturing facilities, ports, and shipyards
- Recreational – Areas where recreational activities are dominant (e.g., parks, fishing spots, walking trails)

- Residential – Areas consisting of buildings, including residential homes, apartment complexes, and schools.

The Shoreline/Habitat Reconnaissance Survey for the NBSA was conducted in 2013 as part of the BHHRA and BERA activities for the RI/FS. Tasks for this work were completed as per the Reconnaissance Survey Work Plan (Tierra 2013d). The survey was completed by boat and video, and still cameras were used to record various shoreline/habitat data, including:

- Shoreline/habitat characterization information
- Characterization of human use of shoreline areas
- Identification of sampling areas and evaluation of sampling approaches
- Bird nest and mammal surveys.

Results of the Shoreline/Habitat Reconnaissance Survey are presented in the Newark Bay Study Reconnaissance Survey Report (Tierra 2015b). Human uses of the NBSA shoreline, shown on Figure 2-2, were found to consist of 19% disturbed uplands, 35% industrial/commercial, 13% recreational or habitat/recreational, and 8% residential shoreline human uses. Approximately 25% of the shoreline was classified as habitat.

3.4 Hydrodynamics

The NBSA has complex hydrodynamics and sediment transport processes. The Bay and its tributaries constitute a microtidal, partially mixed estuary under most flow conditions. Tides are primarily semidiurnal (twice a day), with a mean tide range of approximately 5 feet. The NBSA receives freshwater inflow primarily from the Passaic and Hackensack Rivers at its northern end and smaller contributions from small creeks and various municipal discharges around the perimeter of the Bay. Seasonally variable flows from the Passaic and Hackensack Rivers, as well as periods of high discharge from episodic storm events, can alter the position of the salt front and increase sediment loading at the head of the Bay. At its southern end, the NBSA exchanges estuarine waters with the Kill Van Kull, which connects to Upper NY Bay, and the Arthur Kill, which connects to Raritan Bay. Numerical modeling of the LPR and the Bay system includes a hydrodynamic and sediment transport model, which is further discussed in Section 5.

The NBSA's bathymetry consists of dredged navigation channels and adjacent shallow subtidal flats with sharp elevation gradients in between the navigation channels and the subtidal flats. Phase I investigation bathymetric maps for the NBSA from 2005 are included in the Phase II Remedial Investigation Work Plan (Tierra 2007). Phase III investigation bathymetric maps for the NBSA from 2012 and 2013 are shown on figures included in the Multi-beam and Single-beam Bathymetric Survey Final Report (Tierra 2013b). Bathymetry investigations of the NBSA are discussed in more detail in Sections 2.1.1.3 (Phase I) and 2.1.3.1 (Phase III). As described in Section 2.2.4, the most recent USACE survey of the NBSA main channel (February 2018) and a selection of the most recent NOAA nautical charts from 1844 through 2020 are included in Appendix C (USACE 2018a). The USACE bathymetry survey shows water depths in Newark Bay and the configuration of the shoreline. In addition to water depth and shoreline configuration, the NOAA nautical charts show locations of dangers and aids to navigations, location names, and other features (e.g., bridges).

Hydrodynamics and sediment bed conditions in the Bay likely continue to adjust to the recent deepening of the navigation channels. Channel deepening alters instantaneous tidal currents and bottom velocities, increases saltwater intrusion, reduces bed roughness in the dredged channels, promotes greater retention of sediment within the navigation channels, and consequently may also alter sediment transport in the northern portions of the Bay (north of the deepened channels) and the northern tributaries. The timing and potential effects of channel deepening and potential influence on long-term time trends and fate of contaminants in surface sediments of the Bay is discussed in Section 5.

Hydrodynamics of the Bay are externally forced by several physical processes: 1) freshwater tributary flows from multiple rivers, creeks, CSOs, and SWOs (Section 3.4.1); 2) astronomical (tidal) forcing that induces flow through the Arthur Kill and Kill Van Kull (Section 3.4.2); 3) local and regional meteorological events, which produce waves, circulation, and storm surge (Section 3.4.3); and 4) gravitational forcing (density-driven) that induces circulation (Herrington et al. 2002; Wakeman 2006) (Section 3.4.4). Each of these physical processes is discussed in detail below.

3.4.1 Tributary Inflows

Given the significant amount of dredging since the mid-19th century (USACE 2006a), flows are much different now in the Bay from what they were before human activities. Because of the freshwater inputs in the northern end of the Bay and the resulting density gradient, the system is partially mixed and displays the characteristics of classic two-layer estuarine circulation with a landward flow of saltwater in the bottom layer and a seaward flow of less saline water in the surface layer (Chant 2006; Pence 2004; Suszkowski 1978; Wakeman 2006). High freshwater discharge from the Passaic River increases both vertical stratification and residual flow rate in the landward-flowing bottom layer in the Bay (Chant 2006). Section 3.4.2 discusses two-layered circulation patterns in greater detail.

Freshwater is delivered to the Bay through several major and minor waterways. The principal sources of freshwater are the Passaic and Hackensack Rivers. Minor contributors include the Peripheral Ditch and Pierson's Creek, which empty directly into the Bay, as well as the Rahway River, the Elizabeth River, Piles Creek, Morses Creek, and Fresh Kills Creek, which enter by way of the Arthur Kill tidal strait (Figure 3-2). Two other waterways, Oyster Creek and Maple Island Creek, formerly drained to the Bay (circa 1917), but have since been filled. Table 3-2 lists the flows in tributaries to the NBSA for which data were available[3]. Pierson's Creek and the Peripheral Ditch do not have base flows (they are conduits for rainfall runoff). No flow data were available for Piles Creek.

3.4.1.1 Major Tributary Inflows

Major freshwater inputs to the NBSA are from the Passaic and Hackensack Rivers. The combined watershed for these two tributaries is approximately 726,700 acres in NJ and NY (USEPA 2012a). The Passaic River is roughly 80 miles long with its origin in the center of Mendham, in southern Morris County, NJ. It meanders through the swamp lowlands between the ridge hills of rural and suburban northern NJ, called the Great Swamp. In the upper reaches of the Passaic River, its tributaries drain much of the

[3] Historical data are referenced to further an understanding of the evolution of Newark Bay, and may not describe current conditions due to natural and anthropogenic changes that have occurred in the time period since data collection.

northern portion of the state. Upriver of the Dundee Dam in Little Falls (Figure 3-2), the mean daily flow is approximately 1,145 cfs (USGS 2020a). In its lower reaches, the Passaic River flows through the most urbanized and industrialized areas of the state, including downtown Newark, and then it enters the upper northwestern corner of the Bay (Tierra 2013a). Tributaries of the Passaic include Saddle River, Second River, and Third River. The Passaic River has a drainage area of approximately 935 square miles (mi^2) and has been gauged at Little Falls, NJ since August 16, 1897. The mean and median values of the mean daily discharges over a 123-year period (from 1897 to 2020) are 1,145 and 648 cfs, respectively (USGS 2020a). To estimate flow from the Passaic River into the Bay, Suszkowski (1978)[4] recommended multiplying the discharge at Little Falls by 1.227 to extrapolate the flow to include the additions from the watershed between Little Falls and the mouth of the river. HydroQual (2007) reported a multiplication factor of 1.3. The corresponding revised mean and median discharges reaching the Bay are approximately 1,399 and 788 cfs, respectively (1,482 and 835 cfs using the 1.3 multiplier). Approximately 17 River miles upstream from the Bay is the 20-foot-tall Dundee Dam, which curves 450 feet across the Passaic River from Garfield to Clifton, NJ (Figure 3-2). Dundee Dam was constructed in 1859 to fill a 2-mile canal parallel to the river to improve ship passage. Dundee Dam moderates flow in the lower 17-mile reach of the Passaic River (Tierra 2013c).

The Hackensack River originates in Rockland County, NY, just west of the Hudson River and flows for approximately 50 miles into the Bay's upper northeast portion (Figure 3-2). Tributaries of the Hackensack include Sawmill Creek, Berry's Creek, and Overpeck Creek. Just south of the Oradell Dam in New Milford, NJ, the Hackensack River has a mean daily flow of approximately 87 cfs (USGS 2020b). To the south of this dam is the Hackensack Meadowlands, which includes approximately 8,400 acres of tidal wetlands that filter surface water runoff and protect the uplands from storm surges (Tierra 2013a). The Hackensack River has a drainage area of 202 mi^2 and has been gauged at New Milford, NJ since 1921. The mean and median of the mean daily discharges for the 99-year period from 1921 to 2020 are 87 and 15 cfs, respectively (USGS 2020b). To estimate the flow from the Hackensack River into Newark Bay, Suszkowski (1978)[5] recommended multiplying these numbers by 1.743 to extrapolate flow to include additions from the watershed between New Milford and the mouth of the river. The corresponding revised mean and median discharges reaching the Bay are approximately 152 and 26 cfs, respectively. However, there is uncertainty inherent in use of this scaling factor as it may not be applicable to current conditions due to changes in land use within the watershed over time and because the presence of potentially significant withdrawals and discharges to the Hackensack River both upstream and downstream of the gage location in New Milford have changed.

3.4.1.2 Minor Tributary Inflows

The Peripheral Ditch and Pierson's Creek are manmade ditches that discharge stormwater runoff to the Bay (Figure 3-2). The Peripheral Ditch bounds the Newark Liberty International Airport and receives CSO and SWO loadings from a variety of sources, including the airport, separately sewered portions of Newark, and municipalities including portions of the City of Elizabeth (James P. Purcell Associates 1970; Lowe et al. 2005). The Peripheral Ditch drains to the Bay by way of the Elizabeth Channel.

[4] See Note 3 on page 3-6.

[5] See Note 3 on page 3-6.

Pierson's Creek is an important part of the City of Newark's stormwater sewer system, draining an industrialized watershed of 1.2 mi^2 directly into the Port Newark Channel (Dames and Moore 1998). Plum Creek is another small tributary that is associated with the highly industrialized area north and east of the Newark Liberty International Airport and that flows into the central Bay (Tierra 2013a).

The tidally influenced straits of the Kill Van Kull and Arthur Kill serve as the main connectors between the NBSA and the Upper Bay of NY Harbor and Raritan Bay, respectively (Figure 3-2). The Kill Van Kull is approximately 3 miles long and 1,000 feet wide. The Arthur Kill is approximately 10 miles long and 600 feet wide. Both are maintained by regular dredging to accommodate cargo vessels travelling to ports and/or various private facilities along the NBSA and Arthur Kill (Tierra 2013a). Freshwater tributaries to the Arthur Kill include the Elizabeth River, Rahway River, Fresh Kills Creek, Morses Creek, Old Place Creek, and Piles Creek. The Elizabeth River originates in Hillside, NJ and is approximately 6 miles long (Bonin 2010). It drains a watershed of approximately 16.9 mi^2, with an average daily discharge of approximately 27 cfs between 1921 and 2020 (USGS 2020c). This river flow is affected by inputs from sewers and other outfalls, several small dams, and wetland areas, all of which affect the hydrologic response (Bonin 2010). The Rahway River basin is larger (approximately 41 mi^2 at Rahway, NJ), with an average daily discharge of approximately 52 cfs from 1921 to 2020 (USGS 2020d). Flows in these rivers include inputs from sewers and other outfalls, several small dams, and wetland areas (Bonin 2010). Fresh Kills Creek contributes an average flow of approximately 14 cfs (Thomas 1993). Flow at Morses Creek was measured intermittently between 2002 and 2009, and the average of these measurements is approximately 2 cfs (USGS 2020e). Old Place Creek and Piles Creek are ungauged and discharge into the Arthur Kill. While there may be intermittent rainfall runoff into the Kill Van Kull, there are no continuously flowing creeks or tributaries, thus no significant freshwater inputs to the Kill Van Kull.

Old Place Creek, a small tributary on Staten Island, flows into the southern NBSA. This small tributary has extremely limited data and drains the northwest portion of Staten Island. Old Place Creek drains the marsh area south of Interstate 278, flowing into the NBSA just north of Goethals Bridge. It originates in the Graniteville Swamp Woods and is just over 1 mile long (Tierra 2013a).

3.4.1.3 Point Sources (CSOs, SWOs, and POTWs)

In addition to these freshwater tributaries, there are also significant anthropogenic freshwater inputs to the Bay, including urban runoff, CSOs, SWOs, and POTWs. Table 3-3 summarizes reported industrial and municipal wastewater discharges to the Bay and its tributary waterways for the period from 1978 to 2005. As shown in Table 3-3, Suszkowski (1978)[6] reported undifferentiated industrial and municipal wastewater discharges totaling 231.8 cfs to the Bay. HydroQual (1991) subsequently reported wastewater discharges during 1989. As shown in Table 3-3, they reported a combined total of 474 cfs of industrial and municipal runoff into tributaries of the Bay during that year. Another estimate places freshwater flows into the Arthur Kill from sewage treatment plants at 170 cfs and from permitted industrial discharges at 18 cfs into the Arthur Kill (Thomas 1993). A more recent approximation indicates that the Bergen County POTW and Secaucus POTW discharge an average of 108 and 5.3 cfs, respectively, to the Hackensack River (Lowe et al. 2005).

[6] See Note 3 on page 3-6.

Additionally, as discussed in Section 2.1.3.8, a reconnaissance study was performed to develop an inventory of discharge points to the Bay. The locations and details of the discharge points can be found in the Combined Sewer Overflow and Stormwater Outfall Characterization – Phase I: Reconnaissance Report – Information Gathering (GSH 2018).

3.4.1.4 Non-Point Sources (Direct Runoff and Groundwater)

The State of NJ's annual rainfall typically ranges between 32 and 48 inches, with an average of 45.3 inches (1895 to 2012) (Rutgers University 2013). Newark averages slightly more rain at 46.25 inches per year (FindTheData 2013). Most of the rain falling on the Bay watershed eventually enters the Bay in the form of runoff or groundwater influx. Groundwater sources to the NBSA have not been quantified (GSH 2019a).

3.4.2 Gravitational Circulation and Tidal Currents

Flows through the tidal straits are primarily a result of both salinity gradients (gravitational circulation) and water elevation differences (tidal current) between the ends of each strait (meteorological forcing also plays an important role, see Section 3.4.3). Freshwater inflow, primarily from the Passaic and Hackensack Rivers, can have an important influence on gravitational circulation.

3.4.2.1 Circulation Patterns

The Bay is connected to adjacent water bodies by two straits: the Kill Van Kull on the southeast and the Arthur Kill on the southwest. The Kill Van Kull connects the Bay to the Upper Bay of NY Harbor (eastward), whereas the Arthur Kill connects the Bay to Raritan Bay (southward). Flows through the Kill Van Kull and Arthur Kill are influenced by the density and hydraulic gradients due to variations in tides and meteorological forcing. Because the Kill Van Kull is deeper, shorter, straighter, and aligned with the east-west wind forcing, it typically experiences flows approximately an order of magnitude greater than the flow in the Arthur Kill (Caplow et al. 2003). In this region, the winds frequently generate an east west gradient on the surface. When that gradient is aligned along an east-west channel such as the Kill Van Kull, it can generate significant flow along the channel (Chant 2006). For a more north-south aligned channel such as the Arthur Kill, the dominant wind direction is across the channel (from bank to bank) and is thereby less able to direct flow through the channel. Flows in Arthur Kill are driven more by smaller residual elevation difference between the two ends as tides rise and fall on the west end of Kill Van Kull. The Arthur Kill generally experiences lesser tidal currents than the Kill Van Kull due to greater effective hydraulic drag in the Arthur Kill as a result of its greater length and shallower water depths. The impact of the phase differences in tide/currents between the Kill Van Kull and the Arthur Kill also contribute to lesser tidal currents within the Arthur Kill.

While there are variations in the daily meteorological and tidal currents in the Kill Van Kull and the Arthur Kill, net circulation is typically counter-clockwise around Staten Island (Figure 3-3; Blumberg et al. 1999). This circulation feature occurs during the common situation of tides and/or winds from the east causing an increase of water elevation at the north end of Arthur Kill thereby creating a flow gradient from north to south along the Arthur Kill. The gradient creates flow south toward Raritan Bay followed by east to west flow in Kill Van Kull during the next tidal cycle, which continues the pattern. However, strong or persistent

meteorological events can, at times, alter or reverse this circulation pattern (Chant 2003, 2006; Pence 2004; Rankin et al. 2002; Thomas 1993).

There is a tendency for the Kill Van Kull and the Arthur Kill straits to form a through-flow pattern of circulation around Staten Island, in contrast to a tidal pumping mode of circulation in which the Bay is filled (or emptied) by simultaneous inflow (or outflow) through both Kills (Blumberg et al. 1999; Chant 2006; Pecchioli et al. 2006). The through-flow mechanism involves a net flow of saline bottom water into the Bay through the Kill Van Kull, coupled with a southward flow of surface water from the Arthur Kill out of the Bay. Sommerfield and Chant (2010) measured a residual counter-clockwise flow of 4,238 cfs around Staten Island. Kaluarachchi et al. (2003) simulated annual average flow from east to west through the Kill Van Kull at 2,058 cfs and through the Arthur Kill to the south at 3,388 cfs (the larger residual flow through the Arthur Kill being attributed to the freshwater inflows to the Bay).

Counter-clockwise flow through the tidal straits is supported under two fairly frequent forcing conditions. One of these conditions is a phase lag that commonly exists in the tidal currents that pass through the system between the Kill Van Kull, the Bay, and the Arthur Kill. The currents turn first in the Kill Van Kull, 1 hour later at the Bay, and then 2 hours after that at the Arthur Kill (Chant 2006). For most of the tidal cycle in the Bay, the velocities are flowing in the same direction as the Kill Van Kull, making it easiest for the water to enter and leave through this passage. Moreover, winds out of the west/northwest support counter-clockwise circulation by decreasing the water elevation in the shallow Raritan Bay, thereby establishing a gradient that drives water out through the Arthur Kill and pulls water in from the Kill Van Kull (Chant 2006).

There are notable exceptions to the general counter-clockwise flow pattern around Staten Island. Lowe et al. (2005) suggest that there is a net outflow through the Kill Van Kull of 1,427 cfs. Also, Caplow et al. (2003) conducted a sulfur hexafluoride tracer study in northern Newark Bay and observed (July 14 to 20, 2002) a net seaward flushing through the Kill Van Kull into Upper NY Harbor during the test period. Both clockwise and counter-clockwise residual flows are observed through the tidal straits depending on the specific tidal forcing and winds (see below). Exceptions to the general counter-clockwise flow pattern due to meteorological effects are discussed further in Section 3.4.3.1. Tidal fluxes through the straits in the Bay are an appreciable fraction of its volume. Caplow et al. (2003) measured a mean residence time for water in Newark Bay of 8 days, which is a strong function of freshwater inflow rates. McCormick et al. (1983)[7] describe a residence time in the Bay ranging from less than 5 days to approximately 30 days.

Flow conditions in the deep navigation channels are influenced by a combination of tidal/estuarine circulation, exchanges with the Kills, and river input from the northern tributaries. Because the effects of wind stress are inversely proportional to depth (NOAA 1974), the shallow water depths in the subtidal flats are likely to result in local and regional flow dominated by wind-driven circulation and by wind waves, and are affected to a lesser extent by tidal/estuarine circulation than the navigation channels. Residence times of water in the Bay are highly variable and depend on the magnitude of riverine inflows, tidal phasing, and meteorological events. For example, energetic wind and wave events can generate an intense flushing of the Bay over a very brief period. However, such events are relatively rare and may impact shallow subtidal flats more than deeper dredged channels. In the absence of extreme meteorological forcing, residence time is typically longer for the subtidal flats and shorter for the deep channels. Caplow et al. (2003)

[7] See Note 3 on page 3-6.

conducted a sulfur hexafluoride (SF_6) tracer study to estimate residence time in the Bay, Arthur Kill, and Kill Van Kull waterway. Based on their July 2002 field experiment, mean residence time within the inner waterway of the Bay, Arthur Kill, and Kill Van Kull was estimated to be 3.4 ± 0.4 days based on the sum of net flushing and air-water gas exchange of the SF_6 tracer. SF_6 gas transfer velocities were estimated to determine the expected tracer loss from the waterways due to gas exchange alone, which then allowed calculation of tracer loss due to flushing alone. Accounting for flushing only, the mean residence time was estimated to be 7.7 ± 1.4 days. The Caplow study evaluated the time required for the tracer to travel the full extent of the Kills, whereas the residence time of the Bay itself, as defined by water and dissolved constituents moving from the Bay to the head of the Kills, is expected to be less than reported for excursion through the full length of the Kills.

3.4.2.2 Tidal Currents

Sommerfield and Chant (2010) report the exchange flow (maximum inflow velocity minus maximum outflow velocity) in the Kill Van Kull approximately doubled in intensity from 1997 and 1998 to 2008 due to the 13-foot deepening of the channel in the intervening decade, while tidal currents appear to have decreased over the same time period. The Arthur Kill also displays a subtidal, two-layer flow pattern with top-to-bottom velocity differences ranging from 0.2 to 0.5 feet per second (fps) and a generally persistent flow landward (northward) at depth and seaward (southward) at the surface (Thomas 1993). While there is a north-south salinity difference of approximately 4 to 5 practical salinity units (psu) in the Arthur Kill (less saline in the north), the strait is typically well mixed, with top-to-bottom salinity difference not often exceeding 1 psu (Suszkowski 1978; Thomas 1993)[8]. Despite the two-layer flow pattern, the Kill Van Kull is also fairly well mixed with top-to-bottom salinity differences seldom exceeding 1.5 psu (Suszkowski 1978)[9]. The tidal phase differences between the two connecting channels to the Bay at the Kill Van Kull and the Arthur Kill make predictions of currents in the southern portion of Newark Bay difficult (Chant 2006).

As described by Pence (2004), astronomically driven semi-diurnal and fortnightly tides are the dominant factors that determine the direction and intensity of currents in the Bay. The tidal amplitude is similar throughout the Bay, with only slight variations in mean tide levels between the northern and southern ends of the Bay; mean tide level at the northern end (Kearny Point) is 2.85 feet, relative to mean lower low water (MLLW), as compared with 2.77 feet in the southwestern portion of the Bay (Pence 2004; Wakeman 2006). Within the Bay, the tidal period is dominated by the principal lunar semi-diurnal constituent (M2, period of 12.42 hours) (Chant 2006; Pence 2004). The tidal range varies from a mean of 5.1 feet to a maximum of 6.1 feet during the fortnightly spring tides, relative to MLLW. Although the tidal amplitude is similar throughout the Bay, tidal current velocities vary by location (Pence 2004).

3.4.2.3 Flows through the Tidal Straits

The Kill Van Kull and Arthur Kill are tidal straits. The combination of tidal forcing, significant freshwater flows from the Passaic and Hackensack Rivers, and dredged navigational channels results in measurable

[8] See Note 3 on page 3-6.

[9] Data were collected prior to the 13-foot deepening of the channels. It is unknown whether salinity measurements post-dredging would be different.

(but mild to weak) salinity stratification within both tidal straits, yielding daily-averaged, two-layer, subtidal flow patterns with seaward flows of less saline water near the surface that are offset by landward flows of saltier water near the bottom (Chant 2006; Pence 2004; Sommerfield and Chant 2010).

The Kill Van Kull is tidally dominated and the tidal excursion (distance water travels over half a tidal cycle) is much greater than its length. Water leaves the Bay and travels the full length of the strait before the tide turns. Because of its relatively short length, the Kill Van Kull exhibits strong currents and relatively weak stratification (up to 1.5 psu), promoting a greater degree of tidal exchange and mixing between the Bay and NY Harbor than occurs between the Bay and Raritan Bay by way of the Arthur Kill (Chant 2006; Geyer and Chant 2006). The movement of water through the Arthur Kill is impeded relative to the Kill Van Kull because the tidal excursion is shorter than its length. Tidal currents in the Arthur Kill vary significantly along its length. Tidal currents decrease to virtually zero near the Fresh Kills area, where incoming tides from the south via South Amboy and from the north via the Kill Van Kull converge. Its freshwater sources support a mild vertical salinity gradient of up to 1 psu.

The estimated flows through the Kill Van Kull and Arthur Kill straits, summarized in Table 3-4, vary widely. In part, this may be because of the high degree of variability of the flows through the straits. In addition to the data listed in the table, LMS (2004) estimated tidal flows through the Kill Van Kull and the Arthur Kill to occasionally exceed 50,000 and 10,000 cfs, respectively, with average flows passing through Kill Van Kull up to an order of magnitude larger than those passing through Arthur Kill (Caplow et al. 2003). Average maximum flood/ebb currents in the Kill Van Kull and Arthur Kill are 2.2/3.2 and 2.4/1.9 fps, respectively (USACE 2004b). Navigational channel deepening completed in 2016 (Harbor Deepening Project; see Section 1.1.2) likely increased net flows through the Arthur Kill and Kill Van Kull by 17% and 2%, respectively, according to modeling analysis by Pecchioli et al. (2006). Sommerfield and Chant (2010) found the exchange flow (the mean flow from NY Harbor to Newark Bay) through via Kill Van Kull approximately doubled between 1997 to 1998 and 2008 to 2009.

3.4.3 Meteorological Forcing

Wind-generated currents affect mixing and sediment transport within the Bay (USACE 1997). Strong westerly wind events (mainly occurring in winter) can produce low water levels in Raritan Bay, increasing southward flow in the Arthur Kill and enhancing the counter-clockwise circulation around Staten Island. Such circumstances can also lead to stronger outflow currents and a general lowering of water levels throughout the Bay. Strong wind events were also shown to generate large episodic flushing.

The most frequent type of storm that affects the Bay is the extra-tropical storm (“nor’easter”) that occurs primarily between October and April. Less frequent tropical storms occur in late summer and fall and are usually more powerful (e.g., Hurricanes Irene and Sandy) and can induce widespread flooding. Both types of events can also cause high water levels, large waves, and increased bed stress.

The longest fetch in the Bay is along the southwest-to-northeast direction, and wave heights can be more than 6 feet for the most severe storms but are typically less than 4 feet (USACE 1997). Storm-tide elevations for the region range from 7.8 feet MLLW for the 2-year storm to 10.6 feet MLLW at Bergen Point for the 100-year storm (USACE 1997). For context, water levels reached 10.2 feet MLLW during Hurricane Irene in 2011 and 14.6 feet MLLW during Hurricane Sandy in 2012 at Bergen Point. NOAA’s datum values for the NOAA gauge at Bergen Point are provided on Figure C-1 in Appendix C.

Water level extremes are becoming larger due to sea-level rise (Kemp and Horton 2013); however, data for NY Harbor since the mid-19th century suggests that a secular increase in storm tides is also occurring. The magnitude of the once in 10-year storm has increased by more than 2.3 feet since the mid-1850s, while sea level has reportedly only risen 1.5 feet (Talke et al. 2014). It is difficult to estimate how frequency and intensity of events will vary in the future, and there remains uncertainty in the rate of sea level rise.

Changes in wind-generated currents and storm surges affect bed stresses (and therefore, erosion and deposition patterns) and circulation patterns. As described in Section 3.4.2, most parcels of water are within one tidal excursion of a boundary; therefore, changes in bed stresses and circulation patterns can result in suspended sediment and the contaminants associated with the suspended sediment to be exported, imported, or exchanged across any interface within several tidal cycles (see discussion of residence times in Section 3.4.2).

3.4.3.1 Meteorological Effects on the Kill Van Kull

Rankin et al. (2002) observed that when winds blow from the west (the predominant wind direction), flow is counter-clockwise around Staten Island, while winds from the east result in clockwise flow. Chant (2006) also observed this phenomenon and hypothesized it occurs because of subtidal sea level set-down outside of the Kills in response to wind events (Wong 1994), with winds from the west tending to lower the water level outside the Kills and winds from the east raising the water level at the west end of the Kill Van Kull. However, because sea levels drop more rapidly in the shallow Raritan Bay than in the Upper NY Bay in response to wind forcing, this supports flow into the Kill Van Kull that moves opposite to the local wind force, which would otherwise drive water to the east and out of the strait. Consequently, local wind forcing in the Kill Van Kull competes with the pressure-gradient-driven flow. This mechanism helps explain both the decreased correlation and increased time-lag between sea level and currents in the Kill Van Kull relative to the Arthur Kill (Chant 2006; Pecchioli et al. 2006).

3.4.3.2 Meteorological Effects on the Arthur Kill

Thomas (1993) studied circulation and sediment transport in the Arthur Kill and suggested that, because the tidal circulation in the Arthur Kill is relatively slow and the residual (non-tidal) circulation is weak (approximately 0.7 fps), north/south meteorological forcing determines residual current magnitude and direction. Chant (2006) and Pecchioli et al. (2006) also found that the daily average currents in the Arthur Kill are strongly influenced by local (north/south) winds. Despite the general counter-clockwise flow pattern around Staten Island, Thomas (1993) predicted that during moderate to high winds from the southeast, the Arthur Kill net residual flow is to the north, up to 4,238 cfs. For moderate to high speed winds from the northwest, net flows in the Arthur Kill are reversed, flowing to the south at up to 5,297 cfs. The greater southward than northward maximum flow agrees with other studies reporting that the circulation pattern is generally counter-clockwise around Staten Island (Blumberg et al. 1999; Kaluarachchi et al. 2003; Pence 2004; Sommerfield and Chant 2010).

3.4.4 Gravitational Forcing

The Bay is classified as a partially stratified estuary with lower salinity at the surface and higher salinity at the bottom (Pence 2004). Gradients in salinity, both horizontal (from north to south) and vertical (bottom

salinity to top salinity), are quite variable and a function of freshwater inflows and tidal forcing. Under high Passaic River inflows, salinity in the northern portion of the Bay is low (2 psu). During low Passaic River flows, surface salinity in the northern portion of the Bay can increase to 20 psu. Near the middle of the Bay, surface salinity shows significant variability (4 to 24 psu) as a function of tidal variability and Passaic River flows (Sommerfield and Chant 2010). Mid-Bay stratification is persistent with relatively weak spring-neap variability. During high Passaic River flows, vertical stratification mid-Bay exceeds 10 psu. Low Passaic River flows resulted in 3 psu mid-Bay stratification during neap tides, while spring tides saw stratification of only approximately 0.5 psu during flood tides and more than 5 psu during ebb tides. In the tidal straits, salinities were 17 to 19 psu with mild stratification (up to 1.5 psu in the Arthur Kill and 1 psu in the Kill Van Kull). Mixing of freshwater and saltwater in the embayment increases the circulation within both the Channel and Subtidal Flat areas (Wakeman 2006).

Seasonal variations in salinity include a general decrease in salinity during the spring (Sommerfield and Chant 2010), with a spatial pattern that is dependent on the locations and magnitudes of freshwater input. Rainfall runoff events impact salinity distributions on shorter time scales through dilution (Sommerfield and Chant 2010). Historically, the NBSA experiences a range of event-based meteorological flooding that includes elevated riverine inputs from precipitation events throughout the year in the upper Passaic and Hackensack watersheds and coastal storm surge events that have typically occurred during August to October. The late summer period coincides with the lowest river base flows and a time when salinity intrudes far up the tributaries and the Bay becomes increasingly saline.

The mixing of fresh and saline waters in the NBSA produces both horizontal and vertical density gradients that alter circulation and mixing patterns and frequently produce a two-layer circulation, including density-driven estuarine circulation (Hansen and Rattray 1965). These processes generate an outflow of freshwater at the surface and inflow of saline water near the bed (Chant 2006; Pence 2004; Suszkowski 1978; Wakeman 2006). The estuarine circulation varies in response to the strength of the river flow rate and salinity variations in the Bay and influences the circulation of the Bay. The density stratification is enhanced during high freshwater flow from the Passaic River, producing an increase in the landward-flow in the bottom layer (Chant 2006). An increase in magnitude of exchange flows and increase in the along-channel salinity gradient has also been associated with channel deepening in Newark Bay (Sommerfield and Chant 2010). This estuarine gravitational circulation pattern can be interrupted (i.e., become more uniform with depth) during periods of very low freshwater discharge or during strong meteorological events, which tend to mix the water column. The variable conditions in the Bay make it challenging to identify a long-term average circulation pattern (Chant 2006).

3.5 Sediment Transport

Important sediment transport processes in the Bay are summarized herein and further described, as they affect contaminant fate and transport, in Section 5. Section 5 also includes a discussion of numerical modeling of the LPR and the Bay system that included a hydrodynamic and sediment transport model recently adapted for use in the NBSA RI/FS (HDR 2021b). These sediment transport processes are influenced by the complex geomorphology and hydrodynamics of the Bay (as previously discussed) and the interactions between the Bay proper and its tidal tributaries.

3.5.1 Sediment Budget and Tributary Contributions

Sediment transport and deposition in the Bay is complex and varies based on spring and neap tides, ebb and flood tides, and location within the NBSA. Under typical conditions, the Bay experiences a localized convergence of sediment flux from the rivers and the Kills, and therefore, is a regional sediment deposition area (Wakeman 2006; Sommerfield and Chant 2010; HydroQual 2008). Based on radioisotope data of Be-7, the navigation channels and port channels appear to have the highest recent sediment deposition rates. During a Passaic River high-flow event, measurements of the radionuclide Be-7, a tracer for recent deposition, indicated that deposition was greatest in the northern portion of the Bay, primarily within the navigation channel upstream of Port Newark (Sommerfield and Chant 2010; Huntley et al. 1995). There was little evidence of flood-tide-related deposition on the subtidal flats.

In the southern portion of the Bay, Sommerfield and Chant (2010) indicate that most of the Kill Van Kull sediment influx is not carried into the northern portion of the Bay. They suggest that suspended sediments in the northern portion of the Bay do not leave the Bay during ebb tide or during periods of normal freshwater discharge to the Bay, and only up to approximately 15% of sediments in the southern portion of the Bay might exit the system. The convergence of sediment deposition in the Bay is consistent with the frequent navigational dredging because of sediment deposition.

Tierra (2013a) also reported on Be-7 as an indicator of recent (short-term) deposition. A Be-7 activity of greater than 0.5 picocuries per gram (pCi/g) is referenced as an indicator of recent deposition (Tierra 2013a). In the Bay, Be-7 activity varied by geomorphic area. The port channels and navigation channels had the highest average Be-7 activity (1.69 and 1.17 pCi/g, respectively), with maximum Be-7 activities within the NBSA observed at the west end of Port Newark near Pierson's Creek. Figure 3-7 shows the Be-7 activity in surface sediments. The transitional slopes had an average Be-7 activity of 1.03 pCi/g, and the intertidal areas had the lowest Be-7 activity, with an average activity of less than 0.5 pCi/g, suggesting a low- to non-depositional environment. The Be-7 activity in historically disturbed subtidal flats and undisturbed subtidal flats were similar, with an average activity less than or equal to 0.5 pCi/g in both geomorphic units, suggesting that historically disturbed subtidal flats that one time were high-deposition areas but have since stabilized, and now exhibit similar low- to non-depositional characteristics with undisturbed subtidal flats (GSH 2019a). These data reflect the tendency of incoming sediment to be preferentially focused out of the shallows, down the transitional slopes and into the deeper shipping channels where they accumulate long-term leading to requirements for maintenance dredging.

Estimates of long-term average sedimentation rates in the NBSA are available from: 1) comparison of bathymetric surveys (Suszkowski 1978[10]), 2) sediment budget analyses (Suszkowski 1978[11]; Wakeman 2006), 3) converting dredge volumes to shoaling rates (USACE 2006a), and 4) evaluation of sediment radioisotope data (Tierra 2011). The long-term average sedimentation rates estimated using radioisotopes are considered the most accurate because they are based on data collected with the specific objective of measuring sedimentation rates. Different radioisotopes can be used to estimate deposition over different time periods. Lead-210 and Cs-137 are used to evaluate long-term sediment deposition (decades to a century; Olsen et al. 1978[12]; Orson et al. 1990; Van Metre et al. 2004), while Be-7 can be used to evaluate

[10] See Note 3 on page 3-6.

[11] See Note 3 on page 3-6.

[12] See Note 3 on page 3-6.

short-term sediment deposition (months; Neubauer et al. 2002). Rates estimated based on Cs-137 are long-term averages over the period since peak atmospheric nuclear weapons testing in 1963, or the advent of detectable levels in the environment in the mid-1950s. The non-radioisotope methods use data collected for other purposes, but are interpreted to estimate deposition rates and may be less accurate. Table 3-5 presents the comparison in long-term sedimentation rates (inches per year) among different studies from various locations in the Bay. However, as discussed above, long-term historical sedimentation rates may not represent current sedimentation rates because of the changes to the system from relatively recent channel construction and shoreline filling.

Estimates of sediment loads vary but there is general agreement that the magnitude of sediment load to the NBSA is, from highest to lowest: Kill Van Kull, Passaic River, Arthur Kill, Hackensack River, and other sources (LMS 2004; Suszkowski 1978[13]; Lowe et al. 2005; Sommerfield and Chant 2010) (Table 3-6). The Passaic River introduces sediment into the Bay principally during infrequent high-flow events such as the 100-year discharge. The Kill Van Kull, Arthur Kill, and the Hackensack River can be both sources and sinks of sediment to/from the NBSA. The Arthur Kill primarily is a sink of sediment from the NBSA but periodically is a source. Sediment export from the Bay to Upper NY Bay via the Kill Van Kull is largest during the spring season when high freshwater discharge from the tributaries tends to occur.

The Passaic River introduces sediment into the Bay under various flow conditions, but large discharge events associated with storms are of particular importance (i.e., above approximately 6,000 cfs) (Anchor QEA 2019). For example, during a single high-flow event when the peak flow on December 14, 2008 was 5,610 cfs at Little Falls, the Passaic River exported approximately 8,000 metric tons (MT) to the Bay (calculated as the measured sediment concentrations times the Passaic River flow rates), representing nearly half of its estimated annual load of 17,000 MT per year (MT/yr; as estimated in Sommerfield and Chant 2010). The frequency of such high-flow events can be evaluated based on historical flow data. For example, a flow of 6,000 cfs or greater has occurred 586 days out of 45,058 daily records, or 1.3% of the days between August 16, 1897 and December 29, 2020 (USGS 2020a). Such flows are responsible for much of the terrestrial sediment loading to the Bay. Similarly, during the same time period, there were 33 days during which the 10-year flow of 12,400 cfs at Little Falls was exceeded (USGS 2020a). Overall, low-flow conditions are associated with a net upstream sediment flux, and high flow conditions are associated with a net downstream sediment flux; however, sediment export from the Passaic River has been observed at flows as low as approximately 1,100 cfs (Chant et al. 2010). Because of the dominant role of high-flow events in the Passaic River on sediment loading to the northern Bay, significant inter-annual variations occur in sediment delivery into the Bay.

During periods of low river flow, there tends to be landward (i.e., toward the Bay) sediment fluxes into the NBSA from the Kill Van Kull due to: 1) low sediment supply from the Passaic River, and 2) decreased salinity stratification. The Kill Van Kull is less than one tidal excursion long, and sediment fluxes depend strongly on external events. Sediment supply from the Bay depends on high Passaic River flows, which typically occur from November to May, with the highest average flows occurring in March. Chant (2006) reported estimated net sediment fluxes in the Kill Van Kull for four deployment periods that varied widely, ranging from a net seaward transport of -12,000 MT/yr to a net landward transport of 200,000 MT/yr depending on Passaic River flow and the lateral location of the acoustic doppler current profiler mooring.

[13] See Note 3 on page 3-6.

Observational estimates of the net sediment flux in the Kill Van Kull (and the entire NBSA) are very sensitive to the forcing conditions (tides, river flow, wind) and to the lateral position of the mooring in the Kill Van Kull cross-section (Chant 2006; Sommerfield and Chant 2010). The seaward transports occurred during a peak in Passaic River discharge when the moorings were located on the northern side of the channel. The large landward transports occurred during drought conditions when the mooring was located on the southern side of the channel. Both wind forcing and river flow tend to be variable during the fall, and the net sediment flux through the Kill Van Kull during these times depends on the timing of high freshwater flow events and synoptic sea level conditions. Tropical storms and hurricanes (like Irene) during late summer and fall can be significant sediment supply events but occur sporadically. Winter is likely to be a time of high landward sediment flux, due to typically lower riverine flowrates. Westerly winds are dominant in the winter and drive a strong counter-clockwise circulation around Staten Island, and therefore, a westward flow through the Kill Van Kull. Although Passaic River flows are moderate to high during the winter, a net landward sediment flux (into the Bay) through the Kill Van Kull typically occurs in the winter.

3.5.2 Sediment Processes

Regions of elevated suspended sediment concentrations in surface water, called estuarine turbidity maximum (ETM), occur due to a combination of two mechanisms. First, in regions where tidal currents create local high bottom shear stress, sediments are locally resuspended into the water column. Secondly, the resuspended sediments can become trapped in a region of flow convergence that typically occurs near the limit of salt water intrusion (Sanford et al. 2001). The convergence of transport from several directions results in a region of turbidity maximum. In addition, salt and suspended sediment stratification cause a reduction in turbulence that increases suspended sediment trapping at the ETM in the same location where estuarine convergence causes trapping. The reduction of vertical mixing leads to sinking of sediment that had been suspended by a balance between turbulent mixing and gravitational sinking (Geyer 1993). The ETMs play a role in trapping suspended sediments resulting in areas of deposition, including contaminants associated with the suspended sediments. The location of the ETM may vary over time as the location of the fresh/saline interface changes due to tides and the strength of riverine inputs from the Passaic and Hackensack Rivers. There is often deposition near the ETM; therefore, as the ETM moves, the associated depositional zone will also move. Under most conditions, the ETM is found near the head of salinity intrusion upstream of the Bay, in the Hackensack and the Passaic Rivers (Chant et al. 2011; HydroQual 2008).

Short-term localized resuspension and deposition occurs from ship traffic in the shipping and port channels. Ship-induced resuspension is illustrated on Figure 3-6, which shows satellite imagery of turbidity plumes from vessels. USACE (2009a) projects an increase in vessel traffic, facilitated by the higher Bayonne Bridge. Clarke et al. (2015) compared propwash resuspension to dredging effects on turbidity in the NBSA. Turbidity was measured to evaluate suspended sediment concentration (SSC) in the wake of vessels, and the SSC plumes were found to vary considerably depending on vessel type and on the manner of vessel movement. Large surface-to-bottom plumes were associated with vessel turning at the entrance to berths. Peak SSC levels were much higher than background conditions and elevated near-bed SSC levels were measured for more than an hour after the vessel's movement ceased. Deep-draft ships contribute appreciably to sediment resuspension, while shallow-draft tug/barge traffic had little effect on resuspension. Mobilization of sediments by vessel traffic is more likely in the heavily trafficked

navigation channels from the Kills to Port Elizabeth and Port Newark, and less likely in the navigation channels north of Port Newark, which have much less frequent ship traffic and do not accommodate the larger vessels.

Channel deepening in the Bay has affected the hydrodynamics, including variability in tides, and the sediment transport, including the location and magnitude of sediment resuspension and deposition. These effects have contributed to the evolution of the Bay and continue to impact current sediment transport and deposition processes in the Bay. In addition, decreasing trapping efficiency of sediment is another factor that can cause a change in deposition rate over time. Tidal velocity in the deeper south Bay navigation channel (depth 50 feet mean sea level [msl]) is approximately 30% less than in the shallower north Bay channel (depth 35 feet msl) (datum conversion factors are shown on Figure C-1 in Appendix C). Flow conditions required to resuspend sediment likely occur less frequently in the southern Bay.

3.5.3 Sediment Substrate

The Phase I and Phase II investigations included analyses of grain size in sediment core samples. Median grain size results for surface sediments (0 to 0.5 foot) are presented on Figure 3-4 (Tierra 2008b). Sand or larger median grain sizes, as well as medium/coarse silts, were measured in the north Bay near the mouth of the Hackensack River, in the central Bay across from the Port Newark Channel, and in the south Bay between the South Elizabeth Channel and the Elizabeth River. Medium silt or smaller grain sizes were frequently observed in the navigation channels and port channels (Tierra 2008b). Sand, silt, clay, and gravel composition of bed sediments from Phase I and Phase II investigations are shown on Figures 3-5a and 3-5b. Grain size was also analyzed in Phase III investigations in 2014 as part of the crab and clam sampling program (GSH 2017a), in 2015 as part of the sediment quality triad and porewater sampling program (GSH 2017d), and in 2016 as part of the surface sediment sampling program (Tierra 2016; GSH 2019a). The grain size results from each of these studies are shown on Figure 3-5c. Similar to the Phase I and II results, weight percentages of sand were greatest near the mouth of the Hackensack River, north of the Port Newark Channel (also where the greatest percentages of gravel were measured), and between the South Elizabeth Channel and the Elizabeth River. The greatest weight percentages of silt were observed along the eastern Bay between the Port Newark Channel and the South Elizabeth Channel. The low weight percentage of clay was observed to be fairly evenly distributed throughout the Bay (Figures 3-5a and 3-5b). Sommerfield and Chant (2010) also examined weight percentages of sand, silt, clay, and loss on ignition (OC) in the NBSA (Figure 3-6). Findings were similar to those in Phases I, II, and III, with sand (grain size between 2 millimeters [mm] and 0.063 mm) content highest in the north Bay near the Hackensack River mouth, in the central Bay across from Port Newark, and in the south Bay south of Port Elizabeth. The percentage of sand is higher with proximity to the navigation channel. Non-cohesive sediments are primarily sand and gravel-sized materials (greater than 63 micrometers [µm]). Non-cohesive sediments that may be present in shoreline wave break zones and in portions of the navigational channel, especially in the southern Bay area, are subject to more frequent disturbances by passing ships and tidal and estuarine circulation processes, and they constitute an important fraction of sediment delivery to the Bay due to the higher shear stress required to erode and resuspend non-cohesive sand-sized particles, as compared to unconsolidated silt- and clay-sized particles. Of equal importance, areas of elevated shear tend to limit the deposition of finer-grained particulates. However, non-cohesive sediment is not a significant fraction of the total sediment loading to the Bay (Suszkowski 1978).

Cohesive sediments are composed primarily of clay-sized (<2 µm) and silt-sized (<63 µm) particles, mixed with organic matter and sometimes small quantities of very fine sand. Cohesive sediments have inherent stability associated with cohesive bonding forces. The percentage of silt and clay is higher on the subtidal flats (Figure 3-6). These types of sediment are prevalent and form the sediment bed of the subtidal flats, although studies have shown the presence of a thin veneer (of several mm thickness) of loose unconsolidated sediments on the flats that are easily resuspended by wind and tides (Sanford 1992). Once resuspended, silt- and clay-sized particles can be carried farther distances than sand-sized particles due to lower settling rate compared to sand. However, the cohesive stability characteristics of the sediment on the subtidal flats are important in the long-term fate of historical contaminant inventories buried in these sediments.

3.6 Ecology

A detailed characterization of the ecology of the NBSA is provided in the BERA (Appendix B). The following summary provides an overview of the present-day habitats, and the biological communities that reside in or utilize the Bay.

3.6.1 Habitat

Losses of wetland and tributary habitats and the covering of present-day shorelines by bulkheads, riprap, buildings, and impervious surfaces (i.e., pavement and concrete) limit the available shoreline and nearshore wildlife habitat in the NBSA, particularly nesting and foraging areas for birds and mammals (Iannuzzi et al. 2002). Degraded structures and pilings along the industrial waterfront offer some habitat for aquatic species.

Intertidal mudflats and vegetated wetlands comprise only a small portion of the overall shoreline area (Figure 1-4). Intertidal Areas are characterized by two main features: wetlands and mudflats (or sand/cobble flats) that are typically exposed during low tide. Wetland areas in the NBSA are typically characterized by the presence of emergent vegetation, such as common reeds (*Phragmites australis*) and/or saltmarsh cordgrass (*Spartina alterniflora*), as well as soft muddy or organic substrates. Wetlands may provide important foraging and nesting grounds for seasonally abundant waterfowl and other water birds. Mudflats, sand, and cobble flats are characterized by unvegetated expanses of mud, fine sand, or clay. Benthic organisms (e.g., infaunal invertebrates, crustaceans, bivalves, etc.) and forage fish can be found in these areas. These are also important feeding areas for predatory fish and waterbirds (e.g., herons, egrets, sandpipers).

The subtidal flats in the Bay are broad, generally shallow (9 feet average depth), and cover nearly half of the area of the NBSA (Figure 2-7; Tierra 2013c). These provide substantive foraging areas for various aquatic and semi-aquatic organisms. Deeper transitional slopes and navigation channels also provide seasonal habitat for various shellfish and fish species. All the aquatic bottom habitat in the Bay is considered essential fish habitat (EFH) by NOAA for a variety of fish species, as described in Section 3.6.2.3.

Shooters Island, located in the southern portion of Newark Bay, is one of the major forested areas of Newark Bay. It is partially wooded with species such as black locust (*Robinia pseudoacacia*), tree-of-heaven (*Ailanthus altissima*), and Japanese honeysuckle (*Lonicera japonica*). Small patches of saltmarsh

containing common reeds and cordgrass occur around the island's shoreline, including scattered debris, rotting docks, abandoned buildings, shipwrecks, and barges (U.S. Fish and Wildlife Service [USFWS] 1997). Despite its impacted condition, Shooters Island continues to serve as a bird sanctuary and refuge for birds such as gulls, cormorants, and osprey, which are often observed on the island (Bernick and Craig 2008). Additional forested areas occur along the eastern tip of Kearny Point, just south of the Elizabeth Marine Terminal, along the eastern side of Bayonne Park, and in Richard A. Rutkowski Park. Sporadic forested areas also occur between Veterans and City Parks, in Mariners Marsh, and around the Newark Bay Bridge (Figure 1-4).

Barren lands, consisting of recently cleared or disturbed areas where soils have been disturbed (e.g., coal cinders are often a major soil constituent), are common around the Bay shorelines. Vegetation consists of tolerant, often introduced, species. Vegetation is present in scattered patches, offering little cover for wildlife, particularly in winter. Garbage and debris items are present in the vacant lots/fields. Typical plant species include goldenrod (*Solidago canadensis* or *Solidago virgaurea*), mugwort (*Artemisia vulgaris*), raspberry (*Rubus* spp.), Asian bittersweet (*Celastrus orbiculatus*), pokeweed (*Phytolacca americana*), and saplings of royal paulowina (*Paulownia tomentosa*), mulberry (*Morus* spp.), tree-of-heaven, and black locust. Typical wildlife observed includes terrestrial, urban-tolerant species (United States Coast Guard 2010).

North and south of the NBSA, there are extensive tidal wetlands associated with the Hackensack River and the Arthur Kill that provide wildlife habitat for birds and mammals (GSH 2020).

3.6.2 Biological Communities

Biological communities in and along the NBSA have been surveyed as part of a variety of historical studies, and more recently as part of the data collection efforts for the BERA. A total of 34 different species of wildlife were observed during the 2013 reconnaissance survey conducted as part of the BERA sampling efforts. The wildlife observations are summarized below, and detailed results can be found in the BERA (Appendix B).

The aquatic community data from the BERA studies are also summarized below. In addition, detailed descriptions of the biological communities in the NBSA (vegetation, benthic invertebrates, fish, shellfish, reptiles, birds, and mammals) from historical reports are provided in the BERA (Appendix B).

3.6.2.1 Vegetation

The NBSA shoreline has been industrially developed with approximately two-thirds of the shoreline consisting of riprap and bulkhead (Figure 1-4). The remnant plant community (upland and wetland) reflects such development, consisting of species that are representative of disturbed conditions. As observed during the 2013 reconnaissance survey (Tierra 2015b), upland vegetation along the NBSA generally consists of a patchy mixture of early successional and ruderal plant species, indicative of the high level of shoreline disturbance. Dominant canopy species included eastern cottonwood (*Populus deltoides*), locust trees (*Gleditsia* spp. or *Robinia* spp.), and catalpa (*Catalpa speciosa*), with an understory of honeysuckle (*Lonicera* spp.) and sumac (*Rhus* spp.). Overall, species diversity is low and dominated by fast-growing invasive and/or short-lived vegetation. A total of 22 common plant and tree species were identified during the survey. The intertidal areas of the NBSA shorelines were characterized during the 2013 reconnaissance survey based on their amount and types of emergent vegetation.

Sporadic, intertidal areas that are dominated by emergent wetland vegetation consist of smooth cordgrass (*Spartina alterniflora*) and/or common reed (*Phragmites australis*). Areas with less than 50% emergent vegetation were classified based on visual estimations of habitat segments and were incorporated into the "mixed intertidal" area.

3.6.2.2 Invertebrates

A number of historical studies have been conducted on the benthic invertebrate communities of the NBSA (Tierra 2004). These studies typically demonstrated that the benthic invertebrate communities throughout the Bay were characterized by low abundance and diversity, and that the benthic environment was stressed from various pollutants and anoxic conditions. Species lists in the historical studies were dominated by polychaete worms, oligochaete worms, and small bivalves (clams/mussels). These organisms serve as a forage base for a variety of crustaceans, fish, and wading birds. Summaries of the results of various historical community surveys for aquatic and benthic invertebrates, including species lists and metrics are summarized in the BERA (Appendix B).

More recent studies on infaunal benthic communities, including the USEPA's REMAP survey conducted in 2008 and 2013 and the surveys conducted in 2015 as part of the Sediment Quality Triad and Porewater Study (GSH 2017d) for the BERA have shown an improvement in benthic community conditions in the Bay. Metrics on the diversity and abundance of invertebrates have improved (i.e., more diversity and evenness of species found) in recent years, likely due to improving conditions in the Bay in terms of water and sediment quality. An apparent downward trend in the species diversity (richness) and benthic index of biotic integrity values for the 2013 REMAP dataset may be due to the short-term effects of Hurricane Sandy on benthic communities. The values from the 2015 program show a return to the relatively unimpacted conditions similar to those from the 2008 REMAP study.

The analysis of 90 sample replicates from the 2015 sampling event produced a cumulative total of 106 taxa. The number of taxa identified from individual sample locations ranged between eight and 46, with a mean of 23 (n = 30). The most abundant taxa (greater than or equal to 5.0 % of the total) at one or more stations were:

- Annelida
  - *Alitta succinea*
  - *Glycera Americana*
  - *Glycinde solitaria*
  - *Hypereteone heteropoda*
  - *Laeonereis culveri*
  - *Leitoscoloplos fragilis*
  - *Mediomastus ambiseta*
  - *Pectinaria gouldii*
  - *Spiochaetopterus costarum*
  - *Streblospio benedicti*
  - *Tharyx acutus*
- Mollusca
  - *Haminoea solitaria*
  - *Ilyanassa obsolete*

  - *Macoma balthica*
  - *Mulinia lateralis*

- Arthropoda
  - *Ampelisca abdita*
  - *Cyathura burbancki*
  - *Grandidierella japonica*
  - *Leucon americanus*
  - *Microdeutopus Gryllotalpa*

Community density calculations at particular stations produced values ranging between 406 and 11,237 individuals per square meter, with a mean of 4,771 (n = 30). Shannon-Wiener Diversity values ranged from 1.5 and 3.0, and the mean was 2.2 (n = 30).

Communities of large invertebrates in the channels and shoals are mainly dominated by blue crab (*Callinectes sapidus*), which are present year-round in the Bay. Blue crabs at shallow water stations (subtidal flats) appear to be more abundant in the summer and fall (May to November) and are nearly absent during the other months when they migrate to the deeper channels or offshore (USACE 1997). Bivalve mollusks in the Bay include the softshell clam (*Mya arenaria*), dwarf surfclam (*Mulinia lateralis*), ribbed mussel (*Geukensia demissa*), Eastern oyster (*Crassostrea virginica*), and Baltic clam (*Macoma balthica*).

3.6.2.3 Fish

The finfish assemblage that resides in or is transient to the Bay is typical of large coastal estuaries and inshore waterways located along the Mid-Atlantic Bight. Situated in the transition zone between northern coldwater (boreal) and temperate (warm) water with low to moderate salinity, the Bay acts as a spawning ground, migratory pathway, and a nursery/foraging area for a variety of estuarine, marine, and anadromous fish species.

EFH exists for several finfish species, as documented in Environmental Impact Statements required for federal maintenance dredging (USACE 2015a). The EFH was extracted from NOAA's online EFH data mapper for the Hudson River/Raritan/Sandy Hook Bays area (https://www.habitat.noaa.gov/protection/efh/efhmapper/index.html). The entire Bay is identified as EFH for one or more important life stages (i.e., eggs, larvae, juveniles, adults, and spawning adults) of 21 fish species (Table 3-7). The shortnose and Atlantic sturgeon (*Acipenser brevirostrum, A. oxyrhynchus*) are federally listed as protected species in the NBSA (Tierra 2015b; USACE 1997, 2010, 2015a).

Many of the seasonally abundant fish species in the Bay are transient or migratory, passing through the Bay to upstream spawning grounds or entering the area seasonally from nearby ocean waters. These include estuarine migratory species, such as striped bass (*Morone saxatillis*), that depend on the estuary as a nursery and a forage area for juveniles and adults. Species that frequent the Bay during similar life history stages include both marine and estuarine predators, such as winter flounder, bluefish (*Pomatomus saltatrix*), and summer flounder (*Paralichthys dentatus*). These fish migrate in and out of the Bay seasonally depending on spawning area (estuarine versus marine) and period (winter versus summer) (USFWS 1997; Woodhead 1991).

A few fish species are year-round residents in the Bay; these species generally begin spawning in late spring and continue throughout most of the summer following general onshore and offshore seasonal movement patterns (onshore in spring and summer, offshore to deeper waters in fall and winter). Most life stages of these species may be found in the estuary throughout the year. These species, such as the mummichog (*Fundulus heteroclitus*) and striped killifish (*Fundulus majalis*), provide an important forage base for larger predatory species.

The USACE collected fish community data from within the Bay annually between 2002 and 2013, using a 30-foot otter trawl, as part of the NY/NJ Harbor Deepening Project (HDP). Both bottom and mid-water trawl sampling was conducted to evaluate demersal and pelagic species assemblages. These surveys provide a valuable long-term dataset to assess the consistency of fish communities amid changing conditions and anthropogenic alterations in the Harbor. The USACE data are reported in annual Aquatic Biological Survey Reports from 2003 through 2011 (USACE 2003, 2004c, 2005, 2006b, 2007c, 2008, 2009b, 2010, 2011) and summarized in the USACE's Migratory Finfish Summary Report (2015a). The latter report primarily focuses on the results of mid-water trawls during migratory finfish sampling in 2006, 2011, 2012, and 2013. The number of trawls conducted during each of these years throughout the Bay ranged from 311 to 440, with 23 to 38 finfish species collected in any given year. In Newark Bay, species abundance has varied from year to year, but is generally dominated by a few species (e.g., white perch, striped bass, and bay anchovy).

The aggregate available fish community data collected by the USACE in bottom trawls from Newark Bay between 2002 and 2010 are summarized in Figures 3-8a (overall species composition of multi-year catch) and 3-9b (average monthly composition of multi-year catch). The seasonal data from mid-water trawls collected between 2006 and 2013 are summarized in Figure 3-9.

As described in Section 2.1.3.4, a fish sampling program was implemented as part of BHHRA and BERA activities. As part of this program, fish were collected and identified over three sampling events in fall 2014, spring/summer 2015, and spring 2016. During these fish sampling events, 43 fish species were collected. A listing of the identified species is provided in Table 3-8. *Fundulus* spp. (mummichog and striped killifish), white perch, Atlantic silverside, striped bass and summer/winter flounder were the most abundant species collected for this program because large numbers of individuals were targeted to meet the tissue mass requirement for analysis (Normandeau Associates, Inc. 2017). The USACE demersal fish sampling program (Figure 3-8) had similar species compositions; white perch, bay anchovy, Atlantic herring, striped bass, and winter flounder were the five most abundant species collected by the USACE (2015a). Additional details of the NBSA sampling program can be found in the NBSA Fish Data Report (Tierra 2017) and the NBSA Environmental Sample Collection Report (Normandeau Associates, Inc. 2017).

3.6.2.4 Birds

Despite the highly developed shoreline, the NBSA provides various habitats for birds. Populations of birds that inhabit or utilize the forested (and other) areas of the Bay are mainly water birds, including waterfowl, such as ducks and geese; wading birds, such as herons and egrets; shorebirds, such as sandpipers (Scolopacidae), plovers (Charadriidae), and oystercatchers (*Haematopus*); seabirds, such as gulls, terns, and cormorants (Phalacrocoracidae); and birds of prey, such as osprey (*Pandion haliaetus*). Many of the water bird species found in the Newark Bay region (and NY/NJ Harbor Estuary as a whole) are migratory.

The area is part of the Atlantic Flyway, a major north-south migration route that is used by migrant species as a seasonal stopover (Elphick et al. 2001). The birds utilize open waters of the Bay and Intertidal Areas, feeding and resting for a few days to a few weeks en route to northern breeding grounds or southern wintering areas. Sandpipers, plovers, and their relatives are abundant migrants, and some are winter residents (Walsh et al. 1999). Bird species observed in the NBSA from several bird surveys that have been conducted since 1990 are identified in Table 3-9.

For those water birds that breed in the NBSA, adequate nesting grounds are limited due to the highly urbanized shoreline of the Bay and its tributaries (i.e., the Passaic River, Hackensack River, Arthur Kill, and Kill Van Kull). Therefore, most water birds primarily build their nests for breeding offshore on the 17 islands located within the NY/NJ Harbor Estuary. Two of the islands are located in the Arthur Kill/Kill Van Kull complex (Prall's Island and Isle of Meadows), while Shooters Island is located in the southern portion of the Bay. These islands and, to a lesser extent, mainland areas of the NY/NJ Harbor Estuary, have been surveyed for decades to quantify and characterize the nesting and trends in water bird populations. During the 2013 Reconnaissance Survey, no bird nests were observed along any portions of the shoreline; rather, they were observed/located on structures in the water (e.g., mile markers, abandoned/dilapidated wooden and metal pier structures). Both large and small nests were observed during the survey, which was limited to shoreline areas where field biologists were able to complete survey activities on foot, while looking for bird nests and signs of mammal use (e.g., scat, tracks). Such findings were documented as observed. The large nests consisting of hard sticks are likely to be osprey nests. The smaller nests consisting of softer grasses and seaweed that are also located on structures in the NBSA are likely to be double-crested cormorant (*Phalacrocorax auritus*) nests. Bird nest locations observed during the limited survey are shown on Figure 3-10 (Tierra 2015b). In addition, an extensive inventory of bird observations in the NBSA and tributaries is included in the Problem Formulation (Tierra 2013a).

3.6.2.5 Mammals

Mammals most likely to inhabit the NBSA shoreline areas are human-tolerant species that are commonly found in urban environments, such as squirrels, raccoons, rabbits, bats, and opossum (USACE 1997; USEPA 2008). The USACE (1997) identified nine species of bats, muskrat (*Ondatra zibethicus*), and the harbor seal as "possible" mammalian species utilizing the subtidal areas of the Bay. In addition, the river otter (*Lontra canadensis*) is a common inhabitant of the Hudson River and the NY/NJ Harbor Estuary.

Several mammals (primarily urban opportunistic species, such as rats and coyotes) were observed throughout the NBSA during the Reconnaissance Survey. Direct mammal sightings were documented, as well as any signs of mammals present along the shoreline (e.g., tracks, scat). Most mammals observed are species that are frequently found in urban areas, including Norway rat (*Rattus norvegicus*), skunk (e.g., *Mephitis mephitis*), coyote (*Canis latrans*), deer (e.g., *Odocoileus virginianus*), rabbit (e.g., *Sylvilagus* spp.), cat (*Felis catus*), and muskrat (Tierra 2015b). Locations of mammal observations observed during the limited survey are shown on Figure 3-10.

3.6.2.6 Reptiles and Amphibians

During the 2013 Reconnaissance Survey, the only reptile observed was a diamondback terrapin (*Malaclemys terrapin*) along an area of emergent vegetation (Tierra 2015b). The diamondback terrapin is likely a transient visitor to the NBSA as it moves between the Hackensack Meadowlands Complex and

marshes and tidal creeks along the Arthur Kill (USACE 1997). The diamondback terrapin is the only species of turtle in North America that spends its life in brackish water.

In freshwater wetlands, reptiles and amphibians are typically abundant. However, given the estuarine nature of the water of the Bay, amphibians, such as salamanders and frogs, are unlikely to be present (Tierra 2013a, USFWS 1997). Other than the observation of the terrapin noted above during the Reconnaissance Survey, there are no documented observations of amphibians or reptiles using the Bay during the various ecological surveys that have been performed over the years.

3.6.2.7 Threatened, Endangered, and Special Status Species

The state and federally listed threatened and endangered species consist mainly of birds, but also includes three insects, one plant, and two fish species. The State of NY also lists two habitats. The only federally endangered species are the Atlantic and shortnose sturgeon. The species and habitats are identified in Table 3-10.

4 NATURE AND EXTENT OF CONTAMINATION

This section describes the horizontal and vertical distribution of contaminant concentrations in the NBSA sediments, surface water, and biota.

As discussed in Section 2, extensive sampling, analysis, survey, and testing activities have been conducted under the RI program throughout the NBSA in three phases, each informed by prior phase(s) results. Substantive data have been collected in the following categories:

- Sediment chemistry (surface layer and cores)
- Surface water chemistry
- Porewater chemistry (ex-situ laboratory passive sampling program)
- Sediment toxicity testing (laboratory)
- Sediment bioaccumulation testing (laboratory)
- Fish and shellfish (blue crab/softshell clam) tissue chemistry
- Benthic invertebrate community surveys
- Bathymetric surveys
- Habitat and shoreline surveys
- Secondary data/information compilation and evaluation.

Field data collections also include various in-situ observations of water elevations, current speeds, surface water quality, and qualitative fish community surveys. Collectively, these data provide the necessary information to support the evaluation of the nature and extent of contaminant (RI Goal 1) presented in this section, complete the risk assessments (RI Goal 2; discussed in Section 6), and ultimately support the identification of the significant direct and indirect continuing sources of PCDDs, PCDFs, PCBs, PAHs, pesticides and metals to the sediments in the NBSA (RI Goal 3; discussed in Section 5).

4.1 Overview of Contamination in the NBSA and Identification of Contaminants of Potential Concern

The following section presents an overview of the contamination in the NBSA, describes the methodology used to identify a focused list of contaminants, and summarizes the various statistical and graphical methods used to evaluate the nature and extent of contamination in the NBSA.

4.1.1 Contaminants Detected in the NBSA

As part of the Phase I, Phase II, and/or Phase III investigations, sediment (surface and subsurface), tissue (crab, clam, and fish), and porewater were sampled and analyzed for some or all the following: PCDDs/PCDFs, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), Aroclor PCBs, congener PCBs and homologues, polybrominated diphenyl ethers, polychlorinated naphthalenes,

pesticides, chlorinated herbicides, petroleum hydrocarbons[14], metals[15], butyltins, cyanide, total organic carbon (TOC), percent lipids, and moisture content. Table 2-3 summarizes the parameters measured during Phase I, Phase II, and/or Phase III investigations, while Table 4-1 provides a full accounting of the various chemicals analyzed as part of these investigations.

Table 4-1 summarizes the frequency of detection (FOD) of each chemical analyzed as part of the Phase I, Phase II, and/or Phase III sediment and biota investigations. Over 600 individual chemical compounds have been analyzed in one or more sediment, biota, surface water, and/or porewater samples collected within the NBSA to evaluate the nature and extent of contaminant as part of this RI Report. In general, concentrations of PCDDs/PCDFs, PCBs, chlorinated pesticides[16], PAHs[17], and metals were more frequently detected across the various media sampled as part of the Phase I, II, and III investigations (Table 4-1). As discussed in Section 2, the presence of these chemicals can be attributed to contributions from, in no particular order of significance, CSOs, SWOs, wastewater outfalls (POTWs), direct industrial point sources (current or historical releases such as the Diamond Alkali Site), releases from ships, spills, leaks, surface runoff and/or tributary inflows. Sources are further discussed in Section 5.3.

Surface water samples collected by the LPR CPG as part of the Chemical Water Column Monitoring programs were analyzed for the following: PCDDs/PCDFs, VOCs, SVOCs, congener PCBs, pesticides, metals (including mercury and methyl mercury), and butyltins.

All data were considered in this data evaluation process. However, given the large number of individual contaminants and contaminant groups, a conservative data screening approach was developed and implemented as described in Section 4.1.2.

Consistent with the DEAR (Tierra 2014c), the CSM (GSH 2019a), and risk assessments, and as typical for CERCLA site investigations with large numbers of contaminants under investigation, several chemical classes (including PCDDs/PCDFs, PCBs, select pesticides, and PAHs,) were evaluated using total concentrations for the respective group of compounds. The methods used for calculating these totals are described in Section 4.2.3.

4.1.2 Selection of Contaminants of Potential Concern

For the purpose of discussing nature and extent of contamination in the NBSA, a conservative data screening approach was developed to focus the nature and extent discussion on key constituents of potential concern (COPCs) in sediments, many of which have been evaluated for the human health and ecological risk assessments and are likely to drive decision-making in NBSA. The COPC list discussed herein is expected to be more conservative than the list developed through the risk assessments. The data screening approach is depicted in Figure 4-1 below.

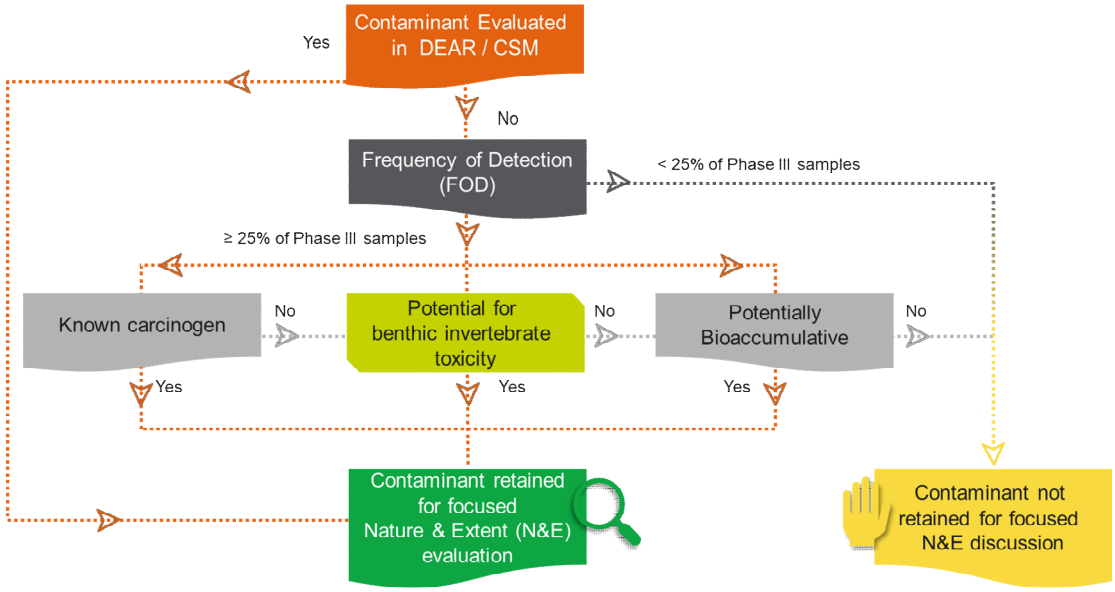
[14] The Phase I/II total petroleum hydrocarbon (TPH) data represent total extractable petroleum hydrocarbons (TEPH) whereas Phase III TPH data represent C9-C40 hydrocarbons. Referred to collectively as TPH in this RI.

[15] The chemical class ‘metals’ also includes other inorganic compounds, such as arsenic and antimony. The ‘metals’ are listed in Table 4-1.

[16] The number of detections in the Phase I/II programs may be biased low due to elevated detection limits.

[17] The number of detections in the Phase III programs may be biased low due to elevated detection limits.

Figure 4-1. Data Screening Process Flowchart for Phase III Samples



The screening utilized data collected during the Phase III investigation because these are the most recent data to best represent current conditions in the NBSA. The following COPCs detected in Phase III and evaluated previously in the DEAR (Tierra 2014c) and the CSM (GSH 2019a) were retained:

- 2,3,7,8-TCDD
- Total Aroclor PCBs
- Total congener PCBs
- Total DDx (4,4')
- Total alpha + gamma chlordane
- Total PAHs
- bis(2-ethylhexyl)phthalate (BEHP)
- TPH
- Metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc).

Additionally, the Phase III data were screened for additional COPCs that were frequently detected and may pose a potential for ecological or human health risks based on contaminant properties - carcinogenicity, toxicity, and potential to bioaccumulate. These screening criteria are summarized below:

FOD: A conservative value of ≥ 25% was selected to include contaminants that may occur only in specific areas of the Bay. COPCs that were detected at an FOD of < 25% were not retained for nature and extent

discussion. The conservative value of 25% was deemed reasonable to identify other frequently detected contaminants that would be potential risk drivers instead of all detected constituents so as to allow for a focused nature and extent evaluation.

Carcinogenicity and noncancer health hazards: COPCs with known carcinogenic effects that are being evaluated concurrently under the baseline human health risk assessment were retained for the nature and extent discussion. The COPCs based on the human health evaluation are listed in Table 6-7. This list includes all chemicals with a hazard index (HI) greater than 0.1 or a cancer risk greater than 10^{-6}. The RI COPC list includes all BHHRA COPCs with an HI that exceeds 1 or a cancer risk that exceeds 10^{-4} but these compounds are sometimes evaluated as part of summations rather than individual chemicals (e.g., total DDx (4,4'), total DDx (2,4' and 4,4'), total PAHs, and total alpha + gamma chlordane). Pyridine and trans-nonachlor were not carried forward from the BHHRA COPC list in Table 6-7 to the RI COPC list based on these criteria. Their human health risk contribution was very low. In addition, pyridine was not detected in sediment or fish.

Toxicity: Spearman correlations of surface sediment COPC concentrations and toxicity endpoints were measured as part of the Phase III SQT program for the BERA. Spearman rank coefficients ≤ -0.3 were significantly correlated with 10- and 28-day survival, growth, and reproduction endpoints. Therefore, COPCs with FOD ≥ 25% and Spearman's coefficient of ≤ -0.3 for any of the toxicity endpoints were retained for the nature and extent discussion. The following were correlated with toxicity endpoints: 2,3,7,8-TCDD (and other PCDD/PCDF congeners), PCBs, pesticides (i.e., dieldrin, hexachlorobenzene, total DDx (4,4'), total DDx (2,4' and 4,4'), alpha + gamma chlordane, cis-nonachlor, and hexachlorocyclohexane [BHC] compounds), PAHs, cadmium, copper, chromium, lead, mercury, selenium, silver and zinc. A complete list of individual compounds and their Spearman correlation coefficients are presented in Appendix A of the BERA (GSH 2020).

Bioaccumulation: The USEPA approach to developing bioaccumulation factors (BAFs) to establish ambient water quality criteria (USEPA 2003b, 2016a) for organic contaminants considers the octanol-water partitioning coefficient (K_{ow}), which is a measure of contaminant's hydrophobicity and therefore tendency to associate with an organic phase such as tissues of aquatic organisms. In this approach, a food chain multiplier (FCM) is applied to the baseline BAFs to establish BAFs for organisms at higher trophic levels. The larger the FCM, the higher the tendency of the contaminant to bioaccumulate. To focus the nature and extent discussion on organic COPCs that exhibit significant potential for bioaccumulation, an FCM ≥ 2.08 (corresponding Log K_{ow} ≥ 4.7) at trophic level 3 (USEPA 2016a) was selected as the screening criteria. Therefore, an organic COPC with an FOD ≥ 25% and FCM of 2.08 was retained for the nature and extent discussion.[18]

Additionally, for organic COPCs with the exception of 2,3,7,8 TCDD, the individual COPCs were not retained if they were included in the total fraction that was retained for discussion.

Based on the screening approach described above, the list of COPCs retained for a focused nature and extent discussion in this section is presented in Table 4-2 below. The screening was specifically based on detection (i.e., >25%) in sediment samples and not all the retained COPCs were detected at a frequency

[18] Note that BAFs are only used to select key sediment constituents to focus the nature and extent discussion in the RI. Site-specific bioaccumulation and food web models are used to predict the uptake and accumulation of contaminants in biological tissue from environmental media.

exceeding 25% in biota. The compound BEHP was only detected in one softshell clam sample and in no other species. Cadmium and nickel were frequently detected in invertebrate tissue (softshell clam and blue crab). In fish, there was only one cadmium detection and the frequency of nickel detection ranged from 0 to 80% depending on species. PAHs were also frequently detected in invertebrate tissue (softshell clam and blue crab), but FOD varied considerably in fish, ranging from 0 to 100% depending on species. This is not unexpected due to the fact that fish (and all vertebrates) metabolize PAHs. Summary statistics for tissue samples are presented in Section 4.6.

Table 4-2. COPCs Retained for Evaluation

PCDDs/PCDFs	PCBs	Pesticides	SVOCs	Metals
2,3,7,8-TCDD[19]	Total PCBs (9 Aroclors), Total PCBs (209 Congeners)	Total DDx (2,4' and 4,4'), Total DDx (4,4'), Total alpha + gamma chlordane, alpha-BHC, beta-BHC, cis-Nonachlor, Dieldrin, Heptachlor epoxide, Hexachlorobenzene	Total PAHs, Total HMW PAHs, Total LMW PAHs, Total Alkylated PAHs, TPH (sum of gasoline range organics and diesel range organics), BEHP	Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Methyl Mercury, Nickel, Selenium, Silver, Zinc

4.2 Data Processing for Statistical Evaluation

This section describes data reduction and handling methods used to prepare the laboratory analytical data for detailed evaluation (e.g., field duplicates, non-detects) and various data normalization techniques. In addition, the statistical and data visualization methods used to evaluate the various datasets for the nature and extent characterization are described.

4.2.1 Field Duplicates

Field duplicate sample results were combined with the parent sample (i.e., corresponding sample) results to generate a single sample result for subsequent data evaluation.

- When both field duplicate and parent sample results were reported as detected concentrations, the sample concentrations were averaged to generate a single concentration.
- When either the field duplicate sample or the parent sample was reported as a detected concentration, but was not detected in the other sample, only the detected concentration was used to represent the concentration of that analyte in that sample. The alternate approach of averaging the

[19] Human health and ecological risks were evaluated for PCDDs/PCDFs and coplanar PCBs on the basis of both individual chemicals and as a summation of toxic equivalence to 2,3,7,8-TCDD (TEQ) as calculated according to USEPA guidance (USEPA 2008). These tissue-based TEQ summations were not included in the nature and extent discussion, but are still recognized as COPCs in the risk assessments. See Section 6 for a discussion of TEQ.

detected value with the detection limit from the non-detect value would introduce unnecessary uncertainty because the detection limit does not provide a known measure of concentration.

- When a given analyte was not detected in either the parent or field duplicate sample, the lower of the two detection limits was used to represent the detection limit for that analyte in that sample.

Appendix D provides the data usability reports that discuss the level of precision for the various parameters in the different media.

4.2.2 Use of Detection Limits for Non-Detect Results

All non-detect results were reported to the quantitation limit[20]. Historically, it has been common practice to estimate the concentration of a chemical not detected in a sample by assuming the chemical is present at a concentration below the detection limit. This approach is typically referred to as a substitution method whereby the detection limit, one-half the detection limit, or a value of zero is used as an estimate of the concentration.

For the purposes of calculating summary statistics (e.g., calculation of mean and standard deviation):

- If the data include both detected and non-detect results, one-half the quantitation limit was substituted for non-detects.
- When all data are reported as non-detect, the mean and standard deviation are calculated using the full quantitation limit; and a “less than” symbol (<) was assigned to the mean quantitation limit.

For the purposes of presenting position statistics (e.g., percentiles), the full quantitation limit was used for non-detects. If the value of the percentile (e.g., the median) was non-detect, the “less than” symbol was assigned to the median value.

For the purposes of calculating total concentrations for a particular chemical group, total concentrations (other than those reported by the analytical laboratory) were defined as the sum of the detected concentrations of individual chemicals within that chemical group; a value of zero is used for non-detects. The calculation of totals is discussed in Section 4.2.3.

For the purpose of the statistical evaluations such as linear modeling and t-tests (see Section 4.2.7), one-half the quantitation limit was substituted for non-detects.

For the purposes of data presentation, individual non-detect sample results were typically shown at the quantitation limit (i.e., no substitution). The specific method used to handle detection limits for non-detected results are described in the notes to each table and figure.

[20] For surface water data collected by the CPG in both the small volume and high volume sampling programs and previously reported (AECOM 2010, 2011, 2019a, and 2019b), non-detect concentrations were reported to the reporting limit. Therefore, for consistency with prior reports, non-detect surface water concentrations are reported to the reporting limit rather than the quantitation limit in this RI Report. Non-detect secondary data (e.g., REMAP data) used in this RI Report were reported to the reporting limit given in the data source.

4.2.3 Calculation of Total Concentrations

For several chemical groups, data were evaluated both as individual chemicals and as total concentrations for a particular chemical group. Total concentrations (other than those reported by the analytical laboratory[21]) were defined as the sum of the detected concentrations of individual chemicals within that chemical group; a value of zero is used for non-detects. These total concentrations were calculated for the following groups:

- Total Aroclor PCBs = sum of Aroclor-1016, Aroclor-1221, Aroclor-1232, Aroclor-1242, Aroclor-1248, Aroclor-1254, Aroclor-1260, Aroclor-1262, and Aroclor-1268
- Total PCBs (209 Congeners) = sum of 209 individual congener PCBs (note that co-elutions were included at the full value for this calculation)
- Total Alpha + Gamma Chlordane = sum of alpha-Chlordane and gamma-Chlordane
- Total DDx (2,4') = sum of 2,4'-DDE, 2,4'-DDD, and 2,4'-DDT
- Total DDx (4,4') = sum of 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT
- Total DDx (2,4' and 4,4') = sum of 2,4'-DDE, 2,4'-DDD, 2,4'-DDT, 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT
- Total Low Molecular Weight (LMW) PAHs = sum of naphthalene, 2-methylnaphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene
- Total High Molecular Weight (HMW) PAHs = sum of fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene
- Total PAHs[22] = sum of naphthalene, 2-methylnaphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene
- TPH = sum of gasoline range organics and diesel range organics.

The totals listed above were only calculated when all the individual analytes comprising the total were analyzed. For example, total alpha + gamma chlordane was only calculated for samples that were analyzed for both alpha-chlordane and gamma-chlordane. In addition, if all analytes that made up a given total for a specific sample were non-detect, the total for that sample was reported as the highest quantitation limit of the individual analytes and were qualified as a non-detect sample.

All DDx isomers are present when at least one is detected; although, sometimes they are not all above the detection limit. In such cases, assuming non-detected congeners to be zero in the summation may introduce a bias to the estimates of total DDx. To evaluate this uncertainty, DDx totals were also

[21] Total dioxin/furan homologues, such as total TCDD congeners, are provided by the laboratory.

[22] A potential low bias was noted when PAH results were compared to USEPA split sample results.

calculated using both one-half the detection limit and the full detection limit for non-detect substitution. Statistics for these alternate total calculations are presented in Section 4.3.

4.2.4 Vertical Depth Categories

For statistical and visual evaluation purposes, sediment data are grouped into four depth categories: 0 to 0.5 foot bss (surface), 0.5 to 3.5 feet bss, 3.5 to 6.5 feet bss, and greater than 6.5 feet bss. The use of these depth categories is consistent with previous analyses conducted for the DEAR that evaluated data within the 0- to 0.5-foot, 0.5- to 3.5-foot, and greater than 3.5 feet bss depth intervals (Tierra 2014c). For this RI Report, the Phase I and II core sectioning was reviewed and the greater than 3.5 feet bss depth interval used in the DEAR was split at the 6.5-foot depth to further refine this RI Report analysis of concentration by depth. Although most of the data were collected from one of these distinct categories, there were some instances where a sample depth spanned two depth categories. A total of 32 of 895 (3.6%) core intervals spanned two depth intervals. For example, a sample collected from 2.5 to 3.75 feet bss falls into both the 0.5 to 3.5 feet bss and 3.5 to 6.5 feet bss categories. In these instances, samples were assigned to the depth category corresponding to the top depth of the sample interval. For the example above, because the top depth of the sample (2.5 feet bss) was collected from the 0.5 to 3.5 feet bss category, the sample was placed into that depth category for statistical and/or visual evaluations. The top depth was a reasonable metric to assign the interval. Using the average interval depth, a single core interval (1 of 895; 0.11%) would be assigned to another interval (NB01SED052B-05 6-8.5 feet).

It is noted that for Phase I and II cores, the percent recovery of the entire core length was required to be greater than 75% of the penetration depth, while for Phase III, the required recovery was 9 inches. Additionally, during processing of Phase I and II cores, the sample segment lengths were adjusted by reducing the interval length to account for percent differences between core penetration and length of recovered sediment. For example, if the core recovery was 75%, a planned 1-foot interval was actually processed as a 0.75-foot interval. This action was taken to “stretch” the potentially compacted core to match the actual penetration length, assuming that the core was only impacted by compaction and there was no loss of material during coring or recovery. Surface sediment samples in Phases I, II, and III represent true 6-inch sediment core tops, so surface sampling intervals between the programs are comparable.

4.2.5 Sediment Data Normalization

The spatial and temporal distribution of contaminants in sediments can be affected by interactions between contaminants and grain size, mineralogy, and OC. Varying sediment sources and flow velocities can affect the size distribution and characteristics of materials deposited in specific portions of the Bay. These hydrodynamic-related variations in the sediment characteristics can in turn influence the concentrations of contaminants accumulated in the sediment. Most natural and anthropogenic substances, including metals and hydrophobic organic compounds, have a higher affinity to fine-grained particulates than to the coarse fraction with fine-grained particles having more specific surface area and thus sorption sites than coarse particles. The density and charge on the sorption sites are in turn governed by particle minerology and geochemistry. Therefore, the affinity of contaminants to particulates is not technically related to grain size, but rather is related to the mineralogy, and thus chemistry, of typical fine-grained particulates. Often organic matter and clay minerals, associated with fine particle fractions,

show the strongest sorption capacity for contaminants. Therefore, even if overlying water concentrations of the contaminants are held constant, there will be a correlation of the contaminant concentration with sediment OC content, clay fraction or other geochemical factors. The challenge is to separate the natural variability component of sediment mineralogy from the anthropogenic contribution of contaminants to sediment.

Normalization is a data analysis procedure that takes into account both background and contaminant concentrations for the influence of the natural variability in sediment size, mineralogy, and OC content driven largely by differences in energy in the aquatic system (Kersten and Smedes 2002). Through normalization to a parameter that reflects naturally occurring changes in contaminant concentrations, the inherent variability relating to that parameter can be reduced, allowing more meaningful assessment of spatial and temporal patterns in contaminant concentrations. For hydrophobic organic compounds, concentrations are usually normalized to the OC content of the sediments. TPH and other organics are included in the TOC measurement and would serve as a source of organic matter for partitioning of other hydrophobic contaminants. For metals, there is no consensus on the most appropriate constituent to be used in the normalization. Aluminum, iron, lithium, TOC, and grain size often vary with sediment texture and show strong relations with metals and can be used as geochemical normalizers (Horowitz 1991; Naval Facilities Engineering Command 2003; San Francisco Estuary Institute 2006). In these cases, the metal of concern may vary with natural differences in sediment composition and mineralogy, but will vary in a relatively constant proportion to the parameter used for the normalization. For the purposes of subsequent evaluations, sediment organics data were normalized to TOC, and inorganics were normalized to aluminum, iron, and/or fraction of silt and clay. In linear modeling analyses, normalizing variables were added as covariates.

4.2.6 Biota Tissue Normalization

Organic compounds are usually associated with the lipid fraction in biota. Biota contaminant concentration is normalized to lipid content to minimize the variability associated with changes in lipid content and facilitate comparisons across locations and species. Lipid normalization is most useful when a direct and proportional relationship exists between lipid content and contaminant concentrations. In these cases, the lipid fraction can be added as a covariate when, for example, comparing concentrations on a spatial basis. This is particularly useful when the lipid fraction is quite variable within the biota samples being compared and thus can act as a confounder in assessing spatial trends. The relationship between lipid content and contaminant concentration is explored and evaluated in Section 4.6. For some species and organic compounds, weak to moderate Spearman correlation was observed. More detailed observations by species are provided in Section 4.6.

4.2.7 Graphical and Statistical Evaluations

Boxplots are used to graphically display measurements in a sample population for the analyses included in this section. Boxplots display the main distributional characteristics (spread and skew) of the data. The "box" contains 50% of the sample values from the 1st quartile (25th percentile) to the 3rd quartile (75th percentile), also referred to as the inter-quartile range. The sample median (50th percentile) is displayed as a horizontal line within the box.

In addition to the graphical displays, several statistical evaluations were conducted on the data to glean information on the similarity or difference in contaminant concentrations between the various spatial features or areas of the NBSA. These tests included:

- Linear Models: Linear modeling was used to evaluate the dependence of chemical concentrations on spatial variables (e.g., geomorphic area) or temporal variables in the NBSA. In comparing the mean concentrations of spatial units, two types of models were used. The analysis of variance (ANOVA) model is a linear model in which the dependent variable (e.g., chemical concentration) is continuous and there is one (or more) independent fixed effect categorical variable (e.g., spatial unit) with two or more possible values. The analysis of covariance (ANCOVA) model is a linear model in which the dependent variable (e.g., chemical concentration) is continuous and the independent variables consist of both a categorical variable (e.g., spatial unit) and a continuous variable (e.g., normalizing variables such as TOC or aluminum). Some of the variance of chemical concentrations can be attributed to other variables in the sediment. Metals concentrations often vary directly with aluminum concentrations and organic chemicals often vary directly with TOC. To examine the effects of these variables on spatial patterns, they were added as covariates along with the spatial categorical variables to form an ANCOVA type model. The ANCOVA models were used to test the dependence of the mean concentrations among various spatial categorical variables while controlling for variability attributable to aluminum for metals or TOC for organic compounds. The form of the linear models used in the temporal analyses are described in Section 4.3. All linear models are subject to the assumption that the residual errors are approximately normally distributed with a mean of 0 (Scheffe 1959). In order to meet this assumption, the chemical concentrations were transformed by natural logarithm prior to analysis. Residual diagnostic plots were reviewed to confirm the approximate normality of residuals for each spatial and temporal model. One-way ANOVA models (i.e., models with one independent categorical variable) are also subject to the assumption of approximately equal variance of the within group residual errors (Hochberg and Tamhane 1987). For these models, the within group residual variances were tested for homogeneity by Levene's test. In addition, Hochberg and Tamhane (1987) found that ANOVA models are robust to departure from homogeneity of variance if the standard deviations are within a factor of two. The homogeneity of variance assumption was confirmed either by Levene's test or by within group standard deviations being within a factor of two. If neither variance criteria were satisfied, the p-value for the Welch’s ANOVA test was reported, a method that is robust to the assumption of equal within-group variances (Welch 1951). A generalized linear model with gamma distribution and log link (McCullagh and Nelder 1989) was considered and tested in a spatial comparison of the Phase III sediments among USEPA subunits and geographic areas for selected COPCs. Two measures of goodness of fit were examined: the scaled deviance and the scaled Pearson chi-square statistics. For a fitting model, these statistics have a chi-squared distribution with degrees of freedom equal to the number of observations minus the number of parameters estimated (McCullagh and Nelder 1989). When goodness of fit statistics for each model were compared to the chi-squared distribution, the p-values were below 0.05 indicating a lack of fit for the models. Therefore, this model was not explored further for use with these data. Statistical outputs for linear models including residual plots and variance tests are found in Appendix E for sediment and Appendix I for tissue. Prior to this evaluation, each dataset was reviewed and those with low FOD (i.e., less than 70% FOD) were removed from the detailed spatial statistical analysis and evaluated qualitatively.

- Two-sample t-test: In the event only two populations were compared, either by design or due to sample size and detection frequency considerations, the unpaired two-sample t-test was used to compare the mean of the two independent groups. Consistent with the ANOVA methodology, each dataset was reviewed prior to evaluation and those with low FOD (i.e., less than 70% FOD) were removed from the detailed spatial statistical analysis and evaluated more qualitatively. Data were log-transformed to better satisfy the assumptions of normality of data residuals and homogeneity of variance. Probability values (p-values) less than 0.05 (i.e., 95% confidence level) indicate a statistically significant difference.
- Multiple Comparison Testing: Based on the results of the initial ANOVA, focused contaminants that showed a statistically significant difference in the mean concentration being compared were further evaluated to determine if specific population means were driving the noted difference. The Tukey-Kramer method for unequal group sample sizes (Kramer 1956) was used to compare the difference between each pair of means adjusting for the multiple comparisons.
- Analysis of Means: In addition to the multiple comparison testing, an analysis of means test (Hsu and Nelson 1998) was conducted for sediments that showed a statistically significant difference between the means being compared in the ANOVA or ANCOVA models. The analysis of means test compares the mean (or least square mean in the case of the ANCOVA model) of each group to the overall mean (or least square mean) of the dataset being evaluated. Least square means are means that are adjusted by the values of the covariates in the ANCOVA models.
- Spearman Rank Correlation: The strength of association between lipid content and the focused organic contaminant tissue concentration results, TOC and the focused organic contaminant sediment concentration results, and focused metal contaminant sediment concentration results and aluminum, iron, and percent silt and clay, respectively, were tested using Spearman's rank-order correlation. The Spearman's rank-order correlation is the nonparametric version of the Pearson product-moment correlation. Spearman's correlation measures the strength and direction of monotonic association between two variables. When one variable generally increases (or decreases) as the other variable increases (or decreases), the two variables are said to possess a monotonic correlation. Correlation coefficients have the characteristic of being dimensionless and scaled to lie in the range -1 to 1. When there is no correlation between two variables, the correlation coefficient is equal to zero (0). When one variable increases as the second increases, the correlation coefficient is positive. Alternatively, when one variable decreases as the second increases, the correlation coefficient is negative.

4.2.8 Data Quality and Usability

Data quality and usability reports for each RI program can be found in Appendix D. In general, few data quality issues were noted. With the exception of a small percentage (i.e., less than 3%) of the data flagged as rejected in the validation process, and recognizing that USEPA noted low bias in the PAH and pesticide sediment data discussed below, RI data were found to be usable to support project objectives. All analytical groups had a small percentage of rejected data. Analytical completeness (i.e., the percentage of non-rejected data for each analyte group within each RI sampling program) is listed in the data quality and usability reports in Appendix D. A systematic data quality issue was identified during the Phase I sampling program that resulted in elevated sample quantitation limits in analytical results for SVOCs, pesticides, Aroclor PCBs, and herbicides. Subsequent corrective action, which included re-

extraction and reanalysis, resulted in an improvement in the affected data set. However, a significant number of results remained as not detected at elevated sample quantitation limits.

USEPA noted that for split sample analysis of PCB and PAH concentrations in Phase III sediments, the sample results were biased low compared to the results from the USEPA split sample laboratory. This resulted in the reanalysis of all Phase III sediment samples (including sediment samples associated with the crab/clam and SQT programs) for PCBs and PAHs. Phase III tissue samples were not reanalyzed and the associated PAH results may be biased low. The resulting PCB data quality was found to be acceptable. The reanalyzed PAH results, while generally greater than the original results, were still found to be slightly biased low compared to USEPA split sample results. A comparison of the original Phase III PAH sediment concentrations to the USEPA split samples resulted in an average relative percent difference (RPD) of 125% for total PAH (USEPA split samples having greater concentrations). Following reanalysis, USEPA split samples still had higher concentrations on average, but the RPD was reduced to 41%, which is in the acceptable range (i.e., < 50%). The data were judged to be usable and used to draw conclusions regarding nature and extent, and concentration trends. In an evaluation of the split sample PAH tissue data, USEPA also found that a statistical bias was observed, but that the majority of the data were within an acceptable relative percent difference range. However, the USEPA split sample comparison was hindered by non-detected PAH tissue results in the project dataset. Where PAH parameters were detected, the data matched well; however, the dilutions and elevated reporting limits in the project dataset yielded non-detected PAH tissue results. Unlike sediment samples, tissue samples were not reanalyzed for PAHs.

For most tissue samples, the methylmercury concentrations were slightly greater than the total mercury concentrations indicating potential bias in the results because it would be expected that the methylmercury concentration be less than or equal to the total mercury concentration in tissue samples.

Some of the analytical methods used were different between the Phase I/II and Phase III programs. While this could affect the comparability of these data, the methodologies used in both programs were standard and USEPA-approved methods at the time of assessment, and, therefore, the differences in concentrations estimates should not be substantial. TPH was analyzed and reported as TEPH for Phase I/II and the sum of C9 to C40 hydrocarbons for Phase III; due to the difference in the reported TPH, no direct comparisons were made between the Phase I/II and Phase III TPH results. Hexachlorobenzene was analyzed as a SVOC in Phase I/II and as a pesticide in Phase III with much lower detection limits; for the purposes of this RI Report, hexachlorobenzene is discussed as a pesticide. Data quality issues are described in the detailed validation reports for each sampling program in Appendix D. Validation flags were added to the data as appropriate to qualify the data.

4.3 Sediments

This section characterizes the nature and extent of the contaminants included on the focused COPC list (Table 4-2) in sediment samples collected from the Bay during the Phase I (2005), II (2007), and III (2016) sampling programs. A sediment sampling summary for these COPCs is included in Table 4-3, and this information is sorted by sampling program, assessment zone (Phase III data only), USEPA subunit, and geomorphic area in Tables 4-4 through 4-7, respectively. Assessment zones are spatial units that were developed in the BERA to assess exposure to biota on a smaller spatial scale (see Section 4.6). Further spatial evaluation of these assessment zones is found in the BERA (Appendix B; see Table 4-13a of the

BERA; GSH 2020). The USEPA subunits are based on a spatial categorization of the NBSA proposed by USEPA in a technical memorandum that described a need to characterize subunits of the Bay at an appropriate scale for RI/FS decision-making (USEPA 2015b). These subunits were used to guide the Phase III surface sediment sampling event and are depicted on Figure 2-8. Finer scale spatial units were developed for contaminant fate and transport modeling as discussed in Section 5.1. To evaluate the uncertainty of DDx summations, Table 4-3 includes statistics for total DDx using three substitution methods for non-detected isomers in the total: the standard summation of detected values only (i.e., zero substitution), one-half the quantitation limit substitution, and full quantitation limit substitution. As shown in Table 4-3, mean concentrations are similar for all substitution methods. For Phase III data, which had generally lower quantitation limits, mean concentrations are identical to three significant figures between the substitution methods. The reason for the similarity in results using these three alternative substitution methods is the fact that the detection rate was fairly high among the six isomers (Table 4-1), mostly > 90%, except for 2,4'-DDT, which has a detection rate of 52.8 % among Phase III sediment. In addition, the quantitation limit values are small relative to most of the absolute values of the detected concentrations. The Phase I data were not analyzed for 2,4' isomers; therefore, only total DDx (4,4') is compared for Phase I/II. The mean of Phase I/II total DDx (4,4') is 14% higher with full quantitation limit substitution versus zero substitution (Table 4-3). The quantitation limits were much higher in the Phase I/II program, and also the detection rate among isomers tended to be lower (Table 4-1). Therefore, for Phase I/II samples with lower concentrations overall, there is a greater disparity among the three summation methods. This adds uncertainty to the evaluation of temporal trends.

Sediment data analyses include evaluation of temporal and spatial COPC concentration trends, along with the effect of adding a normalizing variable as a covariate based on grain size, mineralogy, and TOC. In the temporal trend analysis (Section 4.3.1), surface sediment concentrations were compared between Phase I/II and Phase III data sets to evaluate concentration trends over time. The results of the temporal trends analysis (Section 4.3.1) are presented first because they provided the impetus to focus the subsequent correlation and spatial evaluations of surface sediment on Phase III data. Following temporal trends, correlations of COPC concentrations with physical and chemical parameters were explored (Section 4.3.2). The results of the correlation trend analysis informed the decision to include normalizing variables in the subsequent spatial evaluation. The spatial distribution of COPCs is evaluated in Section 4.3.3. Evaluations were performed on data grouped by geomorphic areas, USEPA subunits, areas of long-term deposition (i.e., USACE accumulation areas), and areas of recent deposition based on Be-7 concentrations.

For surface sediment spatial evaluations, ANOVA and ANCOVA models were used to determine if there were significant differences in geometric mean[23] concentrations among the different areas and USEPA subunits. Where models were significant, the following post hoc testing was conducted:

- Pairwise multiple comparison testing (i.e., Tukey-Kramer test) to determine the specific, statistically-significant differences among the different areas and USEPA subunits. If there are only two groups being compared, then a t-test was conducted.

[23] Data were log-transformed such that geometric means were compared. The assumptions of equal variance of the log-transformed data indicate that when the geometric means are different (or not different), the means are also different (or not different).

- Multiple comparison testing to determine specific, statistically-significant differences between the different areas and USEPA subunits compared to the overall Bay-wide[24] mean (i.e., Nelson-Hsu analysis of means test).

For subsurface evaluations, boxplots were examined for general trends in COPC concentrations by depth within the spatial units. On a smaller scale, station-specific observations were assessed using principal component analysis (PCA). These results were compared to actual sediment COPC concentrations and concentrations that would be expected based on an urban reference area (e.g., Jamaica Bay as discussed in Section 4.3.3.8).

It should be noted that all spatial and temporal comparisons are dependent on measures of central tendency and uncertainty is introduced where there is localized spatial heterogeneity.

4.3.1 Temporal Evaluation of Phase I/II and Phase III Data

Temporal evaluations were conducted to assess whether surface sediment concentrations have changed over time between the Phase I/II and Phase III programs. As requested by the USEPA and described in the approved Phase III QAPP (Tierra 2016), the Phase III program was designed to reoccupy Phase I/II sample locations where possible. Phase III (2016) samples were collected with a systematic grid-based design. Wherever a Phase III grid cell included a Phase I or II location, the Phase III sample was collected at that Phase I/II location rather than at the center of the grid cell. Phase III (2016) samples were collected at 37 locations where Phase I and/or II samples had been previously collected (Figure 4-2). Co-located cores do not include samples collected in 2014 (crab/clam) or 2015 (SQT) because the sampling methods were different. The average spacing of co-located samples is 14 feet (standard deviation = 27 feet, median = 5.5 feet, minimum = 1.4 feet, maximum = 160 feet). Co-location of samples allowed for a temporal comparison of COPC concentrations while controlling for spatial variability. The analysis of the co-located samples is described in Section 4.3.1.1. All pre-planned co-located cores were included in the temporal analysis; yielding one pairing between a Phase I/II core and Phase III core per grid cell. No other pairings with cores from adjacent Phase III grid cells were considered. A second analysis was conducted using all available surface sediment data from Phase I/II and Phase III programs while controlling for spatial variability using USEPA subunits (Section 4.3.1.2). While demonstrable trends can be detected in these evaluations, they are subject to uncertainty because while the Phase I/II sample locations were distributed spatially throughout the NBSA, they were not randomly located in the strict sense. The results of these two analyses are discussed below.

Overall, at most locations and for many COPCs (e.g., 2,3,7,8-TCDD, PCBs, total DDx (4,4'), cadmium, chromium, copper, lead, mercury, and silver), log-transformed concentrations decreased from the Phase I/II to the Phase III sampling program, as detailed in the subsections below. This finding was used to focus subsequent spatial evaluations of surface sediment COPC concentrations on more recent, Phase III data (Section 4.3.3). Note that the summation of total DDx (4,4') adds uncertainty to the interpretation of DDx temporal trends because quantitation limits of the Phase I/II program were higher than in the Phase III program. In addition, the observed decline in PAH compounds from Phase I/II to Phase III may reflect an analytical difference because a known low bias was documented in the Phase III PAH data compared to USEPA split samples.

[24] This refers to the mean of all samples used in the analysis.

4.3.1.1 Analysis of Co-Located Samples

In the NBSA, surface sediment samples collected during the Phase I (2005) and/or the Phase II (2007) sampling programs are co-located with Phase III (2016) sampling locations.[25] This provides a time series of two or three observations at each of 37 locations. A linear mixed model (applied to natural logarithm transformed[26] concentration data) was used to evaluate whether concentrations of the COPCs increased or decreased over the time period (2005-2016). The analyses included 17 COPCs; the full list of 29 COPCs was not included in the analyses because not all COPCs were analyzed in each sampling event and due to low FOD in surface sediments for particular COPCs as noted in the Table 4-8 footnotes. In addition, only detected data were used in the evaluation because the elevated detection limits in the Phase I program (and some Phase II data as well) assigned to some of the non-detect results could have biased high the estimate of decline in the NBSA. For each COPC, the model was evaluated both with (Models B and C) and without (Model A) a normalizing covariate (i.e., TOC [Model B] or aluminum [Model C]). The normalizing variables were also tested separately but not found to be statistically significantly different over time. Concentrations over time depend not only on time but also on location; therefore, each location was treated as a random effect in the mixed model. This type of model is often referred to as a random intercepts linear regression model. It is a model with a slope parameter with an associated error that is treated as a fixed effect and an intercept that is assumed to vary randomly by subject. This approach can add uncertainty to the conclusion because it assumes that the rate of change over time will be the same for each location, independent of the sedimentation rate. The subjects are represented by individual locations. The tested models are expressed as follows:

Model A: $\log_e$ (concentration) = intercept + (β x year0) + γ_i

Model B: $\log_e$ (concentration) = intercept + (β x year0) + (β_{NORM}* $\log_e$(TOC concentration)) + γ_i

Model C: $\log_e$ (concentration) = intercept + (β x year0) + (β_{NORM}* $\log_e$(aluminum concentration)) + γ_i

where $\log_e$ is the natural logarithm transformation, year0 = 2005 (i.e., the first year of sampling), γ_i is the random intercept for co-location *i*, β_{NORM} is the slope term for the normalizing covariate, and β is the slope term representing the change over time.

The models were tested for significance, and the slope parameter, β, was used to calculate the average percent change in the log-transformed concentrations over the time period and the associated half-life. Based on Model A, the slope parameter (β) in the log linear mixed models was significant and negative for 14 of the 17 COPCs (Table 4-8), suggesting that a decline in log-transformed concentrations likely occurred between 2005 and 2016; however, there is considerable variability in the estimates as demonstrated by the confidence limits for percent decline and half-life (Table 4-8). Results with and without the normalizing covariates were generally in agreement though not always both significant. For six of the nine metals evaluated (i.e., cadmium, chromium, copper, lead, mercury, and silver), a significant decrease of 20 to 34% is observed. Significant decreases were observed for all the analyzed organics,

[25] The co-located analysis included only core sediment samples from 2005, 2007, and 2016. Grab sediment samples from the 2014 Crab/Clam and 2015 SQT were not included in this analysis to reduce potential confounding due to sampling methodology.

[26] Data were log-transformed such that geometric means were compared. The assumptions of equal variance of the log-transformed data indicate that when the geometric means are different (or not different), the means are also different (or not different).

ranging from 31 to 87% (Table 4-8). Based on the 37 locations that provide reasonable spatial coverage in the NBSA (Figure 4-2), a Bay-wide decline in COPC concentrations is suggested. However, the actual Bay-wide average rates of decline could be different than those predicted based on the 37 locations because the Bay-wide decline was estimated by averaging together locations with different depositional environments.

Concentrations of total Aroclor PCBs and total congener PCBs showed statistically significant ($p<0.05$) decreases of 71% and 46%, respectively (Table 4-8). The apparent difference in the rate of decline in these two PCB totals could be attributed to differences in limits of quantitation (e.g., congener methods are more sensitive). Only arsenic showed a significant increase in geometric mean concentration (22%) between Phase I/II and Phase III sampling (Table 4-8). Temporal trends for normalizing variables, TOC and aluminum, were not statistically significant (Table 4-8).

The fraction of each COPC remaining when individual Phase III sediment sample concentrations were compared to individual co-located Phase I/II sediment concentrations are presented in Table 4-9. As expected, these results reflect the statistical analysis presented in Table 4-8; however, local variation is observed, which is expected due to differences in local sources of contamination, differences in sources and rates of deposition, and sources of potential error such as localized spatial heterogeneity or analytical error. Six of nine metals evaluated (cadmium, chromium, copper, lead, mercury, and silver) show a fairly consistent decrease within most locations. Arsenic concentrations increased at most locations and nickel and zinc showed increases as well. Concentrations of organic compounds decreased at the majority of locations evaluated, but there are differences among locations as only 12 of 37 locations show agreement among 2,3,7,8-TCDD, total PCB congeners, total DDx (4,4'), and total PAHs (Table 4-9). The fraction remaining for 2,3,7,8-TCDD and total PCB congeners showed a consistent decrease (25 locations) or increase (four locations) at 29 of 37 locations while eight stations were inconsistent. Total DDx (4,4') and PAHs had differing patterns from each other and from 2,3,7,8-TCDD and total PCBs. Total DDx (4,4') decreased at 17 of 37 stations evaluated and total PAHs decreased at 25 of 37 locations. Note that the summation of total DDx (4,4') adds uncertainty to the interpretation of DDx temporal trends because quantitation limits of the Phase I/II program were higher than in the Phase III program. In addition, the observed decline in PAH compounds from Phase I/II to Phase III may reflect an analytical error because a known low bias was documented in the Phase III PAH data compared to USEPA split samples. Six of the 37 co-located stations had concentration increases for more than 50% of the evaluated COPCs, which could suggest ongoing sources or could be attributable to random variation. All other stations showed mostly decreases, even those on the subtidal flats where low deposition rates are generally expected. For example, 2,3,7,8-TCDD and total PCB congeners showed a decline at 14 and 15 of 19 subtidal locations, respectively (Table 4-9).

It is important to note that Phase I/II co-located cores were not randomly or uniformly distributed in the Bay. The estimated rates of decline are subject to uncertainty and may not be predictive of future conditions. And at a few locations, an increase in COPC concentrations between 2005 and 2016 was noted, suggesting that the average rate of decline may not apply in all areas of the Bay, particularly where deposition rates are very low or where particulate concentrations suggest ongoing inputs of COPCs. In addition, it is uncertain how rising sea levels will affect rates of change in COPC concentrations.

4.3.1.2 Analysis of All Surface Sediment Data Controlled for Spatial Variability by USEPA Subunit

A linear model in which the dependent variable is continuous and there are two independent fixed effect categorical variables with two or more possible values is referred to as a two-way ANOVA model. A two-way ANOVA model was used for a temporal comparison of surface sediment concentrations while controlling for spatial variation as a fixed[27] effect, with the advantage being that all observations could be used rather than just those from co-located locations as described in Section 4.3.1.1. The two independent categorical variables were sampling period (Phase I/II, Phase III[28]) and spatial subunit (i.e., six USEPA subunits). An interaction term (i.e., sampling period X spatial unit) was also tested for statistical significance to evaluate if an observed temporal change varied by spatial unit. The six spatial USEPA subunits were used as the strata in the Phase III systematic stratified surface sediment sampling design and are therefore an appropriate spatial variable to control for spatial variation in an unbiased manner. For each COPC, the model was run both with (Models B and C) and without (Model A) a normalizing covariate (i.e., TOC or aluminum). For significant models, a post hoc least square means[29] t-test was conducted to compare Phase I/II to Phase III means concentrations while controlling for variability due to the spatial category. When the least square means are significantly different, the difference was used to calculate the average percent change in concentrations between sampling periods. The tested models are expressed as follows:

Model A: $\log_e$ (concentration) = intercept + subunit + sampling period

Model B: $\log_e$ (concentration) = intercept + subunit + sampling period + $\log_e$(TOC concentration)

Model C: $\log_e$ (concentration) = intercept + subunit + sampling period + $\log_e$(aluminum concentration)

where $\log_e$ is the natural logarithm transformation, subunit is a categorical variable unique to each USEPA subunit, and sampling period is the time of sampling (Phase I/II versus Phase III).

Seventeen COPCs with adequate detection frequency, along with the normalizing variables, were modeled. Results both with and without the normalizing covariate were generally in agreement however not always both significant. The interaction term was not significant for any of the models, suggesting that reductions were similar across spatial units. The estimated percent reductions were generally similar to those estimated in the co-located analysis. Aluminum concentrations showed no significant difference so Model A is appropriate for making inferences regarding metals. Based on Model A, for five of the ten metals (i.e., cadmium, chromium, copper, mercury, and silver), significant decreases of 20 to 39% are suggested. Model C shows similar results although decreases are slightly lower. TOC showed a 19.8% decrease in concentration between Phases I/II and III, which may have affected the concentrations of

[27] A random effects model, while being more flexible, was not needed because there is no individual subject variance to account for, as in the analysis of co-located data, and the USEPA subunits can be treated as fixed effects since they comprise the whole of the NBSA population. Random effects models are used in cases where there are some levels of a categorical variable that were not observed. Fixed effects models are used when all levels of the categorical variable are observed as is the case with the USEPA subunits.

[28] Crab/clam and SQT sediment data were included since they were part of the Phase III sampling grid.

[29] Least square means tests allow for a t-test type comparison while controlling for the covariates in the model. Data were natural logarithm transformed. Based on the assumption of equal variance, when geometric means are different, arithmetic means are assumed to be different.

organic chemicals because they sorb to TOC. However, the ANCOVA model (Model B) controls for TOC and thus removes the possibility that changes in TOC will confound the results of the comparison. When comparing models for organic chemicals both with and without TOC, the TOC model tended to result in a reduction in rate of decline estimate (Table 4-10). Based on Model B, the estimated significant decrease in sediment concentrations between time periods ranged from 27 to 85% for six of eight evaluated organic COPCs. Differences in estimates between PCB Aroclors and congeners are likely due to differences in the precision of the analytical methods. Unlike the co-located sample analysis (Section 4.3.1.1), none of the COPCs showed significant increases in concentrations between Phase I/II and Phase III sampling (Table 4-10).

This analysis is subject to uncertainty because the Phase I/II sample design was not strictly random. The means estimated for Phase I/II data cannot be known to be unbiased since the data locations were subjectively selected. However, it provides a useful line of evidence (LOE) that confirms the findings from the co-located sample analyses regarding apparent declines in surface concentrations of most COPCs between the decadal period of the Phase I/II and Phase III sampling programs under this RI. Note that the estimated rates of decline are subject to uncertainty and may not be predictive of future conditions. And at a few locations, an increase in COPC concentrations between 2005 and 2016 was noted, suggesting that the average rate of decline may not apply in all areas of the Bay, particularly where deposition rates are very low or where particulate concentrations suggest ongoing inputs of COPCs. In addition, it is uncertain how rising sea levels will affect rates of change in COPC concentrations.

The magnitude of temporal concentration trend estimates varies somewhat among COPCs. This would be expected given differences in the magnitude of solids concentrations observed in the Bay as further discussed in Section 5.5.1. Another factor in differences is the magnitude of tributary sources for COPCs. As described in Section 5.4.7, the contaminant fate and transport (CFT) model indicates that, on a percent basis, mass inventory increases for 2,3,7,8-TCDD are up to 5 times greater than for other modeled COPCs (i.e., total PCBs, mercury and total DDx (4,4')). Differences in the changes in other metals concentrations are likely related to how elevated they are relative to background. Those significantly elevated above background concentrations would be expected to show greater rates of change whereas those that are not significantly elevated above background (e.g., nickel) would be unlikely to show significant changes. Finally, varying ongoing local sources of COPCs along the Bay shorelines or from smaller tributaries such as Pierson's Creek, a Superfund Site, would tend to affect the magnitudes of temporal trends.

The differences in the magnitudes of sources may also be expected to result in differences among COPCs at locations where it was observed that some COPCs increased while others decreased (Table 4-9). Small scale heterogeneity may result in apparent increases or decreases in co-located samples that are in opposition to an overall trend. Heterogeneity may be most influential in locations where COPC concentrations tend to be the highest such as the historically disturbed subtidal flats (e.g., core 093) or transitional slopes (e.g., core 089).

4.3.1.3 Temporal Patterns in Low Deposition Areas

Several Phase I/II cores were collected on the subtidal flats in low depositional areas as suggested by low Be-7 concentrations (Figure 3-7) and historically low deposition rates (Figure 4-5). These cores are characterized by low Cs-137 activity (i.e., Cs-137 is either not detected or detected only within the top 6

inches) and a core profile where the highest contamination is observed in the surface sample (0 to 6-inch bss). Where Cs-137 is only detected within the surface sample (or not detected at all), that sample can be assumed to comprise the entire industrial history since the 1950s and therefore would be expected to have the highest COPC concentrations within the core profile. In cores where the highest COPC concentrations are observed at the surface, it could be hypothesized that concentrations are currently increasing at these locations. However, as described below, comparison with co-located data from Phase III sampling, where available, suggests that declines have occurred in COPC concentrations at many of the core locations in low deposition areas.

In the northern Bay the following cores fit this pattern: 045, 050, 053, 054, 059, 062, 064 (Figure 3-7). For example, see the 2,3,7,8-TCDD profiles for these cores in Appendix L (Figures PF-3H (core 059 only) and PF-3K), or the total PCB congener profiles in Appendix L (Figures PF-5H (core 059 only) and PF-5K). As shown in the profiles, the highest concentrations are at the surface and the depth of contamination in these cores is generally limited to the 0 to 6-inch sample interval. All but one of these locations (059) were reoccupied during Phase III sampling (Table 4-9) and in many cases exhibited a decline in COPC concentrations as compared to Phase I/II. For example, a decrease in 2,3,7,8-TCDD and total PCB congeners was observed at four and five of these six locations, respectively (Table 4-9).

In the central and southern Bay east of the navigation channel and near the CDF in USEPA Subunit 5, there are only two cores, 039 and 040, that fit the pattern described above[30]. For example, see the core profiles in Appendix L, Figures PF-3I, PF-3J, PF-5I, and PF-5J for 2,3,7,8-TCDD and total PCB congeners, respectively. Both locations were reoccupied during Phase III sampling and in many cases exhibited a decline in COPC concentrations compared to Phase I/II (Table 4-9). Most of the remaining cores east of the navigation channel in USEPA Subunit 5 and south of core 039 do not fit a pattern of low deposition. There is an increasing trend in the depth of contamination from north to south in this area even though it is largely classified as subtidal flats. The reason for this is that most of this area was subject to some amount of historical disturbance and experienced historical deposition rates of 2 to 5 feet or more over the period evaluated by USACE (Figure 4-5). For example, see the core profiles for cores 032/073, 037, 071, 072, 073, and 091 in Appendix L (Figures PF-3I, PF-3J, PF-5I and PF-5J, for 2,3,7,8-TCDD and total PCB congeners, respectively) where contaminated sediments are observed at depths of 3 to 15 feet bss. This increasing trend in the depth of contamination from north to south is further described in cross-sections discussed in Section 5.5.3.2.

On the southwestern subtidal flats, there are a few cores that fit this low depositional pattern: 013, 014, 019, 020, and 025 (Figure 3-7). For example, see the core profiles in Figures PF-3A, PF-3B, PF-5A, and PF-5B for 2,3,7,8-TCDD and total PCB congeners, respectively. In addition, two other cores fit this low deposition pattern that were located either on a transitional slope (i.e., 018) or in the industrial waterfront area (i.e., 026). They also have non-detectable Be-7 (Figure 3-7) and surface concentrations of 2,3,7,8-TCDD and total PCBs are greatest in the surface sample (Figures PF-3D and PF-5D). Four of these locations (i.e., 013, 014, 019, and 020) were reoccupied during Phase III sampling and in many cases exhibited a decline in COPC concentrations (Table 4-9). For example, at all four locations, 2,3,7,8-TCDD and total PCB congeners declined (Table 4-9). Core 015, which is also located on the southwestern subtidal flat and has a non-detect Be-7 concentration is different than the low deposition cores located in

[30] Core 038 also fits the pattern but was collected in an intertidal area (Figure 3-8).

this area. It is situated where there had been a natural tidal channel and where historical deposition was estimated to be 2 to 5 feet (Figure 4-5). It is also located just north of an historical dike that was designed to prevent sediment from depositing in the navigation channel. The dike likely facilitated deposition at this location where at least 3.5 feet of contaminated sediments are found, and the highest concentrations are below the surface. For example, see the core profiles in Appendix L (Figure PF-3B and PF-5B for 2,3,7,8-TCDD and total PCB congeners, respectively). The historical dike is further discussed in Section 5.5.3.2.

4.3.1.4 Evaluation of USEPA 1993-2013 REMAP Data

Newark Bay is included as a sub-basin area by the USEPA in its REMAP investigation of the NY/NJ Harbor Estuary. As discussed in Section 2.2.1, baseline sediment data were collected in 1993 and 1994, and five-year re-visits occurred in 1998, 2003, 2008, and 2013, as part of the National Coastal Assessment Program (Adams 2016). Surface (top 2 cm) sediment collection locations from 1993 through 2013 as part of REMAP are shown on Figure 2-11. Summary statistics for the 2008 and 2013 REMAP sediment datasets, which are recent data collected during the RI/FS activities in the NBSA (i.e., post-2004), are included in Table 4-11. While collected during the implementation of the RI sediment investigations, the REMAP data are not comparable to the Phase I to Phase III surface sediment data in terms of the data use objectives, locations, collection methods, or depths. For this reason, the REMAP data are summarized separately from the data in this RI Report. Their primary use for this RI Report is to compare temporal trends in COPC concentrations in the NBSA within the 20-year time series of data collected under the program. A detailed analysis and discussion of REMAP temporal trends from 1993 through 2013 is included in Section 5.

For both 2008 and 2013 sampling events, samples were collected from 11 NBSA locations and analyzed for metals, PCDDs/PCDFs (2013 only), PCBs (total Aroclors only), pesticides, and PAHs. Metals, PAHs, and PCDDs/PCDFs were detected in all the samples analyzed under the program. Pesticides and PCBs were detected less frequently (in less than 55% of samples) (Table 4-11).

4.3.2 Correlation Trends for Normalizing Factors

A discussion of sediment data normalization is provided in Section 4.2.5. An evaluation of the correlation between COPC concentrations in Phase III surface sediments (including crab/clam and SQT sediment data) and the normalizing variables was conducted using the Spearman rank correlation coefficient. Organic COPCs were evaluated for correlation with TOC while metals were evaluated for correlations with aluminum, fines (defined as the fraction of silt and clay), and iron. All organic COPCs were significantly correlated with TOC (Figure 4-3a through 4-3e) with correlation coefficients ranging from 0.3 to 0.6. As discussed in Section 4.2.5, TPH and other organics are included in the TOC measurement and would serve as a source of organic matter for partitioning of other hydrophobic contaminants. Therefore, TPH and TOC are expected to be correlated as shown in Figure 4-3c (bottom right panel). All metals were significantly correlated with aluminum (Figures 4-4a through 4-4c) with correlation coefficients ranging from 0.6 to 0.8. Metals were also significantly correlated with iron and percent fines (Figures F-1 through F-6 in Appendix F). These observed correlations are anticipated because hydrophobic organic COPCs tend to partition into particulate or dissolved organic matter, and polar inorganic COPCs are strongly associated with surface charges on clay minerals due to their high surface area and polarity. Based on the findings, normalized concentrations (organics normalized to TOC and metals normalized to aluminum) are

included in graphical and tabular presentations and the normalizing variables (i.e., TOC for organics and aluminum for metals) have been evaluated as covariates in statistical comparisons among the spatial units, in the sediment evaluation that follows (Section 4.3.3).

4.3.3 Spatial Distribution of COPCs

The spatial extent of contamination is discussed below in terms of the spatial units defined for the NBSA (i.e., geomorphic areas, USEPA subunits, and deposition areas). Due to the statistically significant decreasing temporal trends for the majority of the analyzed COPCs (Section 4.3.1), the Phase III data are the focus of the spatial analyses of surface sediment to more closely represent the current condition of the NBSA. The Phase I/II sediment core data are the focus of the discussion of vertical extent. A detailed description of the Phase I/II data, both surface and subsurface, is provided in the DEAR (Tierra 2014c).

As discussed in Section 3.3, the NBSA can be divided into seven distinct geomorphic areas based on natural and anthropogenic processes (Figure 2-1):

- Subtidal flats
- Historically disturbed subtidal flats
- Transitional slopes
- Navigation channels
- Port channels
- Intertidal areas
- Industrial waterfront areas.

COPC concentrations are compared among the geomorphic areas in Table 4-12.

An additional spatial categorization, USEPA subunits (Figure 2-8), was developed for the Phase III surface sediment sampling program to allow characterization of the NBSA at an appropriate scale for RI/FS decision-making (Section 4.3). Phase I/II data only allowed for Bay-wide decision-making. The USEPA subunits were identified as a result of “consideration of modeled bottom shear stresses, bathymetry, geomorphological features, and navigational/anthropogenic activity” (USEPA 2015b). Within each USEPA subunit, a systematic random (grid based) sampling design was implemented for Phase III sampling such that the sampling density was consistent within a USEPA subunit allowing for the calculation of a stratified mean, a spatially weighted average (Table 4-13). The stratified mean (μ_{st}) and the variance of the stratified mean (s_{st}^2) are calculated as follows (USEPA 2006a):

$$\mu_{st} = \sum_{h=1}^{6} W_h \mu_h$$

$$s_{st}^2 = \sum_{h=1}^{6} \frac{W_h^2 s_h^2}{n_h}$$

Where *h* are the six USEPA subunits; μ_h and s_h^2 are the sample mean and variance of each USEPA subunit; and W_h is the weight calculated as the area of the subunit divided by the entire area of all USEPA subunits. The standard error s_{st} is the square root of s_{st}^2. Because the degrees of freedom are sufficiently large, a 95% upper confidence limit (95 UCL) was calculated using the equation: 95UCL = μ_{st} + (s_{st} * 1.645), where 1.645 is the value (i.e., z-score) of the 95th percentile of the standard normal distribution. Similarly, a 95% lower confidence limit (95 LCL) was calculated as follows: 95LCL = μ_{st} - (s_{st} * 1.645). COPC concentrations are compared among the USEPA subunits (Table 4-14).

Both long-term and recent deposition has been investigated in the NBSA (Tierra 2011). For long-term deposition, potential areas of high net deposition (USACE accumulation areas) were identified by the USACE (2006a) based on a study of historical bathymetry (Figure 4-5). COPC concentrations are compared based on location within or outside the USACE accumulation areas (Table 4-15).

Recent deposition in the Bay was assessed through analysis of Be-7 in Phase I and Phase II surface sediment samples collected at a depth of 0 to 1 inch. Detected Be-7 activities in Phase I samples ranged from 0.14 to 3.60 pCi/g with an arithmetic average activity of 0.89 pCi/g. Detected Be-7 activities in Phase II samples ranged from 0.07 to 7.02 pCi/g, with an arithmetic average activity of 1.13 pCi/g (Tierra 2011). Previously, statistical analysis was also performed to determine whether there was correlation between surface Be-7 activity and long-term sediment deposition rates. The results showed that because Be-7 has a known, short half-life of 53 days, Be-7 is not a good indicator of long-term sediment deposition. In addition, there was no positive correlation between Be-7 activity and either the estimated depth of the 1940 horizon or estimated deposition since 1935. Be-7 concentrations greater than or equal to 0.5 pCi/g indicate that recent deposition has occurred at a location; although, the thickness of such recent deposition is not known. Further, it is important to note that in areas where deposition rates are low, the top 6 inches of sediment could contain a considerable proportion of historically deposited sediments regardless of whether Be-7 is present in the top 1 inch. Surface sediment concentrations in the Phase I/II data sets are compared based on whether they are Be-7 bearing (i.e., Be-7 $\geq$ 0.5 pCi/g) or not, and with respect to their geographic area and geomorphic area (i.e., channel versus non-channel). Be-7 bearing locations are identified on Figure 3-8. Bay-mile plots of Be-7 bearing sediment samples are discussed in Section 5.5.2.

Phase I/II sediment core results are used to evaluate the general relationship between COPC concentration and depth from surface because they cover a range of depths. To evaluate the vertical distribution of the COPCs within the NBSA, boxplots were prepared, both on a normalized and non-normalized basis, by grouping the data by spatial unit and depth: 0 to 0.5 foot (i.e., surface), 0.5 to 3.5 feet, 3.5 to 6.5 feet, and greater than 6.5 feet depths (Appendix F). The surface and subsurface data are grouped by geomorphic area in Figures F-36 through F-64 (non-normalized) and Figures F-65 through F-93 (normalized). The surface and subsurface data are grouped by USEPA subunit in Figures F-94 through F-122 (non-normalized) and Figures F-123 through F-151 (normalized). The surface and subsurface data are grouped by USACE accumulation area in Figures F-152 through F-180 (non-normalized) and Figures F-181 through F-209 (normalized). The surface data (Phase I/II only) are grouped by recent deposition (based on Be-7 concentration being greater than or less than 0.5 pCi/g) in Figures F-210 through F-235

(non-normalized) and Figures F-236 through F-261 (normalized). The conclusions regarding spatial distributions of COPCs are described in Sections 4.3.3.1 through 4.3.3.7.

4.3.3.1 PCDDs/PCDFs

Surface sediment 2,3,7,8-TCDD concentrations from Phase I, II, and III sampling events are shown on Figure 4-6. Based on the Phase III data, 2,3,7,8-TCDD surface concentrations range from 0.12 to 1,710 nanograms per kilogram (ng/kg) with a FOD of 100% and a stratified mean concentration in the NBSA of 68.9 (±8.3) ng/kg (Table 4-13). Ninety percent of all measured surface concentrations are less than 148 ng/kg (Figure 4-6). The most elevated concentrations (i.e., the top 10% of concentrations) are often, but not always, associated with areas of historical anthropogenic disturbance that was followed by high net deposition - the areas defined as historically disturbed subtidal flats (Figure 4-6).

ANOVA and post hoc testing of geomorphic areas indicate that Phase III surface sediment 2,3,7,8-TCDD concentrations are statistically significantly greater in the historically disturbed subtidal flats compared to the subtidal flats, the transitional slopes, and the overall Bay-wide mean[31] concentration (Table 4-12). However, the ANCOVA model, which controls for TOC, was not significant (Tables 4-12), indicating that TOC content controls most of the variance in surface 2,3,7,8-TCDD concentrations. Boxplots showing Phase I/II and Phase III sediment concentrations of 2,3,7,8-TCDD by geomorphic area and depth interval are presented in Figure 4-7. The greatest subsurface 2,3,7,8-TCDD concentrations (maximum = 8,840 ng/kg) tend to occur within the historically disturbed subtidal flats. At depths less than 6.5 feet, median concentrations increase with depth in the historically disturbed subtidal flats. Median concentrations decrease with depth in the subtidal flats (Figure 4-7). Boxplots depicting normalized 2,3,7,8-TCDD concentrations by geomorphic unit are included on Figure F-65 in Appendix F.

Among USEPA subunits, ANOVA and ANCOVA results were consistent and indicated that USEPA Subunit 4 had a greater mean 2,3,7,8-TCDD concentration than both USEPA Subunit 1 and the overall Bay-wide mean (Table 4-14). USEPA Subunit 4 is in the northern Bay and includes most of the historically disturbed areas in the northern Bay while USEPA Subunit 1 is in the southern Bay. Boxplots showing Phase I/II and Phase III sediment concentrations of 2,3,7,8-TCDD by USEPA subunit and depth interval are presented in Figure 4-8. The greatest subsurface 2,3,7,8-TCDD concentrations tend to occur within USEPA Subunits 4, 1, and 5. At depths less than 6.5 feet, median concentrations increase with depth in USEPA Subunits 1, 4 and 5 (Figure 4-8). Boxplots depicting normalized 2,3,7,8-TCDD concentrations by USEPA subunits are included on Figure F-123 in Appendix F.

Mean 2,3,7,8-TCDD was statistically significantly greater in the USACE accumulation areas (Table 4-15) however ANCOVA results were not significant (Table 4-15). Boxplots showing Phase I/II and Phase III sediment concentrations of 2,3,7,8-TCDD by accumulation area and depth interval are presented in Figure 4-9. The greatest subsurface 2,3,7,8-TCDD concentrations tend to occur within the USACE accumulation areas, which is consistent with the findings based on geomorphic area because the delineation of the historically disturbed subtidal flats was based on the USACE study (Tierra 2011). At

[31] This refers to the mean of all samples used in the analysis. See description of analysis of means test in Section 4.2.7. The lowest achievable laboratory estimated detection limit reported in the QAPP/FSP Addendum (1.2 pg/L) was achieved; however, subsequent laboratory dilution and extract splits caused the estimated detection limit to double to 2.4 pg/L in six samples, potentially impacting the number of detected 2,3,7,8-TCDD results.

depths less than 6.5 feet, median concentrations increase with depth in the USACE accumulation areas (Figure 4-9). Boxplots depicting normalized 2,3,7,8-TCDD concentrations by accumulation area are included on Figure F-181 in Appendix F.

Boxplots showing Phase I/II surface sediment concentrations of 2,3,7,8-TCDD by recent deposition area are presented on Figures F-210 and F-236 (normalized) in Appendix F. Comparison of the Phase I/II surface sediment concentrations in locations with and without evidence of recent deposition showed that the mean 2,3,7,8-TCDD concentration was greater in samples with recent deposition (i.e., Be-7 bearing samples) (Table 4-16; Figure F-210); although, when controlling for TOC, there was no significant difference based on recent deposition (Table 4-16). Recalling that Be-7 was only measured in the top 1 inch of sediment at each location, it is likely that the co-located 6-inch sediment samples that were analyzed for site contaminants collected from the subtidal flats, where deposition rates are generally lower, also include deeper/older sediment that was not recently deposited (i.e., because all surface sediment collected for chemical analysis included the top 6 inches of the core) thus potentially confounding the results and conclusions of the statistical comparison. In fact, when only samples from the navigation channel are compared, where recent deposition is more likely, the mean in Be-7 bearing samples is lower than in non-Be-7 bearing samples (Table 4-16); although, this difference is not statistically significant. Among Be-7 bearing samples, the mean concentration of 2,3,7,8-TCDD in the north geographic area is greater than in the south (Table 4-16), consistent with the spatial pattern described above for Phase III sediment samples. This spatial trend (i.e., decreasing concentrations from north to south) is further depicted on scatter plots showing 2,3,7,8-TCDD concentrations in Be-7 bearing samples by Bay mile (see Section 5.5.2 and Figure 5-B7-1a). Concentrations in Be-7 bearing sediments from the channel (Table 4-16) are similar to solid phase concentrations in the water column (see Section 4.4).

4.3.3.2 PCBs

PCBs were analyzed as both Aroclors and congeners. Similar spatial patterns were found for all summations of PCBs and the following discussion focuses on total PCB congeners (i.e., the sum of 209 congeners). Surface sediment concentrations from Phase I, II, and III sampling events are shown on Figure 4-10. Based on the Phase III data, surface concentrations range from 2,480 to 5,030,000 ng/kg with a FOD of 100% and stratified mean total PCB congener concentration in the NBSA of 390,000 ($\pm$29,300) ng/kg (Table 4-13). Ninety percent of all measured surface concentrations are less than 1,160,000 ng/kg (Figure 4-10). The most elevated concentrations (i.e., the top 10% of concentrations) are often, but not always associated with the historically disturbed subtidal flats geomorphic area (Figure 4-10).

ANOVA and post hoc testing of geomorphic areas indicate that Phase III surface sediment total PCB congener concentrations were statistically significantly greater in the historically disturbed subtidal flats compared to the subtidal flats and to the overall Bay-wide mean concentrations (Table 4-12). The ANCOVA model, which controls for TOC, was not significant; however, the p-value was low (p=0.058) and the normalized concentrations had a similar spatial pattern as the absolute concentrations (Table 4-12). Boxplots showing Phase I/II and Phase III sediment concentrations by geomorphic area and depth are presented in Figure 4-11. The greatest subsurface total PCB concentrations (maximum = 32,100,000 ng/kg) tend to occur within the historically disturbed subtidal flats. At depths less than 6.5 feet, median

concentrations increase with depth in the historically disturbed subtidal flats. Median concentrations decrease with depth in the subtidal flats (Figure 4-11).

Among USEPA subunits, PCB concentrations tended to be greatest in USEPA Subunit 1; although, ANOVA and ANCOVA results for total PCB congeners were not significant (Table 4-14). Boxplots showing Phase I/II and Phase III sediment concentrations of total PCB congeners by USEPA subunit and depth interval are presented in Figure 4-12. The greatest subsurface total PCB congener concentrations tend to occur within USEPA Subunits 1 and 4. At depths less than 6.5 feet, median concentrations increase with depth in USEPA Subunits 4 and 5 (Figure 4-12). Boxplots depicting normalized concentrations by geomorphic area and USEPA subunits are included on Figures F-67 and F-125, respectively, in Appendix F.

ANOVA and ANCOVA models indicate mean total PCB congeners were statistically significantly greater in the USACE accumulation areas (Table 4-15). Boxplots showing Phase I/II and Phase III sediment concentrations of total PCB congeners by accumulation area and depth interval are presented in Figure 4-13. The greatest subsurface total PCB congener concentrations tend to occur within the USACE accumulation areas, which is consistent with the findings based on geomorphic area because the delineation of the historically disturbed subtidal flats was based on the USACE study (Tierra 2011). At depths less than 6.5 feet, median concentrations increase with depth in the USACE accumulation areas (Figure 4-13).

Boxplots showing Phase I/II surface sediment concentrations of total PCB congeners by recent deposition area are presented on Figures F-212 and F-238 (normalized) in Appendix F. Comparison of the Phase I/II surface sediment concentrations in locations with and without recent deposition showed that the mean total PCB congener concentration was greater in areas with recent deposition (Table 4-16); although, when controlling for TOC, there was no significant difference. Again, recalling that Be-7 was only measured in the top 1 inch, co-located 6-inch sediment chemistry samples could contain a significant proportion of deeper/older historically deposited sediments, thus confounding the results of the comparison. When only samples from the navigation channel are compared, where recent deposition is more likely, the mean in Be-7 bearing samples is lower than non-Be-7 bearing samples (Table 4-16); although, this difference is not statistically significant. Among Be-7 bearing samples, there was no significant difference among geographic areas (Table 4-16). This apparent lack of a spatial trend is further depicted on scatter plots showing total PCB congener concentrations in Be-7 bearing samples by Bay mile (see Section 5.5.2 and Figure 5-B7-2). Total PCB concentrations in Be-7 bearing sediments from the channel (Table 4-16) are similar to solid phase concentrations in the water column (see Section 4.4). Surface sediment concentration maps and boxplots by depth and spatial units for Aroclors are presented on Figures F-8, F-37 and F-95 in Appendix F. Boxplots depicting normalized concentrations by spatial unit and depth interval can also be found on Figures F-66 and F-124 in Appendix F.

4.3.3.3 Pesticides

As both total DDx (2,4’ and 4,4’) and total DDx (4,4’) have similar spatial patterns, the following discussion focuses on total DDx (4,4’) because the 4,4’ isomers were measured in all phases of the RI. Surface sediment total DDx (4,4’) concentrations from Phase I, II, and III sampling events are shown on Figure 4-14. Based on the Phase III data, total DDx (4,4’) surface concentrations range from 93 to 1,800,000 ng/kg with a FOD of 100% and stratified mean concentration in the NBSA of 72,000 (±9,100) ng/kg (Table 4-13).

Ninety percent of all measured surface concentrations are less than 210,000 ng/kg (Figure 4-14). Most of the highest concentrations (i.e., the top 10% of concentrations) are found on the southern subtidal flats and in the Arthur Kill (Figure 4-14).

ANOVA and ANCOVA models comparing total DDx (4,4') among geomorphic areas were not significant (Table 4-12). Boxplots showing Phase I/II and Phase III sediment concentrations of total DDx (4,4') by geomorphic area and depth interval are presented in Figure 4-15. The greatest subsurface total DDx (4,4') concentrations (maximum = 2,800,000 ng/kg) tend to occur within the historically disturbed subtidal flats. At depths less than 6.5 feet, median concentrations increase with depth in the historically disturbed subtidal flats and the industrial waterfront areas (Figure 4-15).

Among USEPA subunits, ANOVA and ANCOVA results were consistent and indicated that USEPA Subunit 1 had greater mean total DDx (4,4') concentrations than all other USEPA subunits (Table 4-14). Boxplots showing Phase I/II and Phase III sediment concentrations of total DDx (4,4') by USEPA subunit and depth interval are presented in Figures 4-16. The greatest subsurface total DDx (4,4') concentrations tend to occur within USEPA Subunit 1. At depths less than 6.5 feet, median concentrations increase with depth in USEPA Subunits 4 and 5 (Figure 4-16). Boxplots depicting normalized concentrations by geomorphic area and USEPA subunits are included on Figures F-69 and F-127, respectively, in Appendix F.

Mean total DDx (4,4') was statistically significantly greater in the USACE accumulation areas (Table 4-15); however, ANCOVA results were not significant (Table 4-15). Boxplots showing Phase I/II and Phase III sediment concentrations of total DDx (4,4') by accumulation area and depth interval are presented in Figure 4-17. The greatest subsurface total DDx (4,4') concentrations tend to occur within the USACE accumulation areas, which is consistent with the findings based on geomorphic area because the delineation of the historically disturbed subtidal flats was based on the USACE study (Tierra 2011). At depths less than 6.5 feet, median concentrations increase with depth in the USACE accumulation areas (Figure 4-17).

There was no significant difference in the mean total DDx (4,4') concentration among areas with or without recent deposition either for all samples or for samples within the navigation channel (Table 4-16). Among Be-7 bearing samples, the mean concentration in the south is significantly greater than in the north and central portions of the NBSA (Table 4-16). This spatial trend (i.e., greater total DDx (4,4') concentrations in the southern Bay below Bay mile 4) is further depicted on scatter plots showing total DDx (4,4') concentrations in Be-7 bearing samples by Bay mile (see Section 5.5.2 and Figure 5-B7-3). Total DDx (4,4') concentrations in Be-7 bearing sediments from the channel (Table 4-16) are similar to solid-phase concentrations in the water column (see Section 4.4). Boxplots showing Phase I/II surface sediment concentrations of total DDx (4,4') (4,4') by recent deposition area are presented on Figures F-214 and F-240 in Appendix F.

Surface sediment concentration maps and boxplots by spatial unit and depth for the remaining pesticide COPCs can be found on Figures F-10 through F-16, Figures F-41 through F-47, Figures F-70 through F-76, Figures F-99 through F-105, and Figures F-128 through F-134 in Appendix F. There were some differences in the spatial patterns of other pesticides compared to those of total DDx (4,4'). The ANOVA results suggest that mean total alpha + gamma chlordane, cis-nonachlor and dieldrin concentrations were greater in the historically disturbed subtidal flats compared to subtidal flats and to the overall Bay-wide mean concentrations (Table 4-12). However, the ANCOVA results were not consistent and suggested that

total alpha + gamma chlordane was greatest in the industrial waterfront. Compounds with FODs less than 70% (i.e., alpha-BHC, beta-BHC, and heptachlor epoxide) were not evaluated statistically.

Among the USEPA subunits, similar to total DDx (4,4'), hexachlorobenzene was greatest in USEPA Subunit 1 (Table 4-12). In contrast, total alpha + gamma chlordane, cis-nonachlor, and dieldrin were greatest in USEPA Subunit 4 (Table 4-12). Similar to total DDx (4,4'), total alpha + gamma chlordane, cis-nonachlor, and dieldrin were greatest in the USACE accumulation areas (Table 4-15). Due to the much lower FOD for pesticides in the Phase I/II programs, they were not compared based on Be-7 bearing status. Due to the low FOD, subsurface spatial patterns depicted in boxplots (Figures F-41 through F-47 and Figures F-99 through F-105 in Appendix F) should be interpreted with caution.

4.3.3.4 PAHs

As described in Section 4.2.3, PAH compounds are represented by several summations – total HMW PAHs, total LMW PAHs, total alkylated PAHs, and total PAHs (i.e., sum of the HMW and LMW PAHs).

Surface sediment total PAH concentrations from Phase I, II, and III sampling events are shown on Figure 4-18. Based on the Phase III data, total PAH surface concentrations range from 37 to 110,000 micrograms per kilogram (µg/kg) with a FOD of 99% and stratified mean concentration in the NBSA of 10,400 ($\pm$731) µg/kg (Table 4-13). Ninety percent of all measured surface concentrations are less than 30,000 µg/kg (Figure 4-18). The most elevated concentrations (i.e., the top 10% of concentrations) are found throughout the NBSA (Figure 4-18). A similar spatial pattern is noted for HMW and LMW PAHs (Appendix F; Figures F-20 and F-21, respectively).

No significant differences in mean total PAH surface sediment concentrations were found in comparisons of any of the spatial units (Tables 4-12, 4-14, and 4-15) or comparison of samples with and without recent deposition (Table 4-16). Among Be-7 bearing samples, the mean concentration of PAHs (i.e., total, HMW and LMW PAHs) in the north geographic area are significantly greater than in the central and the Bay-wide mean (Table 4-16). Total PAH concentrations in Be-7 bearing sediments from the channel (Table 4-16) are similar to solid-phase concentrations in the water column (see Section 4.4).

Boxplots showing Phase I/II and Phase III sediment concentrations of total PAHs by geomorphic area and depth interval are presented in Figure 4-19. The greatest subsurface total PAH concentrations (maximum = 380,000 µg/kg) tend to occur within the industrial waterfront geomorphic area (Figure 4-19). At depths less than 6.5 feet, median concentrations increase with depth in the industrial waterfront, transitional slopes, and the historically disturbed subtidal flats. Median concentrations decrease with depth in the subtidal flats (Figure 4-19). Similar patterns were noted for HMW and LMW PAHs. Boxplots depicting total HMW and total LMW PAHs by geomorphic area are found in Appendix F (Figures F-49 and F-50). Boxplots depicting normalized PAH concentrations by geomorphic area are found in Appendix F (Figures F-77 through F-80).

Boxplots showing Phase I/II and Phase III sediment concentrations of total PAHs by USEPA subunit and depth interval are presented in Figure 4-20. The greatest subsurface median total PAH concentrations tend to occur within USEPA Subunit 1; although, the greatest individual subsurface concentrations occur within the 0.5- to 3.5-foot interval of USEPA Subunit 2. At depths less than 6.5 feet, median concentrations increase with depth in USEPA Subunits 1, 4 and 5 (Figure 4-20). Similar patterns were noted for HMW and LMW PAHs. Boxplots depicting total HMW and total LMW PAHs by USEPA subunit

are found in Appendix F (Figures F-107 and F-108). Boxplots depicting normalized PAH concentrations by USEPA subunits are found in Appendix F (Figures 135 through 138).

Boxplots showing Phase I/II and Phase III sediment concentrations of total PAHs by accumulation area and depth interval are presented in Figure 4-21. The greatest subsurface total PAH concentrations tend to occur within the USACE accumulation areas. At depths less than 6.5 feet, median concentrations increase with depth in the USACE accumulation areas (Figure 4-21). Similar patterns were noted for HMW and LMW PAHs. Boxplots depicting total HMW and total LMW PAHs by USACE accumulation areas are found in Appendix F (Figures F-165 and F-166). Boxplots depicting normalized PAH concentrations by USACE accumulation areas are found in Appendix F (Figures 193 through 196). Boxplots showing Phase I/II surface sediment PAH concentrations by recent deposition area are presented in Figures F-221 through F-223 (non-normalized) and F-247 through F-249 (normalized) in Appendix F.

Alkylated PAHs were only measured in the Phase III surface sediment sampling programs. Surface sediment total alkylated PAH concentrations are shown on Figure 4-22. Total alkylated PAHs range from 38.5 to 168,000 µg/kg with a FOD of 96% and the stratified mean concentration in the NBSA is 9,840 (±837) µg/kg (Table 4-13). Ninety percent of all measured surface concentrations are less than 30,422 µg/kg (Figure 4-22). Alkylated PAHs exhibit a different pattern than total PAHs in that the most elevated concentrations (i.e., the top 10% of concentrations) are mostly found on the southern subtidal flat (Figure 4-22). This pattern, however, did not lead to statistically significant differences based on spatial comparisons (Tables 4-12, 4-14, and 4-15) although Welch's ANOVA was significant for the geomorphic comparison (Table 4-12). While not significant, the mean concentration was highest in USEPA Subunit 1 (21,200 µg/kg; Table 4-14). Alkylated PAHs were found in porewater at levels expected to be toxic at SQT stations 151 and 154 located on the southern subtidal flats (BERA, Appendix A). These stations had alkylated sediment PAH concentrations in the upper tenth percentile (i.e., 30,422 µg/kg and 37,800 µg/kg, respectively) and also exhibited acute toxicity (see Section 4.3.3.8.1). Therefore, with many total alkylated PAH concentrations in the upper tenth percentile, the southern subtidal flats may pose a risk to the benthic invertebrate community. Boxplots of total alkylated PAH concentrations by spatial unit are found in Appendix F (Figures F-51, F-80, F-109, F-138, F-167, and F-196).

4.3.3.5 SVOCs

Other semivolatile compounds on the COPC list are TPH and BEHP. Surface sediment concentration maps and boxplots by depth and spatial unit can be found in Appendix F. TPH concentrations in surface sediments ranged from 6.45 to 2,910 milligrams per kilogram (mg/kg), with a stratified mean of 257 mg/kg and a FOD of 97% (Table 4-13). Mean TPH was significantly greater in USEPA Subunit 1 compared to the Bay-wide mean (Table 4-14). No other spatial comparisons were significant. TPH concentrations increased with depth in the historically disturbed subtidal flats and industrial waterfront geomorphic areas and decreased with depth in the subtidal flats. At depths less than 6.5 feet, median TPH concentrations increased with depth in USEPA Subunits 1, 4, and 5 and within the USACE accumulation areas.

BEHP concentrations in surface sediments ranged from 96 to 38,000 µg/kg, with a stratified mean of 905 µg/kg and a FOD of 78% (Table 4-13). Mean BEHP was significantly lower in the subtidal flats compared to the historically disturbed subtidal flats and the Bay-wide mean. No other spatial comparisons were significant. BEHP concentrations increased with depth in the historically disturbed subtidal flats and industrial waterfront geomorphic areas and decreased with depth in the subtidal flats. At depths less than

6.5 feet, median BEHP concentrations increased with depth in USEPA Subunits 1, 4, and 5 and within the USACE accumulation areas. Surface sediment concentration maps (Figures F-23 and F-24) and boxplots by spatial unit and depth for TPH (Figures F-53, F-82, F-111, and F-140) and BEHP (Figures F-52, F-81, F-110, and F-139) can be found in Appendix F.

4.3.3.6 Metals

Eleven of the 29 COPCs are metals. Most metals have similar spatial patterns to mercury; therefore, mercury is the focus of the following discussion. Surface sediment mercury concentrations from Phase I, II, and III sampling events are shown on Figure 4-23. Based on the Phase III data, mercury surface sediment concentrations range from 5.11 to 22,100 µg/kg with a FOD of 100% and stratified mean concentration in the NBSA of 1,970 (±128) µg/kg (Table 4-13). Ninety percent of all measured surface concentrations are less than 5,600 µg/kg (Figure 4-23). The most elevated concentrations (i.e., the top 10% of concentrations) primarily occur in the southern subtidal flat (Figure 4-23). The maximum values occur between Bay miles 1 and 2 in two co-located samples at the upper end of the Port Newark Channel near the discharge of Pierson's Creek. Pierson's Creek is the location of a designated Superfund site due to elevated levels of mercury and other contaminants.

The results of Welch's ANOVA test suggest that mean mercury differs by geomorphic area (Table 4-12). Post-hoc testing was not conducted because the ANOVA was not significant and variance assumptions were not met. Boxplots showing Phase I/II and Phase III sediment concentrations of mercury by geomorphic area and depth interval are presented in Figure 4-24. The greatest subsurface mercury concentrations (maximum = 758,000 µg/kg) occur within the port channels and industrial waterfront geomorphic areas. At depths less than 6.5 feet, median concentrations increase with depth in the historically disturbed subtidal flats and industrial waterfront (Figure 4-24). In the subtidal flats, concentrations decrease below 3.5 feet (Figure 4-24).

Among USEPA subunits, ANOVA and ANCOVA results indicated that USEPA Subunit 1 had greater mean mercury concentrations than USEPA Subunit 6 and the overall Bay-wide mean (Table 4-14). ANCOVA results also indicated USEPA Subunit 1 being greater than USEPA Subunits 2 and 5 as well (Table 4-14). Boxplots showing Phase I/II and Phase III sediment concentrations of mercury by USEPA subunit and depth interval are presented in Figure 4-25. At depths less than 6.5 feet, median concentrations increase with depth in USEPA Subunits 1, 4, and 5 (Figure 4-25). Boxplots depicting normalized concentrations by geomorphic area and USEPA subunits are included on Figures F-88 and F-146 in Appendix F.

Mean mercury concentration was significantly greater within USACE accumulation areas (Table 4-15). Boxplots showing Phase I/II and Phase III sediment concentrations of mercury by accumulation area and depth interval are presented in Figure 4-26. At depths less than 6.5 feet, median concentrations increase with depth in the USACE accumulation areas (Figure 4-26).

Among samples collected from the navigation channel, the mean mercury concentration in Be-7 bearing samples is significantly lower than in non-Be-7 bearing samples, but such differences were not observed for other metals (Table 4-16). Among Be-7 bearing samples, geographic area mercury means were not significantly different (Table 4-16). This apparent lack of a spatial trend is further depicted on scatter plots showing mercury concentrations in Be-7 bearing samples by Bay mile (see Section 5.5.2 and Figure 5-B7-4). Despite the lack of trend, a likely source of mercury is apparent at the head of the Port Newark

Channel (Figure 4-23) where Pierson's Creek, a designated Superfund Site, enters the channel. At this location, the two highest mercury concentrations in surface sediment were observed (i.e., 38,800 and 77,000 µg/kg) and both of these samples were Be-7 bearing suggesting recent deposition had occurred. Boxplots showing Phase I/II and Phase III sediment concentrations of mercury by recent deposition area are presented on Figures F-231 and F-257 in Appendix F. Mercury concentrations in Be-7 bearing sediments from the channel (Table 4-16) are similar to solid-phase concentrations in the water column (see Section 4.4).

Other COPC metals (i.e., arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc) exhibited similar patterns of distribution as mercury. Like mercury, the most elevated concentrations for other metals (i.e., top 10%) were found on the southern subtidal flats. Except for chromium, mean metals concentrations were significantly greater in USEPA Subunit 1 (Table 4-14). For copper and arsenic, this spatial pattern was also observed among Be-7 bearing Phase I/II samples (Table 4-16). Unlike mercury, however, cadmium, nickel and silver concentrations were significantly greater in the historically disturbed subtidal flats (Table 4-12) and when controlling for aluminum, concentrations of several metals (i.e., copper, lead, methylmercury, nickel, and zinc) were significantly greater in the industrial waterfront (Table 4-12). Chromium was most elevated in USEPA Subunits 1 and 4 (Table 4-14); although, not significantly so when compared to the Bay-wide mean. Like mercury, mean concentrations of most other metals were greater within the USACE accumulation areas (Table 4-15). Exceptions were arsenic and selenium concentrations, which were not significantly different among USACE accumulation areas (Table 4-15). Subsurface patterns of other metal COPCs were also similar to those of mercury. At depths less than 6.5 feet, median metals concentrations increase with depth in the historically disturbed subtidal flats and industrial waterfront geomorphic areas (Figures F-54 through F-64 in Appendix F). In the subtidal flats, metals concentrations decrease below 3.5 feet. At depths less than 6.5 feet, median metals concentrations increase with depth in USEPA Subunits 1, 4, and 5 and in the USACE accumulation areas (Figures F-170 through F-180 in Appendix F).

Methyl mercury was only measured in surface sediments in the Phase III programs. Methyl mercury concentrations were more than three orders of magnitude lower than mercury concentrations in surface sediment (Table 4-13). Mean methyl mercury concentration was lowest in subtidal flats (Table 4-12). No other spatial comparisons were significant. Surface sediment concentration maps (Figures F-25 through F-35) and boxplots by spatial unit and depth for all metals can be found on Figures F-112 through F-122 in Appendix F.

4.3.3.7 Summary of COPC Spatial Distribution

Based on Phase III samples, mean surface sediment concentrations for several COPCs (i.e., 2,3,7,8-TCDD, PCBs, total alpha + gamma chlordane, cis-nonachlor, dieldrin, BEHP, cadmium, nickel and silver) are greater in the historically disturbed subtidal flats compared to the subtidal flats and the Bay-wide means (Table 4-12). USEPA Subunit 1 in the southern Bay has the highest mean surface concentrations for PCBs, total DDx (4,4'), hexachlorobenzene, TPH, and most metals (arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc). USEPA Subunit 4 has the highest mean surface sediment concentrations for 2,3,7,8-TCDD and chlordanes (Table 4-14). Most COPCs have greater mean concentrations within USACE accumulations areas; although, comparisons are not always statistically significant (Table 4-15).

Based on Phase I/II surface samples in which Be-7 was measured, samples with recent deposition (i.e., Be-7 $\geq$ 0.5 pCi/g) had significantly greater mean concentrations for 2,3,7,8-TCDD, total PCB congeners, nickel, and silver; however, this comparison is potentially confounded by the fact that surface sediment samples from areas with low deposition (e.g., subtidal flats) could contain a significant proportion of historically deposited material with much higher concentrations than in recently deposited sediments. In fact, among navigation channel samples, where recently deposited sediments are likely to contain greater thicknesses of more recently deposited material, Be-7 bearing samples tended to have lower concentrations than non-Be-7 bearing samples, but the comparison was only significant for mercury (Table 4-16). ANCOVA models were not significant (Table 4-16). Among Be-7 bearing samples, higher concentrations were observed in the northern part of the NBSA for 2,3,7,8-TCDD and PAHs (Table 4-16) whereas for total DDx (4,4'), arsenic, and copper, higher concentrations were observed in the southern part of the NBSA. These spatial patterns are similar to those observed for Phase III samples although Phase III PAH comparisons were not significant. Trends in Be-7 bearing samples are further discussed in Section 5.5.2.

At depths less than 6.5 feet, median subsurface concentrations for all COPCs increase with depth in the historically disturbed subtidal flats. Median concentrations also increase with depth in the industrial waterfront area for PCBs, total DDx (4,4'), PAHs, TPH, BEHP, and metals. Median COPC concentrations tend to decrease with depth in the subtidal flats. At depths less than 6.5 feet, median concentrations of most COPCs increase with depth in USEPA Subunits 1, 4, and 5 and in the USACE accumulation areas. One exception is that median PCB congener concentrations do not increase with depth in USEPA Subunit 1 (Figure 4-12).

It should be noted that future proposed dredging may change current patterns of contamination locally in the NBSA. The proposed harbor deepening project is expected to increase the federal navigational channel (south of Port Elizabeth) to a depth of -55 feet MLLW and also widen the channel (USACE 2020). Based on the USACE 2006 investigation, the proposed widening of the channel may affect previously identified high net depositional areas both east and west of the channel. Section 5.7.6 discusses the areas potentially impacted by this project.

4.3.3.8 Station-Specific Observations and Comparison of NBSA COPC Concentrations to Urban Reference

This section examines the NBSA surface sediment chemistry data from a station-specific perspective, with the goal of documenting observed patterns in elevated chemistry on a more localized scale, and identifying areas of the NBSA that will require more examination with respect to fate and transport (i.e., Section 5) and risk assessment (BHHRA, BERA, Section 6). In addition, a discussion on the concentrations of contaminants in the NBSA sediments relative to concentrations considered urban reference for the NY/NJ Harbor Estuary is presented. The latter is based on recent sediment chemistry data collected between 2008 and 2013 in Jamaica Bay as part of USEPA's REMAP program. Jamaica Bay is considered by USEPA to be the least impacted area in the Harbor Estuary, with very limited potential influence from legacy CERCLA sites within the embayment. This area was used as the marine/estuarine urban reference location for the LPRSA RI as well.

4.3.3.8.1 Station-Specific Observations

As part of SQT analyses conducted for the BERA, a PCA was conducted using all Phase III sediment data to evaluate the co-occurrence of COPCs in surface sediments for the Phase III sampling locations. As detailed in the BERA, the PCA was conducted on a subset of chemicals potentially related to observed sediment toxicity in support of dose-response modeling. While there is some variability in the spatial distribution of COPCs as described in Section 4.3.3, COPC concentrations tend to be highly correlated and the first principal component explains 67% of the variance of all COPC concentrations. Therefore, individual scores on the first principal component can be used to examine which locations tend to have the highest concentrations overall of all the COPCs.

The resulting PCA scores are depicted in Figure 4-27[32]. As described in the BERA (GSH 2020), stations with scores greater than 5 (i.e., 21 stations colored pink on the figure) were predicted to exhibit acute toxicity by the dose-response model of 10-day amphipod survival. These stations occur primarily in the southwestern and southern shoreline areas of the NBSA, in addition to a few in the northeast subtidal flats.

Table 4-17 depicts 29 sampling locations in the NBSA where at least 10 of the COPCs had concentrations in the top 10th percentile of the NBSA-wide concentrations for Phase III data only. These stations are labelled on Figure 4-27. The majority of these stations are located in the southwestern and southern shoreline areas. The remaining seven are located in the northern part of the NBSA. These stations coincide with the areas with the highest PCA scores and all of them have scores greater than 4.3. (Figure 4-27). These stations also tend to coincide with areas of finer-grained sediments (Figure 3-6), which is consistent with the correlation findings described in Section 4.3.

These findings are consistent with the spatial patterns noted in Section 4.3.3 for individual chemicals in that many (e.g., metals, total DDx (2,4' and 4,4') and total DDx (4,4'), hexachlorobenzene, and TPH) had the highest mean concentrations in the southern portion of the NBSA (i.e., USEPA Subunit 1) while a few others (e.g., 2,3,7,8-TCDD, dieldrin, chlordane) had the highest mean concentrations in the northern part of the NBSA (i.e., USEPA Subunit 4). While not significant, total PCB congeners were most elevated in USEPA Subunits 1 and 4 (Table 4-14). The stations with the highest PCA scores tend to be found within USEPA Subunits 1, 4, and 6.

In addition, sediment toxicity results based on 10- and 28-day survival for the amphipod *Leptocheirus plumulosus* were mapped as part of the BERA (Figure 4-28). The two locations exhibiting both acute (i.e., 10-day mortality) and chronic (28-day mortality) toxicity (i.e., stations 151 and 154) were located near the shoreline in Newark Bay South. Four additional locations in Newark Bay North and Central exhibited chronic toxicity. Based on the benthic index of biotic integrity (B-IBI) assessed in the BERA, the only station considered impacted (i.e., 148) was also found along the shoreline in Newark Bay South (Figure 4-29); although, this station did not exhibit either acute or chronic survival effects (Figure 4-28). Slightly impacted stations were found throughout the Bay, though more frequently in the north and south, generally in the areas with the most elevated contamination. The two acutely toxic stations (i.e., stations 151 and 154) were classified as slightly impacted by the B-IBI evaluation (Figure 4-29).

[32] Note that the dredged navigation channels are not represented as only composite surface sediment samples were collected in this area.

4.3.3.8.2 Comparison of NBSA Surface Sediment to Urban Reference

The NBSA surface sediment data were compared to the urban reference concentrations measured in nearby Jamaica Bay (Figure 2-12). Jamaica Bay was used as one of the reference comparisons in the LPRSA (OU4). Jamaica Bay data are being evaluated in the RI because Jamaica Bay is physically similar to the open water habitats of the NBSA and is considered less influenced by point sources of contamination. However, while the USEPA considers Jamaica Bay a NY/NJ Harbor Estuary reference dataset for comparison, they do not consider it to be background data for the NBSA.

Qualitative comparisons can be made between NBSA Phase III data collected between 2014 and 2016 and the most recent Jamaica Bay surface sediment data collected as part of REMAP (2008 and 2013) (Table 4-18). Surface sediment concentrations of metals, PCDDs/PCDFs (2013 only), PCBs (Aroclors only), pesticides, and PAHs were analyzed in both REMAP sampling programs. Samples were collected from 0 to 6 inches during Phase III sampling and from 0 to 2 cm (0.8 inches) in REMAP sampling. The difference in sampling depths is an important limitation of the comparison because the depth horizon could influence the magnitude of the measured concentration and introduce significant uncertainty. The mean metals concentrations were 1.1 (silver) to 7.2 (mercury) times greater in the NBSA than in Jamaica Bay, with many exceedances of the upper 95th percentile of the Jamaica Bay concentrations noted (Table 4-18). The mean 2,3,7,8-TCDD concentration in the NBSA is 85 times greater than the Jamaica Bay mean (Table 4-18). Total Aroclor PCBs were infrequently detected in Jamaica Bay; however, 90% of the NBSA concentrations exceeded the Jamaica Bay maximum. Pesticides were infrequently detected in Jamaica Bay. The detection limits for the Jamaica Bay sediment samples (Method 8081) tended to be greater than those in the Phase III data (Method 1699), making comparison difficult. Mean total DDx (4,4') in the NBSA is more than three times the maximum detected value in Jamaica Bay and 51 times greater than the mean in Jamaica Bay (Table 4-18). Total PAHs (total HMW, total LMW, and total) are elevated in the NBSA compared to Jamaica Bay, with ratios of means ranging from 25 to 30. Eighty-five to 88% of Phase III total PAH concentrations exceed the 95th percentile of the Jamaica Bay concentrations (Table 4-18). It should be recognized that these comparisons, as with any reference assessment, could be misleading for constituent concentrations that may reflect the impact of a localized source in Jamaica Bay that is not present in the Bay.

The results of this analysis help to provide some perspective on the COPCs in Newark Bay in terms of distinguishing those that are comparable to urban reference areas for the NY/NJ Harbor Estuary (e.g., silver), versus those that are clearly elevated in the NBSA. While somewhat limited in its overall usefulness due to analytical limitations of the REMAP Jamaica Bay dataset identified above for many COPCs, this information can be used as a LOE to inform decision-making regarding risk management and remediation options.

4.4 Surface Water

Surface water in the NBSA and tributaries was monitored in 2011, 2012, and 2013, with samples collected and analyzed for typical water quality parameters, as well as COPC concentrations (AECOM 2010, 2011, 2019b). Sampling locations are shown on Figure 2-10. Summary statistics for COPC analytical results at all NBSA locations are presented in Table 4-19. Statistics by depth, sampling event, location, and tidal phase at all NBSA locations are presented in Appendix G. Boxplots by sample station, sampling event, tidal cycle, and depth at NBSA stations are provided in Appendix H (Figures H-1 through H-37).

Scatterplots of concentration versus total suspended solids (TSS) concentration at NBSA stations are provided in Appendix H (Figures H-38 through H-44).

Of the NBSA COPCs, TPH was not analyzed in surface water samples. Concentrations of organic and metals COPCs were below their respective New Jersey Surface Water Quality Criteria (SWQC; as available for saline water) for aquatic life (Table 4-19). An exception was an exceedance for 1 out of 158 dieldrin samples. Total copper, but not dissolved copper, exceeded the criterion for dissolved copper in 8 of 274 samples. For total DDx (4,4'), there is no SWQC for aquatic life however, when compared to the criterion for 4,4'-DDT, there are 38 exceedances out of 157 samples.

Mean concentrations of arsenic, 2,3,7,8-TCDD, total PCBs, chlordane, dieldrin, DDT metabolites (4,4'-DDE and 4,4'-DDD), heptachlor epoxide, and cis-nonachlor exceed human health SWQC, which are based on the consumption of fish. Individual exceedances of the human health SWQC for other COPCs were observed (i.e., 4,4'-DDT, hexachlorobenzene, BEHP, and mercury). All detected concentrations (i.e., 84 of 233) of 2,3,7,8-TCDD exceeded human health SWQC. The remaining 149 samples were non-detect; however, because the detection limits were above the value of the criteria[33], many of these non-detect samples likely exceed the human health criteria as well. The actual exposure risks from fish consumption in the NBSA are evaluated in the BHHRA (GSH 2019b) and summarized in Section 6.

Box plots showing surface water results for selected COPCs grouped by sample station and depth within the NBSA as well as within the LPR and the Kill Van Kull are shown in Figures 4-30 through 4-34. The stations are arranged from upstream to downstream (and exclude the Hackensack River station which is outside the NBSA boundary). Summary statistics for all COPCs by NBSA station and tributary are given in Table 4-20. The summary statistics include all data collected regardless of depth, event, or tidal cycle. An examination of the box plots indicates a decreasing trend from the LPR into Newark Bay for all COPCs shown (i.e., 2,3,7,8-TCDD, total PCB congeners, total DDx (4,4'), total PAHs and mercury). This trend is most pronounced in the samples collected near the sediment surface (i.e., "Below Surface"), which is expected given that a higher sediment load is expected in the deeper samples.

Within the NBSA higher concentrations of the following COPCs were observed at the northern stations compared to the southern stations (Table 4-20 and listed figures): 2,3,7,8-TCDD (Figures 4-30 and H-1); total PCB congeners (Figures 4-31 and H-2); total PAHs (Figures 4-33 and H-14); mercury (Figures 4-34 and H-28); total alpha + gamma chlordane (Figure H-9); and chromium (Figure H-21). For total DDx (4,4'), the highest concentrations within the NBSA were observed at station NB ARK at the mouth of the Arthur Kill (Figures 4-32 and H-4; Table 4-20). No significant temporal trend or tidal cycle influence was observed in the surface water results for most COPCs except for arsenic (Figure H-16), nickel (Figure H-30), and total alpha + gamma chlordane (Figure H-9), all of which showed a decline between 2011 and 2013. Additionally, within the NBSA, COPC concentrations were similar in depth-discrete samples collected at and below the surface (Figures 4-30 through 4-34; Appendix G, Table G-1; Appendix H, Figures H-1 through H-37). This finding differs from surface water observations in the LPR where the estuarine

[33] It was acknowledged in the approved Quality Assurance Project Plan/Field Sampling Plan Addendum (QAPP/FSP Addendum; AECOM 2011) that it would not be possible to achieve a detection limit in surface water as low as the human health criteria (i.e., 0.0051 pg/L) in the small volume program. The lowest achievable laboratory estimated detection limit reported in the QAPP/FSP Addendum (1.2 pg/L) was achieved; however, subsequent laboratory dilution and extract splits caused the estimated detection limit to double to 2.4 pg/L in 6 of the 233 samples collected at NBSA stations, potentially impacting the number of detected results.

turbidity maximum can cause higher suspended solids and higher contaminant concentrations in the bottom interval of the water column (Figures 4-30 through 4-34). Note that the box plot results for 2,3,7,8-TCDD (particularly within the NBSA), beta-BHC, BEHP, hexachlorobenzene, and selenium should be interpreted with caution due to the low FOD.

Scatter plots of COPC concentrations versus TSS are shown in Appendix H (Figures H-38 through H-44) along with Spearman rank correlation coefficients. Concentrations of the following COPCs were significantly positively correlated with TSS: 2,3,7,8-TCDD, total PCB congeners, total DDx (2,4' and 4,4'), total DDx (4,4'), cis-nonachlor, total PAHs, total LMW PAHs, total HMW PAHs, arsenic, cadmium, chromium, copper, lead, mercury, methylmercury, nickel, silver, and zinc. The following COPCs were not significantly correlated with TSS with the magnitude of the insignificant correlation given in parentheses: alpha-BHC (-0.08), beta-BHC (0.07), dieldrin (-0.09), total alpha + gamma chlordane (0.14), hexachlorbenzene (0.08), and BEHP (-0.05). Heptachlor epoxide was significantly negatively correlated with TSS.

As a first approximation, estimates of the COPC concentrations in water column solids were made by dividing total surface water concentrations by the suspended solids concentrations (Table 4-21). For metals, dissolved concentrations were first subtracted from total concentrations before dividing by the suspended solids concentrations. (Dissolved concentrations were not measured for organic compounds). The summary statistics in Table 4-21 include all data collected regardless of depth, event, or tidal cycle. Again, some spatial patterns are noted. The LPR has the highest solid-phase (partitioned onto suspended solids) concentrations for most organic COPCs including 2,3,7,8-TCDD, total PCBs, PAHs, and some pesticides (i.e., heptachlor epoxide and chlordanes), which is consistent with the trend observed in water concentrations. In contrast, the NBSA station near the mouth of the Arthur Kill has the highest solid-phase concentrations of total DDx (2,4' and 4,4') and total DDx (4,4') (Table 4-21). This suggests that the apparent decreasing trend in water concentrations of DDx from the LPR into the NBSA (Figure 4-32) is driven by higher concentrations of suspended solids in the LPR rather than higher concentrations of DDx within those suspended solids. Both the LPR and the Hackensack River have the highest solid-phase concentrations of mercury.

In 2012 and 2013, a high volume surface water sampling program was conducted (AECOM 2019a). Sampling took place during two events at a subset of the surface water sampling locations (Figure 2-10) for the analysis of PCDDs/PCDFs, PCB congeners and suspended solids. Large volumes of water were collected over a period of hours and then filtered in a three-step process. The objective was to characterize concentrations on the separated solids and dissolved phase fractions, and among other things achieve lower detection limits than were possible in the small volume program. The data are summarized in Table 4-22. Based on the measured concentrations in the filtered solids and the filtrate sorption media (i.e., the captured dissolved fraction), along with the total volume collected and filtered, total, dissolved, and solid-phase concentrations for dioxins and PCBs in the water column can be estimated (Table 4-22). Concentrations of 2,3,7,8-TCDD in water and solids were greatest in the LPR samples (Table 4-22). The dissolved concentration was, on average, 5% of the total water concentration reflecting the low solubility of 2,3,7,8-TCDD. The northernmost NBSA station had higher 2,3,7,8-TCDD concentrations than the other NBSA stations. The Kill Van Kull samples had the lowest 2,3,7,8-TCDD concentrations. The Kill Van Kull samples were collected only during the incoming tidal cycle and therefore reflect solid-phase concentrations entering the NBSA from this tributary. For PCBs, spatial patterns were less distinct. The highest concentrations were noted in samples from the first event at River

mile 4.2 followed by the northernmost NBSA location. The remaining samples had similar ranges of water and solids PCB concentrations even in the Kill Van Kull. Dissolved PCBs make up approximately 26% on average of the total water concentration.

Estimates of solid phase concentrations (Tables 4-21 and 4-22) can be compared to the concentrations of recently deposited sediments in the navigation channel (Table 4-16) to determine if those sediments reflect the concentrations of depositing solids. Concentrations of 2,3,7,8-TCDD in the solid-phase are best estimated by the high volume program (Table 4-22) rather than the small volume program, which had low detection frequency. Solids concentrations ranged from 11.6 to 157 ng/kg (average 52 ng/kg) and are similar to the average concentration of Be-7 bearing sediment samples in the navigation channel (51.7 ng/kg; Table 4-16).

Solid-phase concentrations for PCBs can be estimated from either program. Concentrations measured in the high volume program ranged from 53,000 to 883,000 ng/kg (average 366,000 ng/kg; Table 4-22). Concentrations in the small volume program average 554,000 ng/kg (Table 4-21). These estimates are similar to the average concentration of Be-7 bearing sediment samples in the navigation channel (534,000 ng/kg; Table 4-16).

Other COPCs can only be estimated by the small volume program (Table 4-21). Average solid-phase concentrations of total DDx (4,4') range from 59,500 to 131,000 picograms per gram (pg/g) at NBSA stations. The average concentration of Be-7 bearing channel samples is 106,000 pg/g, which is within the range of potential depositing solids. Average solid-phase mercury concentrations range from 917 to 1,520 µg/kg in the NBSA while the average of Be-7 bearing sediments is 1,500 µg/kg.

Average solid-phase and Be-7 bearing sediment concentrations are similar for other COCs such as total PAHs (14,300 and 14,000 µg/kg), arsenic (18 and 11.7 mg/kg), lead (109 and 109 mg/kg), and nickel (23.9 and 32.7 mg/kg).

Therefore, Be-7 bearing channel samples are useful for characterizing recently-deposited material. These trends are further demonstrated in the Bay mile plots of Be-7 bearing surface sediment, and particulate concentrations discussed in Section 5.5.2.

4.5 Porewater

Table 4-23 presents summary statistics (including number of detections, minimum and maximum concentrations, mean and median concentrations, and standard deviations) for the COPCs analyzed in porewater, which included PCDDs/PCDFs, PCB congeners, pesticides, PAHs, and metals. A majority of metal COPCs (arsenic, cadmium, copper, lead, nickel, selenium, silver, and zinc) were characterized by either low FOD or no detection. For metals, the low FOD in the porewater (or low bioavailability) is likely due to the tendency of metals to exist as metal-sulfide solids. Acid volatile sulfide (AVS) and simultaneously extracted metals (SEM) data from the NBSA suggest that divalent metals (i.e., cadmium, copper, lead, nickel, and zinc) are likely bound to the sediments (see further discussion in Section 5.6.3). Because the sediment geochemistry was maintained during the porewater laboratory study, these metals remained bound as sulfide solids and were not detected in the porewater. Pesticides alpha-BHC and beta-BHC also exhibited low or no detection; however, most of the remaining organic COPCs had a high FOD (Table 4-23).

The porewater data were used to assess the risk of COPCs to the benthic invertebrate community that comprise organisms exposed to the freely dissolved contaminants in porewater. A detailed evaluation of the porewater data is presented as part of the SQT assessment in the BERA (GSH 2020). Part of this evaluation included a comparison of porewater concentrations to New Jersey saline water quality criteria (WQC) for aquatic life or, where WQC were not available, to surface water screening values from literature (Buchman 2008). WQC or screening values were available for all detected porewater compounds except barium, manganese, titanium, and vanadium. Based on this comparison, the following number of exceedances (out of 30 porewater samples) of chronic WQC were observed: total DDx (4,4') (14), total PCBs (3), arsenic (3), copper (3), and zinc (3). The following number of exceedances of acute WQC were observed: arsenic (1), copper (1), and zinc (3). No other exceedances of WQC or screening values were observed. Although fully detected in porewater, 2,3,7,8-TCDD did not exceed the chronic screening value from the literature (i.e., 10 pg/L). These porewater data are also useful for the evaluation of partition coefficients for organic chemicals in sediment based on their freely dissolved concentration in porewater.

As described in Section 2.1.3.5, porewater concentrations were measured ex-situ in the laboratory using passive samplers exposed to collected sediments. For metals and other analytes (i.e., mercury, methyl mercury, dissolved OC, ammonia, and total sulfide), large-volume (0.5 liter) diffusion bags were used to capture porewater for direct analysis. The diffusion bags were placed in the sediment and allowed to equilibrate for a period of two weeks. Methods used for analysis of organic compounds are subject to more uncertainty. Concentrations of organic compounds were obtained using polyethylene (PE) and polyoxymethylene (POM) passive samplers. The PE passive samplers, loaded with performance reference compounds (PRCs), were used to determine the freely dissolved porewater concentrations of PCBs, PAHs, and pesticides. POM passive samplers (without PRCs) were used to measure freely dissolved concentrations of PCDDs/PCDFs.[34] Following exposure to sediment, the PE and POM samplers were transferred to the analytical laboratories where the target organic compounds were extracted in solvent (acetone/hexane [1:1 by volume]) and the concentrations in final extracts were measured. Porewater concentrations were estimated using the laboratory-reported concentrations in the PE/POM extracts as described by Ghosh et al. (2014). A simple mass balance calculation is used to convert extract concentrations to concentrations within the PE/POM. Then the porewater concentration is estimated as the ratio of the PE/POM concentration and a literature derived polymer-water partition coefficient (K_{PS}). PE samplers were tumbled for eight weeks. The PRCs were used to assess the extent of equilibrium achieved during the period that the samplers were in contact with the sediment. Some of the strongly hydrophobic compounds, in particular, the higher chlorinated PCB congeners, did not achieve equilibrium during the period of contact. Therefore, a mathematical correction was performed to calculate the true equilibrium concentrations (Fernandez et al. 2009). Uncertainty in the porewater concentrations arises from the fact that the source of the K_{PS} values are regression relationships derived in other experimental studies with these samplers (Ghosh et al. 2014; Choi et al. 2013; Fernandez et al. 2012; Cornelissen et al. 2008). Another source of uncertainty for the PCDD/PCDF concentrations is that PRCs were not used in the POM samplers and therefore no equilibrium corrections were made. PCDD/PCDF concentrations may be biased low; however, if non-equilibrium occurred, this bias is more likely to have occurred in the higher chlorinated (and less toxic) PCDD/PCDF congeners than in the lower chlorinated congeners such as

[34] At the time of this study, the only reliable polymer partition coefficients that were available for PCDDs/PCDFs were from the work by Cornelissen et al. (2008). PRC impregnation and correction were not performed for POM as Cornelissen et al. (2008) did not use PRC correction.

2,3,7,8-TCDD. For PCBs, non-equilibrium occurred infrequently and only among the higher chlorinated congeners (i.e., hexa-, hepta-,octa-, nona-, and deca-chlorinated congeners).

The uncertainty of K_{PS} values is further described in USEPA's passive sampling user's manual (USEPA/SERDP/ESTCP 2017). Estimated values of K_{PS} are expected to be accurate within 0.3 log units (i.e., a factor of 2) even for highly hydrophobic compounds. The resulting error is similar to those for other environmental partition coefficients. Therefore, porewater concentrations could be as much as two times greater or lower than the calculated values presented for organic compounds in Table 4-23.

The similar concentrations of total and methyl mercury in porewater (Table 4-23) indicate that close to 100% of the mercury in porewater is present in the methylated form. Studies elsewhere have documented varying levels of percent methyl mercury in porewater and high percentages have also been observed in other estuarine sediments. In the Gulf of Trieste (Adriatic Sea), about 23% of total mercury in porewater was measured to be methyl mercury (Covelli et al. 1999). At a moderately contaminated estuary in Texas, methyl mercury comprised approximately 75% of total mercury in porewater from the upper 3 cm of the sediment, and about 35% of total mercury in porewater at deeper depths (4 to 12 cm) (Bloom and Lasorsa 1999). In four contaminated estuarine sediments, the percent methyl mercury of total mercury in porewater ranged from less than 5% to close to 100% (Gilmour et al. 2013).

4.6 Biota Tissue

Biota sampling was conducted as part of sampling activities for the baseline human health and ecological risk assessments (BHHRA/BERA) and were collectively used to support the BHHRA by estimating potential human exposures and assessing the potential impact of COPCs on human health via consumption of fish and shellfish from the NBSA, and as input parameters to a food web model to evaluate bioaccumulation-based risks to fish, shellfish, and wildlife in the BERA.

The purpose of this section is to characterize the nature and extent of the COPCs in biota and is limited to that scope. This section summarizes the COPC results for biota (shellfish and fish) tissue samples collected from the NBSA and discusses general spatial trends by the assessment zones evaluated in the BERA (i.e., North, Southeast, and Southwest Zones). The BERA assessment zones are shown on Figure 4-35. The number of biota samples collected in each assessment zone are provided in Table 4-24. This section also includes an evaluation of the influence of lipid content in biota tissues on observed differences in concentrations of organic COPCs. The use of the biota data in support of the BHHRA and BERA are discussed in Section 6.

Table 4-24. Number of Target Biota Samples Analyzed by BERA Assessment Zone

Group	Species	Tissue Type	NBSA BERA Assessment Zone			Total
			North	Southeast	Southwest	
Invertebrate	Softshell Clam	Whole Body	8	4	6	18
Invertebrate	Blue Crab	Whole Body[a]	12	13	12	37
Sport Fish	American Eel	Whole Body	6	6	6	18
Sport Fish	American Eel	Fillet	6	6	6	18
Sport Fish	Bluefish	Fillet	3	13	2	18
Sport Fish	Striped bass	Fillet	0	0	18	18
Sport Fish	Summer Flounder	Whole Body	2	2	4	8
Sport Fish	Summer Flounder	Fillet	6	6	6	18
Sport Fish	Winter Flounder	Whole Body	4	4	2	10
Sport Fish	White Perch	Whole Body	9	9	9	27
Sport Fish	White Perch	Fillet	6	6	6	18
Sport Fish	White Perch	Liver	3	3	5	11
Forage Fish	Atlantic Menhaden	Whole Body	2	0	0	2
Forage Fish	Atlantic Silverside	Whole Body	1	3	3	7
Forage Fish	*Fundulus spp.*[b]	Whole Body	8	3	6	17

Notes:
[a] Muscle, carcass and hepatopancreas were analyzed separately.
[b] Fundulus spp. includes mummichog and striped killifish.

Given the general open water habitat of the system, and the fact that the biota in the Bay are primarily migratory in their life histories, discerning statistical trends on a broad geographic scale is most relevant. In addition, while it is likely that migratory fish have some background level of contamination in their tissues related to integrated exposures that occur while they are outside Newark Bay, the assumption for this characterization is that their residence time in the NBSA on an annual basis is sufficient for these organisms to achieve an equilibrium with respect to uptake of the primary COPCs in the system.

Sections 4.6.1, 4.6.2, and 4.6.3 summarize softshell clam (*Mya arenaria*), blue crab (*Callinectes sapidus*), and fish (various species) sampling data, respectively, focusing on observed concentrations and analyses of broad spatial trends.

4.6.1 Softshell Clam

Softshell clam tissue samples were collected in the NBSA in the late summer/early fall of 2014 as part of sampling activities for the BHHRA/BERA and in accordance with the Crab and Clam Sampling and Analysis Quality Assurance Project Plan (Crab and Clam QAPP) (Tierra 2014a).

Softshell clams were collected from September 8, 2014 through October 2, 2014 from 18 intertidal areas throughout the NBSA by manual digging using a stainless steel spade. Tissue samples were composited at each individual location from several clams (Figure 2-3). Table 4-24 summarizes the number of clam tissue samples collected by zone in the NBSA.

The results from the analysis of the COPCs from softshell clam samples are summarized below. In addition, organic COPC results were lipid-normalized by dividing the individual analytical result reported by the laboratory for a given sample by the percent lipid value reported for the same sample.

Table 4-25 presents the statistical summary of softshell clam samples by assessment zone, both in wet weight and normalized to percent lipids. Box plots of COPC concentrations are provided in Appendix I (Figures I-1 through I-43); however, because there were an insufficient number of clam samples, the box plot and associated statistics were only generated for the clams located in the BERA North Zone. For the Southeast and Southwest Zones, the few available clam samples are plotted as points. For organic compounds both wet weight (Figures I-1 through I-16) and lipid-normalized concentrations (Figures I-28 through I-43) are presented.

A qualitative comparison of COPC concentrations in softshell clam samples shows that, in general, concentrations were similar among assessment zones; however, some spatial patterns were noted. The mean 2,3,7,8-TCDD concentration was highest in the North Zone (Table 4-25). The maximum concentration (13.4 ng/kg) is an apparent outlier as shown on the boxplot (Figure I-1 in Appendix I) and was measured at location 133 (Figure 2-3) located in the northern Bay west of the navigation channel. The mean concentrations of total PCBs and total DDx (2,4' and 4,4') are highest in the Southwest Zone (Table 4-25). The highest mean concentrations of some metals (i.e., copper, lead, and zinc) were observed in the Southwest Zone (Table 4-25). The highest mean mercury concentration was observed in the North Zone (Table 4-25) and the apparent outlier shown on the boxplot (Figure I-22 in Appendix I) was measured at location 133, the same location as the 2,3,7,8-TCDD outlier.

Scatter plots depict the relationship between the organic COPC concentrations and lipid content (Figures I-44 through I-47 in Appendix I). Included in each plot are the results of the Spearman Rank Correlation test (if applicable). Statistically significant correlations were not observed among organic COPCs and lipid content, except for total DDx (2,4' and 4,4') and total DDx (4,4'), which showed weak but significant positive correlations between concentration and lipid content. While many organic compounds are expected to be associated with the lipid fraction in biota, the lipid fraction in softshell clam is low (<0.5%) and does not vary much (Table 4-25), making these relationships difficult to detect.

When the softshell clam concentrations are normalized to lipid content, similar trends in concentration are observed, generally higher lipid-normalized dioxin concentrations in the North Zone and higher pesticides in the Southwest Zone (Table 4-25).

4.6.2 Blue Crab

Blue crab tissue samples were collected in the NBSA in the late summer/early fall of 2014 as part of sampling activities for the BHHRA/BERA and in accordance with the Crab and Clam QAPP (Tierra 2014a).

From September 8, 2014 through October 23, 2014, blue crabs were collected from 37 locations throughout the Bay (Figure 2-3) using baited crab traps that were deployed from a boat and left overnight. Blue crabs were collected from September 8, 2014 through October 14, 2014 from 12 intertidal areas in the NBSA. Blue crabs were also collected from an additional 25 locations from October 6, 2014 through October 23, 2014 from the three assessment zones of Newark Bay: North Zone (eight locations), Southeast Zone (nine locations), and Southwest Zone (eight locations). Blue crab samples collected from

the zones represent a composite for each zone and do not have coordinate data associated with them. Table 4-24 summarizes the number of crab (whole body) tissue samples collected by assessment zone in the NBSA.

Blue crab tissue types (i.e., muscle, hepatopancreas, and carcass) were analyzed separately in each sample. Whole body crab concentrations were estimated using a weighted average of the concentrations of the individual tissue types in each sample as described in the BERA (GSH 2020). The weights used are based on the average fractional mass of each tissue type: 0.54 for muscle, 0.19 for hepatopancreas, and 0.27 for carcass. The edible portions of blue crab (i.e., muscle and hepatopancreas) were evaluated in the BHHRA (GSH 2019b) for the specific purpose of assessing potential human health risks from crab consumption. The findings are summarized in Section 6.

Statistical summaries of the COPCs in whole body crab are presented in Table 4-26. Box plots of COPC concentrations are provided in Appendix I (Figures I-48 through I-90). For organic compounds, both absolute (Figures I-48 through I-63) and lipid-normalized (Figures I-75 through I-90) concentrations are presented. Scatter plots and Spearman rank statistics depict the relationship between the organic COPC concentrations and lipid content (Appendix I; Figures I-91 through I-94).

One-way ANOVA was used to conduct a spatial comparison of COPC concentrations in whole body blue crab (Table 4-27). For organic compounds, an ANCOVA model was also tested by adding lipid content as a covariate to the model (Table 4-27). For several organic compounds (e.g., total DDx (2,4’ and 4,4’), total PAHs), the lipid covariate, while significantly correlated to concentration on its own, was not marginally significant when added to the model (indicating that assessment zone explains most of the variance) and therefore is not demonstrated as a useful covariate in the spatial comparison (see footnote c in Table 4-27). The Tukey-Kramer multiple comparison test was conducted for significant models (alpha = 0.05). An alphabetic letter indicates the order of mean concentrations for each COPC with A being the highest and C being the lowest (Table 4-27). Spatial groups that share a letter (e.g., AB versus A) are not significantly different. Comparison of the blue crab concentrations across assessment zones showed statistically significantly different mean concentrations for several metals (arsenic, mercury, and selenium), 2,3,7,8-TCDD, total PCB congeners, PAHs (HMW and total), and pesticides (total DDx (2,4’ and 4,4’), total alpha + gamma chlordane, beta-BHC, cis-nonachlor, dieldrin, heptachlor epoxide, and hexachlorobenzene) (Table 4-27). For organic compounds, the ANOVA and ANCOVA models were in agreement with respect to order and comparison of means, but not always significant (i.e., total HMW PAHs is significant for ANOVA but not ANCOVA). The highest concentrations were observed in the North Zone for 2,3,7,8-TCDD, total PCBs, pesticides (except total DDx (2,4’ and 4,4’)), PAHs, and mercury. Total DDx (2,4’ and 4,4’) and arsenic were highest in the Southwest Zone (Table 4-27). Most total LMW PAH results were below 75 µg/kg, but the Southeast Zone contained a result equal to 400 µg/kg. However, this extreme outlier did not result in a statistically significant difference in the spatial comparison for total LMW PAHs or total PAHs (Table 4-27). Due to low FOD among the sample populations, BEHP concentrations were not statistically evaluated.

With a few exceptions, weak to moderate positive correlations were observed among organics and lipid content (Appendix I). No statistically significant correlation was noted between lipid content and total Aroclor PCB, total DDx (2,4’ and 4,4’), total alpha + gamma chlordane, heptachlor epoxide, and total and LMW PAHs (Appendix I; Figures I-91 through I-94).

4.6.3 Fish

This section presents the results from the fish collection program conducted in the NBSA. The field investigation was conducted in three phases (fall 2014, spring/summer 2015, and spring 2016) as part of sampling activities for the BHHRA/BERA and in accordance with the Fish Sampling and Analysis Quality Assurance Project Plan (Tierra 2014b).

Fish were collected from various locations along the intertidal mudflats, subtidal flats, transitional slopes, and navigational channel throughout the NBSA (Figures 2-4 through 2-6). Fish were collected using seven different methods based on the targeted fish species and their associated habitats. Sampling methods/gear included trawling, gill nets, beach seines, eel pots, minnow traps, trotlines, and traditional angling. Fish were collected from each of the three assessment zones (North, Southeast, and Southwest Zones; Figure 4-35) to provide spatial coverage across the entire NBSA.

Overall, the three sampling events yielded 12,516 individual fish encompassing 44 individual fish species. Species of sport fish that were targeted and collected for tissue sampling include white perch (*Morone Americana*), winter flounder (*Pseudopleuronectes americanus*), summer flounder (*Paralichthys dentatus*), American eel (*Anguilla rostrate*), striped bass (*Morone saxatilis*), and bluefish (*Pomatomus saltatrix*). Additionally, forage fish were targeted and sampled including mummichog (*Fundulus heteroclitus*), striped killifish (*Fundulus majalis*), Atlantic menhaden (*Brevoortia tyrannus*), and bay anchovy (*Anchoa mitchilli*).

Additional details regarding the fish collected during these events are provided in the NBSA Environmental Sample Collection Report (Normandeau Associates, Inc. 2017) and in the BERA (GSH 2020). Table 4-24 summarizes the number of fish tissue samples collected by target species and assessment zone in the NBSA.

The discussion is broken down into two categories: sport fish (i.e., species that may be sought by recreational anglers) and forage fish (i.e., small species that make up the base of the food web for predatory fish and wildlife). Box plots of COPC concentrations in sport fish (by species) and forage fish by assessment zone are provided in Appendix I. For organic compounds, both absolute and lipid-normalized concentrations are presented. Scatter plots and Spearman rank statistics depict the relationship between the organic COPC concentrations in sport fish and forage fish and lipid content (Appendix I).

4.6.3.1 Sport Fish

Statistical summaries of the COPCs by species and tissue type (i.e., American eel, bluefish, striped bass, white perch, winter flounder, and summer flounder) are presented in Table 4-28. Samples of edible fillets of sport fish (i.e., American eel, bluefish, striped bass, summer flounder, and white perch) were evaluated in the BHHRA (GSH 2019b) to assess the potential human health risks from fish consumption. A limited number of white perch liver samples were collected to support the assessment of ecological risks in the BERA (GSH 2020). More detailed evaluations of the fish data by species and risk-based exposure areas are presented in the BERA (GSH 2020). Whole body sport fish samples were evaluated for spatial trends by assessment zone using linear modeling and graphical presentations (i.e., box plots) as discussed below. Box plots of COPC concentrations in whole body sport fish samples by assessment zone are provided in Appendix I (Figures I-95 through I-137).

One-way ANOVA was used to conduct spatial comparisons of COPC concentrations in whole body sport fish (Tables 4-29, 4-30, and 4-31). Winter and summer flounder results were combined for these analyses

(Table 4-30). For organic compounds, an ANCOVA model was also tested by adding lipid content as a covariate to the model (Tables 4-29, 4-30, and 4-31). The Tukey-Kramer multiple comparison test was conducted for significant models (alpha = 0.05). An alphabetic letter indicates the order of mean concentrations for each COPC, with “A” being the highest and “C” being the lowest (Tables 4-29, 4-30, and 4-31). Spatial groups that share a letter (e.g., AB versus A) are not significantly different.

For American eel, statistically significant differences among assessment zones were observed for 2,3,7,8-TCDD, some pesticides (heptachlor epoxide, hexachlorobenzene, total alpha + gamma chlordane and total DDx (2,4’ and 4,4’)), PAHs, and selenium (Table 4-29). For organic compounds, the ANCOVA models generally had a higher likelihood of significance. For 2,3,7,8-TCDD and pesticides (except total DDx (2,4’ and 4,4’)), concentrations were higher in the North Zone. For total DDx (2,4’ and 4,4’) and PAHs, the highest concentrations were in the Southwest Zone. Selenium was highest in the Southeast Zone. When added to the PAH models, the lipid content was not marginally significant indicating that the assessment zone explains most of the variance in PAH concentrations. Due to low FOD, concentrations of cadmium, chromium, nickel, silver, BEHP, and alkylated and HMW PAHs were not statistically evaluated.

Winter and summer flounder results were combined for statistical analysis. Mean 2,3,7,8-TCDD was significantly greater in the North Zone (Table 4-30). ANOVA and ANCOVA model results were in agreement; although lipid content was not marginally significant when added to the model, indicating that the assessment zone explains most of the variance in 2,3,7,8-TCDD concentrations. Statistical significance was not observed for other COPCs. Due to low FOD, concentrations of cadmium, nickel, silver, BEHP, and PAHs were not statistically evaluated. The low detection frequency for PAHs may be due to elevated detection limits (see Section 4.2.8); however, it is important to note that fish efficiently metabolize PAHs and therefore they are generally not detected at substantive levels in tissue.

For white perch, statistically significant differences were observed for 2,3,7,8-TCDD, total PCBs, some pesticides (alpha-BHC, beta-BHC, cis-nonachlor, dieldrin, hexachlorobenzene, total alpha + gamma chlordane, and total DDx (2,4’ and 4,4’)), PAHs, and some metals (arsenic, copper, lead, selenium, silver, and zinc) (Table 4-31). For organic compounds, the ANOVA and ANCOVA models were not always in agreement with respect to statistical significance. For 2,3,7,8-TCDD, PCBs, some pesticides (cis-nonachlor, hexachlorobenzene, and total alpha + gamma chlordane), and PAHs, concentrations were greater in the North assessment zone (Table 4-31). When lipid content is added to the PAH models, it is not marginally significant indicating that most of the variance is explained by assessment zone. For some pesticides (alpha-BHC, beta-BHC, dieldrin, and total DDx (2,4’ and 4,4’)) and some metals (arsenic, copper, selenium, and silver), the highest concentrations were in the Southwest Zone. Zinc and lead were lowest in the Southwest Zone. Due to low FOD, concentrations of cadmium, nickel, BEHP, and alkylated and HMW PAHs were not statistically evaluated. While most total LMW PAH results were $\leq$ 160 µg/kg, an extreme outlier in the North Zone white perch dataset had a value of 610 µg/kg (Appendix I; Figure I-109). This resulted in a mean concentration three to 10 times greater and a median three to nine times greater than those for the other two assessment zones (Table 4-31). However, even without this outlier, the mean/median concentrations in the North Zone, 105/110 µg/kg, are significantly greater than those for the other two assessment zones. Similarly, if this outlier is excluded from the total PAH dataset, where its value is 640 µg/kg, the resulting mean/median concentration in the North Zone (i.e., 109/110 µg/kg) is more than two times greater than those for the other assessment zones.

Except for total HMW PAHs, weak to moderate positive correlations were observed among all organic compounds and lipid content (Appendix I; Figures I-138 through I-141). The lack of a correlation between total HMW PAHs and lipid content can be attributed to the lower FOD for total HMW PAHs.

4.6.3.2 Forage Fish

Summary statistics for forage fish are presented by species in Table 4-32. Atlantic menhaden and Atlantic silverside are migratory forage fish found on a seasonal basis in the NBSA (GSH 2020). Species of the genus *Fundulus* (i.e., mummichog and striped killifish) are resident benthic species in the NBSA with small home ranges that would tend to reflect exposure in the vicinity of where they are caught. One-way ANOVA was used to conduct spatial comparisons of COPC concentrations in the pooled *Fundulus* data set (Table 4-33). For organic compounds, an ANCOVA model was also tested by adding lipid content as a covariate to the model (Table 4-33). The Tukey-Kramer multiple comparison test was conducted for significant models (alpha = 0.05). An alphabetic letter indicates the order of mean concentrations for each COPC, with “A” being the highest and “C” being the lowest (Table 4-33). Spatial groups that share a letter (e.g., AB versus A) are not significantly different. Statistically significant differences were observed for 2,3,7,8-TCDD, total PCBs, some pesticides (cis-nonachlor, dieldrin, and total DDx (2,4’ and 4,4’)), and mercury (Table 4-33). With a few exceptions, the ANOVA and ANCOVA models were in agreement with respect to statistical significance. When added to the models for 2,3,7,8-TCDD, dieldrin, and total DDx (2,4’ and 4,4’), lipid content was not marginally significant indicating that most of the variance is explained by the assessment zone. For 2,3,7,8-TCDD, PCBs, cis-nonachlor, and mercury, mean concentrations were greater in the North Zone (Table 4-33) while the mean total DDx (2,4’ and 4,4’) concentration was greater in the Southwest Zone. Due to low FOD, concentrations of cadmium, nickel, BEHP, and alkylated and HMW PAHs were not statistically evaluated.

The correlation between the COPC concentrations in forage fish and lipid content was statistically significant for PCBs and most pesticides (Figures I-142 through I-145) with the exception of hexachlorobenzene. Correlation coefficients for 2,3,7,8-TCDD (Figure I-142) and PAHs (Figure I-145) were not significant.

4.6.4 Biota Tissue Summary

There were some similarities among species with respect to the spatial distributions of some COPCs (e.g., 2,3,7,8-TCDD and total DDx (2,4’ and 4,4’)). However, spatial patterns were not consistent among species for all COPCs. Among all species, mean 2,3,7,8-TCDD concentrations were consistently higher in the North Zone (Figure 4-36) and were statistically significantly higher in all species tested (Tables 4-27, 4-29, 4-30, 4-31, and 4-33). Total PCBs in blue crab, flounder and white perch were highest in the North Zone (Figure 4-37), with blue crab and white perch being significantly higher (Tables 4-27 and 4-31). However, total PCBs in American eel, *Fundulus* (i.e., mummichog and striped killifish), and softshell clam were highest in the Southwest Zone (Figure 4-37); although, this observation was only statistically significant for *Fundulus* (Table 4-33). Patterns in pesticide concentrations varied by species. In blue crab, most pesticides (except total DDx (2,4’ and 4,4’)) were significantly higher in the North Zone (Table 4-27) whereas in white perch they tended to be higher in the Southwest Zone (Table 4-31). Among all species, except flounder, mean total DDx (2,4’ and 4,4’) concentrations were consistently higher in the Southwest Zone (Figure 4-38) and this observation was statistically significant for blue crab, American eel, white

perch and *Fundulus* (Tables 4-27, 4-29, 4-31, and 4-33, respectively). Except for white perch and flounder, mercury tended to be higher in the North Zone (Figure 4-39) and this observation was statistically significant in blue crab and *Fundulus* (Tables 4-27 and 4-33). Statistically significant differences for other metals were rarely observed; however, mean concentrations of arsenic, copper, selenium, and silver were significantly higher in the Southwest Zone for white perch (Table 4-31) and mean arsenic was significantly higher in the Southwest Zone for blue crab (Table 4-27). Patterns in total PAHs were variable, being significantly higher in the North and Southeast Zones in crab (Table 4-27); significantly higher in the Southwest Zone in American eel (Table 4-29) and significantly higher in the North Zone in white perch (Table 4-31).

4.7 Summary

The extensive sampling and activities that have been conducted under the three phases of RI have informed the assessment of the nature and extent of contamination in the NBSA. Contaminants detected in the NBSA include PCDDs/PCDFs, VOCs, SVOCs, Aroclor PCBs, congener PCBs and homologues, pesticides, chlorinated herbicides, TPH, metals, butyltins, and cyanide. Of these, COPCs were identified through the data screening and prioritized for a focused nature and extent discussion. In general, concentrations of PCBs, PAHs, chlorinated pesticides, PCDDs/PCDFs, and metals were more frequently detected across the various media.

Sediment data analyses include evaluation of temporal and spatial COPC concentration trends based on actual and normalized (using grain size, mineralogy, and TOC) data. For the spatial analysis, statistical evaluations were performed on data grouped by geomorphic areas and their further refinement as USEPA subunits, in addition to areas of long-term and recent deposition that span the boundaries of geomorphic areas and USEPA subunits. The statistical analyses of the data included ANOVA, ANCOVA, and multiple comparison testing. On a smaller scale, station-specific observations were assessed using PCA. These results were compared to actual sediment COPC concentrations and concentrations that would be expected based on urban reference (e.g., Jamaica Bay as discussed in Section 4.3.3.8). Finally, COPC concentrations as a function of depth were examined for trends, considering geomorphic, USEPA subunit, and deposition areas.

Sediment data show surface sediment COPC concentrations in the Bay are declining, but ongoing contaminant sources exist. In temporal comparisons of co-located samples, mean concentrations of most COPCs with the exception of arsenic and total alpha + gamma chlordane, have decreased from the Phase I/II to the Phase III sampling program. A separate temporal analysis, a two-way ANOVA of all surface sediment data, which controlled for spatial variability by USEPA subunits, suggested that the reduction in COPC concentrations were similar across the USEPA subunits and none of the COPCs exhibited significant increases in concentrations between Phase I/II and Phase III sampling when controlling for spatial variability. This second analysis, however, is subject to some uncertainty due the non-random design of the Phase I and II sample collection.

The metal COPCs were found to be statistically significantly ($p < 0.05$) correlated with aluminum, fines, and iron and the organic COPCs were significantly correlated with TOC.

Mean surface sediment concentrations for several COPCs (i.e., 2,3,7,8-TCDD, PCBs, chlordanes, dieldrin, BEHP, cadmium, nickel, and silver) are greater in the historically disturbed subtidal flats compared to the subtidal flats and the Bay-wide means; although, models were not always significant

when normalizing covariates (i.e., aluminum or TOC) are considered. USEPA Subunit 1 in the southern Bay has the highest mean surface concentrations for PCBs, DDx, hexachlorobenzene, TPH, and most metals (arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc). USEPA Subunit 4 has the highest mean surface sediment concentrations for 2,3,7,8-TCDD and chlordanes. Most COPCs have greater mean concentrations within USACE accumulations areas; although, comparisons are not always statistically significant. Areas with recent deposition had significantly greater mean concentrations for 2,3,7,8-TCDD, PCBs, nickel, and silver; although, not when normalizing covariates are added.

At depths less than 6.5 feet, median subsurface concentrations for all COPCs increase with depth in the historically disturbed subtidal flats. Median concentrations also increase with depth in the industrial waterfront area for PCBs, DDx, PAHs, TPH, BEHP, and metals. Median COPC concentrations tend to decrease with depth in the subtidal flats. At depths less than 6.5 feet, median concentrations of most COPCs increase with depth in USEPA Subunits 1, 4, and 5 and in the USACE accumulation areas.

The PCA illustrates the areas where the highest COPC concentrations are located. The majority of sample locations having at least 10 of the COPCs with concentrations in the top 10th percentile of the NBSA-wide concentrations (for Phase III data only) are located in the southwestern and southern shoreline areas. The remaining seven are located in the northern area of the NBSA. These locations tend to coincide with areas of finer-grained sediments. In addition, the sediment toxicity results based on 10- and 28-day survival for *Leptocheirus plumulosus* and the benthic index of biotic integrity assessed in the BERA showed the most impacted stations to be along the shoreline in Newark Bay South. These findings are consistent with the spatial evaluation of the surface sediment data, which demonstrates the highest mean concentrations of most COPCs being in the southern area of the NBSA.

Concentrations of metals and organic COPCs, with few exceptions, were below their respective New Jersey SWQC for aquatic life in saline waters. Total copper exceeded the dissolved copper criterion in eight of 274 samples, dieldrin exceeded its criterion in one of 158 samples, and total DDx (4,4') exceeded the criterion for 4,4'-DDT in 38 of 157 samples. Mean concentrations of 2,3,7,8-TCDD, total PCBs, several pesticides (dieldrin, heptachlor epoxide, chlordanes, 4,4'-DDD, and 4,4'-DDE) and arsenic exceeded human health SWQC which are based on fish consumption. While mean mercury concentration was below the human health criteria, individual concentrations in 17 out of 274 samples exceeded the criterion.

COPC concentrations were significantly correlated with the concentration of TSS. Surface water concentrations and concentrations associated with suspended solids concentrations for many COPCs (e.g., 2,3,7,8-TCDD, total PCBs, PAHs, chlordanes, DDx, and mercury) are greater in the LPR compared to the NBSA. DDx is also elevated in the Arthur Kill, which has the highest solids concentrations. Mercury is also elevated in the Hackensack River compared to the NBSA. Within the NBSA, marginally higher concentrations of some COPCs (i.e., 2,3,7,8-TCDD, PCBs, chlordanes, PAHs, chromium, and mercury) were observed at the northern stations than the southern stations and Arthur Kill.

Results of the high volume surface water sampling program indicate that 2,3,7,8-TCDD has higher water and solid-phase concentrations in the LPR compared to the NBSA and that the northern NBSA station had a higher concentration than the central and southern NBSA stations. Solids entering from the Kill Van Kull on the incoming tide had lower 2,3,7,8-TCDD concentrations than in the NBSA. For PCBs, spatial patterns were not particularly pronounced among the NBSA and tributaries.

Biota tissue data were evaluated to assess potential risks to human health and ecological receptors in the NBSA (under the BHHRA and BERA, respectively) and are further discussed in Section 6. All 29 COPCs

were detected in biota; although, some COPCs had low FODs. Some spatial patterns in COPCs were observed. COPC concentrations in softshell clam samples, while generally similar Bay-wide, were noted in a qualitative comparison to be higher in the North Zone for 2,3,7,8-TCDD and to be higher in the Southwest Zone for metals and other organic COPCs. For blue crab, a statistical comparison indicated that the highest concentrations were observed in the North Zone for 2,3,7,8-TCDD, total PCBs, PAHs, mercury, and most pesticides (except DDx). Total DDx (2,4' and 4,4') and arsenic were highest in the Southwest Zone. Statistical comparisons for species of sport fish (i.e., American eel, summer and winter flounder, and white perch) indicate that mean concentrations of 2,3,7,8-TCDD and some pesticides are generally greater in the North Zone, while mean total DDx (2,4' and 4,4') is greater in the Southwest Zone. Statistical comparisons of benthic forage fish (i.e., *Fundulus spp*.) indicate greater mean concentrations of 2,3,7,8-TCDD, PCBs, cis-nonachlor and mercury in the North Zone, while mean total DDx (2,4' and 4,4') is greater in the Southwest Zone. Concentrations of organic COPCs were correlated with lipid content in most biota samples.

5 FATE AND TRANSPORT OF CONSTITUENTS OF POTENTIAL CONCERN

The Bay is a complex system at the interface of oceanic and fluvial environments. Over time, multiple sources have contributed COPCs to the NBSA, resulting in COPC-impacted sediment in the Bay. Fate and transport processes affecting COPCs in the sediments have changed over time as the Bay has progressively been altered and deepened by navigational projects (e.g., ports, berths, channels, and associated infrastructure). An overview of the system is described here, before being discussed in further detail in Section 5.

Broad relatively shallow areas – including both subtidal and historically disturbed subtidal flats– comprising approximately 49% of the NBSA, and the navigational channels comprising approximately 31% of the NBSA, are the dominant environments. Fate and transport processes differ between these environments. The navigational channels are more depositional and are subject to periodic maintenance dredging and experience heavy ship traffic. The subtidal flats are subject to relatively slow rates of sedimentation and experience wind-wave and tidal forces. Historical deposits of impacted sediments remain in areas outside of the dredged navigational channels.

Spatial distributions of COPCs in the sediment bed reflect the urban and industrial history of the area, the geomorphology of the Bay, and proximity to the major inflow and outflow channels as well as proximity to past and present sources. Long-term dynamics of COPCs in sediments reflect external loading histories including source controls, the dredging and development history of the Bay, the storm event history, and natural recovery processes. Due to high tidal exchange volumes, large quantities of suspended sediments and their associated contaminants are exchanged between the NBSA and the major connecting waterways – the Passaic River, the Hackensack River, Arthur Kill, and Kill Van Kull.

Surface water concentrations of COPCs are influenced by COPC concentrations in water entering the NBSA from the tributaries, and by resuspension of sediments. Decline of surface water concentrations of COPCs depends on both reduction of external inputs (direct sources), and reduction of surface sediment COPC concentrations in the NBSA (through natural recovery processes, such as burial), with subsequent reduction of resuspension and dissolved phase flux and redistribution within the system. Declines of COPC levels in biota in the NBSA depends on decline of exposure concentrations of COPCs in the NBSA sediments and water column, but also on reductions in uptake of contaminants from areas outside of the NBSA due to migratory behavior and large habitat ranges of many species in the Bay.

This section summarizes CFT of organic and inorganic COPCs, identified through the data screening process presented in Section 4, and focuses on RI/FS modeling results for four representative COPCs as discussed in Section 5.1 below. The NBSA RI/FS model (described further in Section 5.4.7) provides a means to quantify fluxes of COPCs and plays an important role in describing the fate and transport of COPCs. A conceptual model of CFT is presented on Figure 5-CFT, which depicts the major physical, hydrodynamic, and sediment transport processes (previously described in Section 3).

5.1 NBSA RI/FS Model

The USEPA and other collaborators have developed a hydrodynamic, sediment transport, and CFT and bioaccumulation model system for the Bay estuary system. The focus of the modeling to this point was predominantly the lower 17 miles of the Passaic River (Anchor QEA 2019; USEPA 2014a). The model has most recently been adapted for use in the NBSA RI/FS by USEPA's contractor HDR, Inc. (HDR 2021b). The model simulates the hydrodynamics, sediment transport, OC transport, and contaminant fate and transport in the Bay estuary system including the lower 17 miles of the Passaic River, the tidal portion of the Hackensack River, Kill Van Kull, and Arthur Kill[35]. The extent of the model domain is beyond the boundaries of the NBSA. Contaminant fate and transport model results are linked to a bioaccumulation model for the Bay that was prepared by USEPA (Warren Pinnacle Consulting, Inc. 2020) to predict biota tissue concentrations of bioaccumulative chemicals[36]. The model system is used to evaluate long-term contaminated sediment fate and transport within the NBSA and across its boundaries with the adjoining waterways to provide a tool to forecast concentrations of COPCs in surface sediment, surface water, and biota tissue in the NBSA for a range of remedial options. Model documentation is provided in Appendix J.

Model results for a 10-year simulation period – 2004 through 2013[37] – were provided to GSH by USEPA (HDR 2019). Modeled mass balances for sediment solids and four representative COPCs (2,3,7,8-TCDD, mercury, total DDx (4,4')[38], and tetra-PCB) for a longer 18-year simulation period (1996[39] to 2013) (HDR 2021b) are also presented in this section to support a description of COPC long-term CFT in the NBSA and to provide a quantitative understanding of the relative importance of sources and losses of sediments and COPCs for the water column of the NBSA during that period. Model-computed mass balances for the sediment bed are also presented and discussed.

5.2 Section Organization

The remainder of this section is organized as follows:

- Sources of COPCs to the NBSA are discussed in Section 5.3.
- Processes governing the fate and transport of COPCs in the NBSA are discussed in Section 5.4, supplemented by field data and NBSA RI/FS model results.
- Temporal and spatial COPC trends, including evaluation of long-term changes in surface sediment concentrations and observations from sediment core profiles, are discussed in Section 5.5.

[35] The model does not account for site-specific direct discharges of contaminants to the Bay estuary system and USEPA is not aware of any significant, direct discharges of contaminants that are not accounted for in the model.
[36] The USEPA bioaccumulation model is being used to predict tissue concentrations of 2,3,7,8-TCDD, Tetra-PCBs, and total DDx (4,4') and will be used to support development of preliminary remedial goals for use in the Newark Bay Feasibility Study.
[37] The 10-year simulation results provided by HDR are referred to as the initial calibration run and include Hurricane Irene.
[38] Sum of 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT
[39] The modeling period is provided in water years which begin in October of the preceding year (i.e., water year 1996 begins on October 1, 1995).

- The linkage of sediment COPC concentrations to measured bioaccumulation of COPCs in biota, and the implication to long-term risks to humans and wildlife that consume aquatic organisms, are discussed in Section 5.6.
- A summary of CFT in the NBSA, and evidence for ongoing declines in surface water and sediment COPC concentrations, is presented in Section 5.7.

5.3 Contaminant Sources

The sources of COPCs to the surface water of the Bay (Figure 5-SC-1) include contemporary and historical releases. These sources, which are typical of many urban waterways, include: discharges from CSOs, SWOs, and POTWs; direct industrial point sources; releases from ships, spills, leaks, surface runoff; tributary inflows (Passaic River, Hackensack River, Kill Van Kull, and Arthur Kill); existing contaminants in the sediment bed; groundwater discharge from contaminated upland areas; and atmospheric deposition (Crawford et al. 1995). The most important historical sources of COPC inputs to the Bay have been industrial sources including historical releases to the Bay and its tributaries. The relative importance of different waterways as sources of COPCs may vary among the COPCs. Releases associated with OU1 within the Passaic River are among the important historical sources of contamination to NBSA. The contribution of COPCs from the various tributaries to the NBSA varies by chemical and is discussed further in Section 5.3.2. Based on information available at the time this RI Report was prepared, POTWs, CSOs, and SWOs are of lower historical significance for COPC loadings to the Bay. These sources currently contribute organics, nutrients, and a minor COPC load to the Bay. Spills and other releases from shipping activity have been present throughout the industrial history of the Bay and continue into the present. With curtailment of industrial sources and reduction or remediation of tributary inputs, the contributions of ongoing inputs from atmospheric sources, POTWs, CSOs, SWOs, and shipping will change in the future; however, the magnitude of these ongoing inputs is expected to remain relatively minor in comparison to the historical inputs.

Existing contamination in the NBSA reflects the combination of the influence of these sources over more than a century, paralleling the urban and industrial history of the Bay. Additional information regarding sources of COPCs in the Bay is provided in the Report on Investigation of Sources of Pollutants and Contaminants (Tierra 2006) and the Waterfront Sources Inventory from that report is included in Table K-1 of Appendix K. The remainder of this section focuses on external sources of contaminants to the NBSA.

5.3.1 Industrial Sources

There are a multitude of industrial sources of COPCs that contributed to and likely continue to contribute to NBSA contamination. Direct discharge and runoff of COPCs from industrial facilities currently and historically located along the waterfronts of the Bay and its tributaries are significant sources of COPCs (Interstate Sanitation Commission 1981, 1988). Waterfront properties that could be historical or current sources of contamination to the NBSA include industrial, commercial, and manufacturing operations; former rail yards; steel drum recycling sites, landfills; and dredge spoils fill or deposit areas. At least 177 of these properties operated from the mid-1800s to present based on the Report on Investigation of Sources of Pollutants and Contaminants (Tierra 2006) which summarizes documented releases in Appendix K. A large proportion of the companies are related to chemical oil or storage/distribution. Industrial source

discharge mechanisms included storm sewer outfalls, CSOs, wastewater outfalls, surface runoff, spills, leaks, and direct discharge. Chemicals that have been identified in the documented discharges include various solvents, metals, acids, petroleum products, pesticides, PCBs, PCDDs/PCDFs, and unpermitted discharges of wastewater (Tierra 2006). Little information has been collected to estimate the magnitude and relative importance of these direct discharge sources to the NBSA. However, given the municipal infrastructure to control stormwater and treat wastewater, it is unlikely that these sources are presently important contributors to contamination in the Bay.

5.3.2 Tributary Inputs

As discussed in Section 3, the NBSA has four primary tributaries: the Passaic River and Hackensack River to the north, and the Arthur Kill and Kill Van Kull to the south. These and other smaller tributaries (such as the Peripheral Ditch and Pierson's Creek) have numerous upstream waterways that all contributed to the loading of COPCs into the NBSA (Shrestha et al. 2014; Tierra 2006). Tributaries impact NBSA water and sediment quality via transport of dissolved-phase and sediment-associated COPCs, which can be from both legacy and present-day sources. The planned remediation of historical contamination in the lower 8 miles of the Passaic River (i.e., OU2) is intended to reduce the residual contaminated sediment load into the NBSA (USEPA 2018). As such, the LPR project will have an influence on future surface sediment concentrations of the NBSA and will be considered throughout the remedial decision-making process. Similarly, the planned remediation in the upper 9 miles of the LPRSA will be taken into consideration as a source reduction action in the FS to be conducted for the NBSA.

As part of a USGS study (USGS 2015) examining chemical concentrations and contaminant loads to the Newark and Raritan Bays, the Hackensack River and Passaic River were studied as tributaries to the Bay. Water and sediment from these two rivers were sampled near the head-of-tide between 2000 to 2003 during both stormflow and low-flow conditions for PCBs, PCDDs/PCDFs, PAHs, organochlorine pesticides, mercury, lead, and cadmium. Measured concentrations were used to estimate average annual contaminant loads between 1975 and 2000 as shown in Table 5-1 (Wilson and Bonin 2007). At the time of the USGS study, the Passaic River (USGS gage 01389500 at Little Falls, New Jersey) had a mean daily discharge of 1,132 cfs, while the Hackensack River (USGS gage 01378500 at New Milford, NJ) had a mean daily discharge of 90.4 cfs that is controlled by an upstream reservoir (Bonin and Wilson 2006)[40]. The annual loads were calculated based on average year sediment loads, average annual water discharge, and present-day average chemical concentrations (Wilson and Bonin 2007). Based on the annual loads measured at the head of tide, the authors suggest that the Hackensack and Passaic Rivers serve as net sources of contamination to the tidally-influenced portion of the Newark Bay system; although, the Passaic River represents a greater annual net loading (approximately two orders of magnitude or more) for the parameters measured than does the Hackensack River as shown by the data in Table 5-1. For the period between 1975 and 2000, the authors estimated the annual load of total PCBs, PCDDs/PCDFs, PAHs, organochlorine pesticides, mercury, lead and cadmium from Passaic River to be 7,200 kilograms per year (kg/yr), 260 grams per year (g/yr), 1,000 kg/yr, 6,400 g/yr, 80 kg/yr, 2,100 kg/yr, and 88 kg/yr, respectively. In comparison for the same contaminants, the annual total load from Hackensack River reported by these authors were 74 kg/yr, 2.2 g/yr, 15 kg/yr, 420 g/yr, 0.073 kg/yr, 20

[40] As presented in Table 3-2, recent (2020) average flows based on real-time data measured at these two gages were 1,145 cfs and 87 cfs, respectively.

kg/yr, and 0.26 kg/yr, respectively. While Wilson and Bonin (2007) emphasized the chemical load over this period cannot be truly defined, as present-day chemical concentrations do not represent past concentrations in these rivers, the use of average values in the calculation present a useful measure for relative comparison between rivers at the head-of-tide location.

As described in Sections 2.1.3.7 and 4.4, surface water data were collected in the NBSA and tributaries in 2011, 2012, and 2013 (AECOM 2010, 2011, 2019a, 2019b). Sampling locations are shown on Figure 2-10. Summary statistics for suspended solids, OC, and select COPCs are summarized in Table 5-2 by tributary and water column sampling depth. Mean COPC concentrations, particularly 2,3,7,8-TCDD, are substantially higher in the LPR compared to the NBSA and other tributaries (Table 5-2). All COPCs are detected in the tributaries indicating that each of these tributaries exchange fluxes of COPCs with the NBSA. As described in Section 4.4, dissolved concentrations of 2,3,7,8-TCDD, PCBs, and mercury are generally a small fraction of the total, reflecting that the majority of contaminant mass for these COPCs within the water column is associated with suspended solids[41]. Solid-phase concentrations are further discussed in Section 5.5.1. Section 5.4.7 examines model results to provide additional perspective on the relative importance of transport of COPCs in the sediment bed and water column of the NBSA, including contributions from tributaries.

5.3.3 Publicly Owned Treatment Works, Combined Sewer Overflows, and Storm Sewers

Prior to construction of POTWs for the local municipalities of Newark, Jersey City, Bayonne, Elizabeth, and Staten Island in the 1950s and 1960s, there was continuous discharge of untreated wastewater that included raw sewage and industrial inputs to the sewer system from outfalls in the NBSA and its tributaries. Currently, sewage is treated before discharge, except during heavy precipitation events, when the POTW is bypassed and untreated sewage is mixed with stormwater and discharged through CSOs. Bypassing is controlled by the POTW to avoid excess surcharging at a POTW plant. Regional sewerage authorities control and operate certain intercepting sewers, regulators connecting the intercepting sewers to the local systems, treatment works, and discharge points for treated effluent. CSO discharges were included in the USEPA CFT model and comparison of their relative solids loadings indicates where the largest CSO contributions to the Bay are located. Table K-2 of Appendix K lists the CSOs that discharge to the NBSA. Discharges of untreated or partially treated effluent from Newark and Elizabeth POTWs to the NBSA are presented in Table K-3 of Appendix K.

Figure 5-SC-2 shows the locations of local sewerage systems, CSOs, and POTWs, including nearby significant industrial users (SIUs), that discharge to the NBSA. Figure 5-MOD-1 shows where the CSO discharges were included in the USEPA CFT model. Note that the main outfall for Passaic Valley Sewerage Commissioners discharges to the Upper New York Bay, and the outfall shown along the NBSA discharges only when the main outfall's hydraulic capacity is exceeded during precipitation (Tierra 2006). Figure 5-SC-2 also shows the locations of SIUs, which are defined under 40 Code of Federal Regulations (CFR) 403.0. This category generally includes:

[41] The fate and transport of suspended solids – both those introduced via tributary inputs and those associated with resuspension of sediments within the NBSA – is discussed in detail in Section 5.4.

- Industrial users subject to Categorical Pretreatment Standards under 40 CFR 403.6 and 40 CFR chapter I, subchapter N
- Any other industrial user that discharges an average of 25,000 gallons per day or more of process wastewater to the POTW (excluding sanitary, non-contact cooling, and boiler blowdown wastewater); contributes a process waste stream that makes up 5% or more of the average dry weather hydraulic or organic capacity of the POTW; or is designated as such by the Control Authority on the basis that the industrial user has a reasonable potential for adversely affecting the POTW's operation or for violating any Pretreatment Standard or requirement.

In addition to the federal definition above, the State of New Jersey defines SIU in N.J.A.C. 7:14A-1.2 to include users that are:

- A hazardous waste facility that received a permit in accordance with N.J.A.C. 7:26G-12
- A discharger of landfill leachate, which is either pure, treated, or diluted
- A discharger of 25,000 gallons per day or more of process wastewater and/or polluted groundwater that is pumped from the ground to decontaminate an aquifer.

Between 2000 and 2004, contaminants were measured in samples of discharges from POTWs, CSOs, and storm sewer outfalls to the NBSA or its tributaries (Great Lakes Environmental Center [GLEC] 2008). The study results suggest POTW outfalls are sources of COPCs to NBSA, as concentrations of target analytes were detected in treated effluents from all POTWs sampled. Only one of the 12 POTWs included in the study, Joint Meeting of Essex/Union, has its primary effluent discharge into the NBSA (Figure 5-SC-2). PCBs, chlorinated pesticides, PAHs, PCDDs, PCDFs, and metals were all detected in effluent samples collected from the Joint Meeting of Essex/Union POTW (GLEC 2008).

While analyte concentrations measured in POTW-treated effluent were generally lower than CSO and storm sewer outfall effluent, CSOs and storm sewer outfalls were also shown to discharge PCBs, PAHs, chlorinated pesticides, PCDDs/PCDFs, and metals to the NBSA and its tributaries (GLEC 2008). Additionally, analytical data for aqueous samples collected in 2008 by Malcolm Pirnie, Inc. (MPI) at several locations along the Passaic River show that several contaminants have discharged at higher concentrations from storm sewers than from CSOs (MPI 2008a, 2008b); however, CSOs and storm sewer outfalls were not found to be a significant source of key contaminants to the LPR (Anchor QEA 2019).

Ongoing permitted discharges from POTWs, CSOs, and storm sewers are potential remaining external sources of contaminants to the NBSA (GLEC 2008), but their volumetric discharges and COPC mass loadings to NBSA are lower than those from the tributaries. As part of the LPR OU2 RI and Focused Feasibility Study (i.e., USEPA 2014a), USEPA investigated CSOs and stormwater outfalls as potential sources of COPCs. Their data and screening-level analyses show that these sources are relatively minor contributors at present compared to contaminated sediments that are already present on the river bottom in the lower 8.3 miles and that are resuspended and then resettle as a result of natural processes.

Continuing contribution by these sources, along with other sources to the NBSA, will be considered as part of the remedial decision-making process, as cleanup goals and remedial alternatives for NBSA sediments are developed and will account for ongoing contaminant inputs within the present and future urban port.

5.3.4 Spills

Table K-4 of Appendix K lists significant contaminant spills that have occurred in the NBSA. As indicated in the table, some of these discharges occurred onsite at industrial facilities with storm sewers that discharge to NBSA waters, some occurred on piers of industrial facilities along the NBSA, and some spills occurred on-board cargo ships entering Newark ports.

5.3.5 Groundwater and Atmospheric Deposition

Contributions of COPCs from groundwater discharge through the sediments of the Bay is believed to be a minor or negligible contribution to the CFT processes due to the hydrogeology of the NBSA, with the possible exception of some near shore areas. For this reason, groundwater discharge has not been measured or modeled for the NBSA, including within USEPA CFT model. Darcy velocity (DV) measured at three locations in the northern end of the Bay (Kearny Point) as part of the OU2 pre-design investigation range from -30 to 100 centimeters per year (cm/yr). The DV in Kearny Point was measured using UltraSeep meters and differential pressure piezometers (DPZs). The UltraSeep meters provide direct measurements of DV. DPZ-derived DV values were estimated using Darcy's law, the UltraSeep data, and the vertical hydraulic gradient (VHG) measurements using the DPZs per equation below.

Equation 1:

$$DV = \frac{Q}{A} = -K * VHG$$

Where:

$\frac{Q}{A}$ = Direct UltraSeep measurements

-K = vertical hydraulic conductivity (calculated)

VHG = direct VHG from piezometers.

The UltraSeep measurements in Kearny Point range from -30 to 74 cm/yr with an average of 39 cm/yr. The DPZ-derived DV values in Kearny Point range from -50 to 100 cm/yr with an average of 40 cm/yr. These measurements in the Kearny Point mudflat of NBSA are representative of groundwater discharge conditions in the northern Bay.

Atmospheric deposition was estimated by others to be a minor contributor to contamination in the Bay. Based on estimates for overall mass loadings of contaminants from to the NY/NJ Harbor Estuary developed by HydroQual (1991), Crawford et al. (1995) suggested that the combined contributions of pollutants to the Bay from atmospheric deposition and groundwater combined is less than 1%. Contributions to the NBSA by atmospheric deposition may increase in relative importance due to future reductions in industrial sources and tributary inputs.

5.4 Fate and Transport Processes

COPC fate and transport processes in the NBSA are discussed in this section based on interpretation of available RI data for the Bay, and the USEPA CFT model results (Section 5.4.7). These multiple LOEs from data and modeling are useful to consider together to mitigate uncertainty associated with any individual LOE. Based on USEPA CFT model results for 1996 to 2013, COPC source pathways

influencing fate and transport processes in the NBSA water column are ranked by approximate order of importance:

- Tributary inflows[42] (Passaic River, Hackensack River, Kill Van Kull, and Arthur Kill) – see Section 5.4.1
- Resuspension (tidal, wind-wave, and ship movement) – see Sections 5.4.1 and 5.4.6
- Dissolved-phase contaminant flux from sediment to overlying water (diffusion) – see Sections 5.4.1 and 5.4.2
- Point sources and non-point sources[39] (POTWs, combined sewer overflows, storm drains) – see Section 5.3.

Similarly, losses from the NBSA water column can also be ranked by order of importance:

- Deposition to the sediment bed – see Section 5.4.5
- Outflows (Passaic River, Hackensack River, Kill Van Kull, and Arthur Kill) – see Section 5.4.1
- Volatilization – see Section 5.4.3.

Removal of a portion of accumulated sediment, OC, and COPCs in the strata above the designated channel depths by maintenance dredging of the federally maintained channels is also represented by the USEPA CFT model results. The model simulates periodic removal of previously deposited materials from the channels. This is discussed further in Section 5.4.5.

These pathways are influenced by a variety of factors. Transport of COPCs in the NBSA water column is strongly governed by tidal exchange and tidal circulation due to the large tidal exchange volumes and relatively short residence time of water – on the order of hours to several days dependent upon seasonal fluctuations (GSH 2019a). The COPCs in the water column undergo bidirectional exchange across the boundaries of all four major connecting waterways driven by semi-diurnal reversing tidal flows. On an annual basis, the directional flux difference determines if the waterway is a net source or a net exporter of COPCs from the Bay.

Particulate concentrations of COPCs in the water column of inflows to Newark Bay are useful to examine with respect to sources of contaminated sediment in the NBSA. Particulate-bound COPCs flowing into the NBSA are adsorbed to the surfaces of fine-grained particles or absorbed into organic particles. These fine-grained sediments contribute to deposition and if their COPC content is different from surface sediments, they may contribute to increases or decreases in surface sediment COPC concentrations (see Section 5.5.1).

Partitioning of inorganic COPCs to fine sediments is subject to geochemical transformation associated with redox and salinity effects and can vary spatially and with depth in the sediment bed. Partitioning of

[42] USEPA's CFT model setup includes various point sources such as POTWs, CSOs, storm sewers, and landfills. For the purposes of the mass balance reported herein around the Bay, point sources include publicly owned treatment works discharging directly to the Bay, as well as point and non-point loads discharged to the Elizabeth River. Nonpoint sources include combined sewer overflows and storm drains discharging directly to Newark Bay Point; point and nonpoint sources discharging to the Hackensack, Passaic, Arthur Kill, or Kill Van Kull are included in the flux terms associated with those model regions (HDR 2021a).

organic hydrophobic COPCs is less subject to these factors and these compounds tend to remain tightly bound to organic materials – consequently, OC levels in the sediment are important to determining the bioavailability of these chemicals. Within the sediment column, processes that move fine-grained sediments (such as bioturbation), or that affect biogeochemical conditions (environmental conditions of microbial activity, redox, pH, dissolved oxygen, etc.) govern the fate of particulate-bound COPCs.

Depending on the biogeochemical conditions in the Bay, COPCs can undergo transformations that convert them to break down products. These breakdown products may have different toxicity and mobility.

Bioavailable COPC concentrations in the biologically active zone of the surface sediment depth interval are most relevant to potential for ecological or human health risk. This layer has been shown to be approximately the uppermost 15 centimeters (cm) in the Bay (Tierra 2008a). The bioavailability of COPCs in this layer can be lowered naturally through deposition and burial below the mixed layer depth, mixing with comparatively less contaminated sediments, (bio)geochemical transformation (abiotic or biodegradation, redox transformation to insoluble form, sorption, precipitation, etc.), increases in organic materials content, or resuspension and export from the system.

Bioavailability of COPC concentrations in surface sediment can be sustained by ongoing inputs via deposition of contaminated sediment particles, sorption from the water column, mixing with deeper sediments containing higher concentrations, and/or by diffusional processes from underlying sediment.

This summary of CFT processes is elaborated further below, supported by mass balance results from the USEPA CFT model.

5.4.1 Advection/Dispersion

Hydrodynamic processes include advective/dispersive transport of water column COPCs, both externally derived and internally sourced from the sediment bed. Within the Bay, advective currents are dominated by tidal currents and to a lesser extent by salinity gradient-induced estuarine circulation wherein denser seawater flows landward and less saline lighter overlying water from the rivers flows seaward. Dispersion (spreading of sediment and COPCs in the water column) in the NBSA is primarily controlled by tidal currents. These tidal exchange volumes contain suspended sediments and associated particulate and dissolved contaminants, which are exchanged in both directions between the NBSA and all four connected waterways.

Estuarine circulation is an important process with respect to impacting the net exchange of contaminants between the Bay and its tributaries. Modeling results show that for years with low annual average discharge, the LPR can be a net *importer* of sediment from the Bay (i.e., more sediment enters the LPR from the Bay than leaves the LPR). This is because of estuarine circulation moving sediments upriver where they are retained by deposition such that this flux is greater than the export flux in those years. One of the mechanisms that creates these periods of net landward flux is asymmetry of the tides, as described previously in Section 3.4.4. Specifically, annual net flux results show that in 2000 to 2002 and 2012, the LPR was a net importer of sediment from the Bay, and for the remaining 14 years of the 18-year simulation period, the LPR was a net source to the Bay (Figure 5-MOD-2A)[43]. Based on the USEPA CFT

[43] This process of sediment flux into the LPR may occur more frequently in the future once the LPR is deepened as a result of the OU2 remedy.

model (Figure 5-MOD-2A), the net solids transport is from the Bay to the Hackensack River. Examining the Hackensack River, the gross solids fluxes are higher compared with the LPR; however, a small net flux of sediment into the Hackensack River is shown for all years simulated[44]. There is uncertainty associated with this result due to the simplified representation of the sediment bed in the lower portion of the Hackensack River as a hard bottom (CPG 2019)[45]. The model calibration period includes Hurricane Irene in 2011, which was an extreme freshwater discharge event. Results indicate solids loading from the Passaic River in 2011 were larger than the total of all other Passaic River solids loads simulated years combined 1996 to 2013. Kill Van Kull is net source of solids into the Bay and Arthur Kill acts as a sink for solids coming from the Bay.

Figures 5-MOD-2B through 5-MOD-2E show the Passaic River is a net source of all COPCs to the Bay during the 18-year simulation period. For the Hackensack River and Arthur Kill, the net flux of all four COPCs are out of the Bay for the 18-year simulation period, except in Arthur Kill where there is a net flux of total DDx (4,4') into the Bay during the first 15 years and year 18 of the simulation period. For the case of Kill Van Kull, there is net flux of 2,3,7,8-TCDD and total DDx (4,4') out of the Bay and net flux of mercury and tetra-PCB into the Bay for the 18-year simulation period.

Due to the high tidal exchange volumes, the dominant source of sediment inputs to the water column of the Bay are tributary inflows (81%). Resuspension, including erosion and navigational scour, provides most of the remainder of sediment inputs to the water column (~19%), with point source and other contributions being negligible in comparison. Outflows of suspended sediment account for 80% of losses from the water column, followed by deposition at 20% (Figure 5-MOD-3).

Wind generated waves along with wave-current interaction imparts a stress on the sediment bed that is a function of the bottom orbital amplitude and bottom orbital currents (Shrestha et al. 2014). Water particle displacement is large in shallow water as compared to deep water where the particle displacement goes to zero (USACE 2002). Flow in deeper areas of the NBSA system are driven by a combination of tidal, estuarine circulation, and riverine flow (as opposed to wind). The shallower areas, including the subtidal flats, are dominated by a combination of wind driven circulation and wind generated waves.

Within the navigational channels, turbulence from propeller wash and hull displacement flows are important on localized scales and may move resuspended sediments to or from the navigational channel side slopes. Wind-driven currents in the Bay can be important for short periods such as during hurricanes or major wind events. High freshwater discharge events cause locally short-lived variation in advective currents within the northern channels of the Bay. Episodic changes in discharge can in turn create episodic changes in flow field that can temporarily change advective currents. Changes in discharge can also contribute to changes in sediment transport, resuspension, and deposition. Higher than normal discharge can drive larger sediment influxes to the NBSA from the Passaic River and lower than normal discharge will reduce sediment load.

[44] The model has not been rigorously evaluated with respect to accuracy of exchanges with the Hackensack River due to more limited available data and less of a study focus on the Hackensack River than the Passaic River. Therefore, predicted Hackensack River exchanges may be relatively more uncertain than for the Passaic River.

[45] The representation of the Hackensack River with a hard bottom, or non-erodible bed, refers to the parent bed; sediment deposited on the parent bed during the model simulation period is subject to erosion (HDR 2021b).

Across the northern boundaries of the NBSA, advective exchanges are dominated by semi-diurnal tidal exchanges, which during normal conditions dwarf daily freshwater discharge from the northern tributaries. The large tidal exchange produces fluxes of sediments and contaminants into and out of the Bay across these boundaries. The direction of net transport (difference between incoming and outgoing fluxes) varies with the amount of freshwater discharge. During high rainfall, freshwater discharge can dominate for short periods. Across its southern boundaries at the kills, advective exchange is governed by the semi-diurnal tidal fluctuations and coastal storm surge events. A counter clockwise circulation exists around Staten Island such that the net flow direction in Arthur Kill is discharge to Raritan Bay and the net flow direction in Kill Van Kull is inflow from New York Harbor (Blumberg et al. 1999), which is in contrast to a tidal pumping mode of circulation in which the Bay is filled (or emptied) by simultaneous inflow (or outflow) through both Kills (Blumberg et al. 1999; Chant 2006; Pecchioli et al. 2006). On an annual basis, the upstream-downstream flux difference determines if the waterways are a net importer or exporter of sediments and associated COPCs from the Bay.

Dispersion is an additional process affecting the redistribution of COPCs within the NBSA. For example, dispersion of resuspended sediment induced by ship-related turbulence within the shipping channels will tend to redistribute COPC concentrations in sediments along the channels. The USEPA CFT model includes navigation resuspension in the navigational channels (see Figures 5-MOD-4A through 5-MOD-4D). Modeled losses due to navigational scour is less than resuspension loss in all channels except the Port Newark channel, where loss due to navigational scour is approximately equal to resuspension losses. As noted in Moffatt & Nichol and Deltares 2021, navigation scour was simulated in the USEPA CFT model as a constant rate of resuspension providing an additional source of solids at areas of active shipping channels considered to be impacted by frequent ship-induced resuspension. The resuspension rate accounting for ship-induced resuspension (i.e., the mass loading from the bed to the water column) is specified as a constant 2.5×10^{-7} grams per square centimeter per second. The formulation represents the long-term average impact of ship-induced resuspension.

In comparison to resuspension, porewater advection and dispersion are of lower importance in the Bay for transfer of contaminants to surface water. Model results show that porewater-mediated transport of contaminants to the water column (via diffusion or advection) is a small fraction of the total mass balance of COPCs entering and leaving the surficial sediment layer (see Figure 5-MOD-4A through 5-MOD-4D).

5.4.2 Sorption/Partitioning

The COPCs tend to adsorb to sediment surface or partition into sediment organic matter to greater or lesser degrees depending on their chemical properties. Sorption of polar inorganic COPCs is strongly associated with surface charges on clay minerals due to their high surface area and polarity, iron/manganese solids, and organic matter. Hydrophobic organic COPCs tend to partition into particulate or dissolved organic matter. These dependencies are evident in data correlations presented in Section 4. The control of sewage and nutrient inputs to the Bay is an important factor governing OC production in the Bay. The historical inputs of carbon may be different than what the Bay is experiencing currently due to both reduction in direct inputs via sewage and reduction in primary production in the water column.

Sorbed COPCs can desorb from sediments resuspended into the water column, or directly from the bed surface, particularly if the local water chemistry (e.g., salinity, temperature, dissolved OC concentrations, or pH) changes. Metals complexation with sulfides and associated precipitation to particulate form is one

important reversible geochemical process that affects partitioning of inorganic chemicals in marine sediments. Resuspension of these metals complexes into overlying water can result in desorption of metals (Hong et al. 2011). Desorbed or dissolved mass of chemicals would be more readily transported from the Bay with advective flows; thus, greater amounts of resuspension, even without greater net export of solids, can lead to increased transport of dissolved contaminants. However, for strongly partitioning chemicals, which generally describes the NBSA COPCs, dissolved phase transport will be less significant compared to solid phase transport because the bulk of the contaminant mass is associated with sediments based on the surface water and sediment results discussed in Section 4.

5.4.3 Degradation/Transformation

Degradation or transformation of COPCs can occur through abiotic or biotic pathways over long intervals of time and is affected by ambient environmental conditions such as redox conditions, water temperature, and microbial processes[46] (Eggleton and Thomas 2004). Organic COPCs, particularly nonionic compounds such as PCDDs/PCDFs, PCBs, and various pesticides, have high chemical stability and are considered persistent organic pollutants because of their ability to resist chemical degradation or biodegradation. Weathering can alter functional groups (de-chlorination of PCB congeners is one example), reduce the molecular weight, and change the chemical properties of the compounds, rendering them less toxic, which can modify associated environmental risks. Chemical transformation may potentially assist to reduce risks associated with COPC exposure over long-term time scales.

Photolysis, especially photodechlorination, is one of the few environmentally significant degradation mechanisms for PCDDs/PCDFs in water; although, due to the low solubility, studies have not been conducted to quantify photodegradation rates (USEPA 2006c). In the NBSA, sunlight is not likely to penetrate very far into the water column as result of turbidity and turbulence. Therefore, photolysis and photodechlorination are likely limited to shallow depths. Studies suggest that PCDDs/PCDFs are subject to biodegradation in the environment as part of the natural chlorine cycle (Field and Sierra-Alvarez 2008). Based on studies of dated sediment cores from Lake Ketelmeer (Netherlands), Queensland (Australia), and the Baltic Sea, the literature reported degradation half-lives of PCDDs/PCDFs vary from 12 years to 170 years (Field and Sierra-Alvarez 2008). Lower chlorinated PCDDs/PCDFs can be degraded by aerobic bacteria (Field and Sierra-Alvarez 2008). Studies also indicate that PCDDs/PCDFs undergo biodegradation in anaerobic sediments (USEPA 2006c). Microcosm studies with PCDDs/PCDFs spiked sediments from the Hudson River have reported half-lives ranging from 1 to 4 years (Adriaens and Grib-Galic 1994; USEPA 2006c). Additionally, reductive dechlorination of 2,3,7,8-TCDD extracted from Passaic River sediments has been demonstrated under methanogenic conditions in microcosm studies with microorganisms present in the sediments (USEPA 2006c). Higher chlorinated (tetra- to octa-) PCDDs/PCDFs are known to be reductively dechlorinated in anaerobic sediments indicating that biodegradation is likely to contribute to the natural attenuation of PCDDs/PCDFs in sediments (Field and Sierra-Alvarez 2008).

[46] The USEPA CFT model does not include degradation and transformation processes. The contribution of these processes to model accuracy during the calibration period is likely negligible. Future long-term predictions could be more subject to uncertainty associated with the omission of this process. This imparts a conservatism in the long-term forecast results.

The ability of PCBs to be degraded or transformed in the environment depends on the degree of chlorination of the biphenyl molecule as well as on the isomeric substitution pattern (Agency for Toxic Substances and Disease Registry [ATSDR] 2000). Photolysis appears to be the only viable abiotic degradation process in water, while in sediments anaerobic microbial degradation is primarily responsible for transformation (ATSDR 2000). Aerobic biodegradation of PCBs in surficial sediments results in dechlorination mostly in congeners with three or less chlorines, while those with five or more chlorines are not readily degraded and thus persistent. Tetrachlorobiphenyls are intermediate in persistence (ATSDR 2000). PCBs can be biodegraded in anaerobic environments by reductive dechlorination (ATSDR 2000). Through this process, concentration decreases are seen mostly in tetra- through hexachlorobiphenyl congeners with increases in mono- and dichlorobiphenyls (Bedard 2001; Magar et al. 2005). Octa-through decachlorobiphenyl congeners are dechlorinated to a lesser degree. There are at least eight different pathways for anaerobic biodegradation and the rate, extent, and specificity of anaerobic dechlorination can vary greatly even in the same sediment (ATSDR 2000).

Pesticides can be degraded or transformed in the environment though abiotic (chemical and photochemical reactions) and biotic processes. The environmental conditions such as redox gradient will determine which degradation or transformation process will be predominant (Fenner et al. 2013). DDT is converted to DDE and DDD through biotic pathways mediated by bacteria and fungi. Similarly, dieldrin can be transformed to aldrin under anoxic conditions, and various compounds that make up the technical chlordane pesticide mixture can be found as their individual components in sediments.

In surface water, PAHs can volatilize, photolyze, oxidize, biodegrade, or bind to suspended particles or sediments (ATSDR 1995). The rate and extent of photodegradation varies widely among PAHs and is a complex function of structure (ATSDR 1995). LMW PAHs are more susceptible to volatilization if suitable conditions exist (i.e., high temperatures, shallow depths and high wind [Southworth 1979]). In sediments, PAHs can biodegrade by microbial metabolism (ATSDR 1995). The rate and extent of biodegradation of PAHs in sediment varies by organic content, particle size, characteristics of the microbial population, the presence of other contaminants such as metals and cyanides that are toxic to microorganisms, and the physical and chemical properties of the PAHs. PAHs can be significantly metabolized by microbes under oxygenated conditions; however, under anoxic conditions, degradation is extremely slow (Neff 1979).

Depending on the biogeochemical conditions (environmental conditions of microbial activity, redox, pH, dissolved oxygen, etc.) in the Bay, metals can undergo transformations that convert them from a dissolved and mobile state to a less mobile and bioavailable solid state. For example, dissolved metals such as arsenic, cadmium, copper, lead, mercury, nickel, and zinc can precipitate as metal sulfide solids under sulfate reducing conditions. Under the same conditions, chromium can be reduced from a dissolved hexavalent form to a less mobile and bioavailable trivalent form. These transformations appear prevalent in the Bay as the porewater samples were characterized by either low FOD or no detection for metal COPCs. Because metals are not destroyed but rather converted from one physical state or species to another, the transformations are reversible. Redox reactions are critical to the fate of mercury in aquatic environments. As described by O'Driscoll et al. (2005), elemental mercury is relatively insoluble and volatile and therefore is the predominant form in atmosphere, whereas inorganic mercury is highly soluble and reactive and also binds to particulate matter. Photooxidation via abiotic and biotic pathways is the key mechanism by which gaseous elemental mercury is converted to inorganic mercury in surface water. Similarly, abiotic and biotic photoreduction processes result in the conversion of inorganic mercury to elemental mercury, which volatilizes from the system. Methylation of mercury resulting in formation of

methylmercury occurs predominantly under anoxic conditions and is mediated by sulfate reducing bacteria. Considering that sulfate-reducing conditions are prevalent in the Bay, methylmercury was the predominant form of mercury detected in the porewater collected as part of the SQT investigation. While sulfate-reducing bacteria, along with methanogens, can also demethylate mercury, this demethylation process is not expected to be of significant importance for the Bay given the predominance of methylmercury in porewater. In anoxic sediments, dissolved inorganic mercury can bind to sulfides and precipitate as mercury sulfide solids. These solids can undergo various anoxic processes in sediments to form methylmercury or elemental mercury, which are then released to the water column or are available for bioaccumulation. Factors affecting mercury speciation and fate include organic matter, pH, redox conditions, and biological activity.

5.4.4 Bioturbation

Bioturbation is the mixing of sediment and porewater resulting primarily from feeding and movement of infauna and, to a lesser extent, from epifauna and megafauna (Tierra 2008a). Bioturbation by infauna mixes sediment vertically and horizontally at various rates depending on a combination of factors that include sediment grain size, organic content, community structure, biomass density, and season. Except for areas of high sedimentation or areas devoid of infauna (such as anoxic basins), bioturbation mixes sediment and reduces evidence of short-term depositional conditions by mixing a thin stratum of the sediment bed. Bioturbation is represented in the USEPA CFT model (HDR 2021b).

Bioturbation may bring COPCs to the surface of the bed or resuspend COPC-adsorbed sediments into the water column and expose anoxic sediments to oxygen. This exposure to oxygen may result in the oxidation of sulfides and release of metal COPCs associated with sulfides. Organic COPCs may desorb from sediment, but the rates are contaminant-specific. Bioturbation, moreover, mediates the response to load reduction (by mixing comparatively less contaminated surface layers with more contaminated deeper sediments) and plays a key role in governing natural recovery rates of COPCs in surface sediments. Bioturbation depths also determine the extent to which buried contamination is sequestered from the food web. A BAZ investigation was performed as part of Phase I field activities (Tierra 2008a, 2008b). Using sediment profile imaging, bioturbation was observed in samples collected from 14 stations throughout the NBSA. Based on the observations, the mean depth of the total BAZ was estimated to be 5.4 inches for the subtidal flats, 5.7 inches for intertidal areas, and 5.2 inches for the Channels. Physical processes (e.g., surficial sediment transport processes) dominated sediment surface characteristics at four (002, 003, 038, and 065) of the five intertidal area stations, while at one station (058) the sediment surfaces appeared to be dominated by a combination of physical and biological processes with small pits and mounds from faunal feeding activity. (Note: Phase I locations are shown on Figure 2-1.) Sediment surfaces at all the Channel (004, 043, and 063) and subtidal flat (014, 022, 041, 045, and 056) stations were characterized as a combination of physical and biological processes, except for one subtidal flat station (060) that was primarily physically dominated. Surface relief, primarily in the form of small feeding pits and mounds at muddy stations and bed forms at sandy stations, was not significantly different between geomorphic areas (geomorphic areas are described in Section 3.3).

5.4.5 Sediment Deposition and Burial

COPCs that are adsorbed to the surfaces of the clay and organic particles are transported with the cohesive sediments, which comprise a mixture of clays, silts, fine sands, and organic matter. Interparticle attractions give these fine particles their cohesive properties in sediment. As described in Section 3.5.2, suspended sediments can become trapped in areas of flow convergence near the limit of saltwater intrusion (Sanford et al. 2001). This is also where salt and suspended sediment stratification reduce turbulence, leading to suspended sediment trapping at the ETM. With reduced vertical mixing, sediment that had been suspended by a balance between gravitational sinking and turbulent mixing sinks (Geyer 1993). Once deposited on the sediment bed, the cohesive and consolidation processes result in greater shear stresses required for remobilization than for initial deposition – imparting stability to cohesive sediment deposits. Successive accumulation of new sediment "buries" the deeper sediments out of the BAZ depth interval, sequestering them from the food chain unless loss of sediment through erosion or deep mixing occurs. In long-term stable depositional areas of the NBSA, burial is a key fate mechanism of COPCs reducing risk over time.

The advective transport of COPCs in the water column depends on both the strength of the currents and the settling velocity of particles to which they are attached. Settling properties have a major influence on where COPC-containing fine-grained sediments flowing into the NBSA are deposited. If settling velocity is large relative to vertical mixing, suspended sediment will settle to the bottom of the water column and near–bed currents may govern transport. Bed-load transport tends to be a dominant transport mechanism for sand or coarser particles. Fine slow settling particles (flocs, silts, and clays) tend to remain well mixed in the water column and are susceptible to longer advective transport distances. Low concentrations of fine particles tend to remain in suspension even during slack tide and during ebb and flood tide higher concentrations can exist. Thus, a portion of fine-particulate bound COPCs flowing into and resuspended within the NBSA are exported from the NBSA as suspended sediment (see Figure 5-MOD-2A).

The complex interaction of oceanographic and hydrologic processes, in particular during episodic storm events, can influence both the rate of sediment delivery to the Bay (via inflows) and the stability of the sediments in the NBSA (due to higher bed stresses associated with winds, river discharge flows and storm surges). These competing influences may affect the rate of reduction of COPC concentrations in surface sediments.

The high level of shipping activity in the NBSA navigational channels may influence surface sediment COPC trends in these areas. Passing of ships can resuspend sediments along the bottom and sides of the navigational channel, mixing newly deposited sediments and older sediments. The periodic removal of accumulated sediment and COPC inventory by maintenance dredging conducted by the USACE is the most important factor affecting sediments in the channels and may also promote long-term reduction of sediment contaminant levels in the Bay and water column quality by removal of the contaminant inventory associated with these sediments; the continuing need for maintenance dredging underscores the continued delivery of sediment to the channel.

Non-cohesive sediments such as sands have lower COPC binding capacity due to their smaller surface area per mass and lower organic content; however, adsorption can still occur to the coatings on such particles. As presented in Section 4, sediments in NBSA are predominantly silt and fine sand. Percent sands vary from about 3% to 97% depending on location. The average percent sand (> 200 μm sieve) in the subtidal flats is 46% (+/- 27%) and in the navigational channel surface sediments is 36% (+/- 22%).

Resuspended sand particles are transported by bedload in the NBSA and due to their lower binding capacity, are of less significance to movement of contaminants than finer grained sediments.

Under typical conditions, the Bay experiences a localized convergence of sediment flux from the Passaic and Hackensack Rivers and Arthur Kill and Kill Van Kull, and therefore, is a regional sediment deposition area, which is reflected in the sediment transport modeling results (Figure 5-MOD-5 and Table 5-3) and is evidenced by the need for regular maintenance dredging (Table 1-1) since the early 1900s (Tierra 2011). Approximately 80% of the sediments deposited in Newark Bay are captured in the Port Channels. More recently, 285,000 and 250,000 cubic yards were dredged in 2016 and 2015, respectively, from critically shoaled areas in the Port Newark approach channels and placed at upland permitted sites (USACE 2018b). Maintenance dredging in the federal and port channels is performed by USACE on an as-needed basis (Tierra 2011)[47].

Radioisotope data of Be-7 indicated recent deposition of sediment in the navigation channel in the Bay (USEPA 2014; Sommerfield and Chant 2010; Huntley et al. 1995), providing evidence that this important process continues. Model predictions are in general agreement with the Be-7 observations (Figure 5-MOD-6) and suggest recent sediment deposition primarily occurs in and near the channel areas, with low rates of sediment accumulation and non-detect levels of Be-7 on the subtidal flats. A comparison of model-predicted long-term average bed accretion/erosion (2004 to 2013) and Be-7 sampling results (2005-2007) is shown in Figure 5-MOD-6. Simulated deposition rates are shown in Figure 5-MOD-7 and Figure 5-MOD-3. Overall, the deposition rates are higher in the channels in the Bay as compared to the LPR (see solid gray and blue bars). Flux values in the Passaic Channel and subtidal flats (see hashed gray and blue bars on Figure 5-MOD-3) are higher than the flux in the channels and subtidal flats in the Bay, suggesting that the Passaic River is likely acting as a source of sediments to the Bay, which is also supported by the modeled annual solids flux from 1996 to 2013 (Figure 5-MOD-2A). Dredging planned as part of the remediation of the lower 8.3 miles of the Passaic River may result in greater retention of sediment in the river and alter the direction of net flux of solids between the Passaic River and the Bay.

To evaluate differences across geomorphic areas (Section 4.3), net fluxes were computed for groups of model cells representing each area (Figure 5-MOD-8). The aggregated annual average net deposition[48] and areal deposition (mass per year per square meter) by geomorphic area (Figure 5-MOD-7) show deposition is highest in the 50-foot deep port channels (Port Channels, Elizabeth Channel, and Port Newark Channel). The lowest deposition fluxes are computed for the subtidal flats, approximately 5 kilograms per square meter per year (kg/m^2/year) compared to approximately 30 kg/m^2/year in the port channels. Deposition on the Kearny Point subtidal flat area within the OU2 boundary shown on Figure 5-MOD-8 is approximately three times higher than the flats in the NBSA, likely due to its proximity to sediment discharge from the Passaic and Hackensack Rivers.

Evaluation of long-term average sedimentation rates (assuming undisturbed, continuous net deposition) is also useful to understand how sediment deposition rates and depositional areas may have varied within

[47] Navigational channel dredging events are reflected in the NBSA RI/FS model by modifying the water depth in the model at intervals as part of its calculations (Moffatt & and Nichol and Deltares 2021). This occurs three times during the 18-year simulation run: at the start of water years 2000, 2003, and 2009.

[48] The aggregated annual average net deposition was obtained by summing the average net deposition of regions within an entire geomorphic area type (Figure 5-MOD-8). Regions represent groups of model cells representing geographic areas (e.g., Port Newark Channel).

the NBSA. Estimates of long-term average sedimentation rates in the NBSA are available from: 1) comparison of bathymetric surveys (Suszkowski 1978); 2) analysis of sediment budgets (Suszkowski 1978; Wakeman 2006); 3) conversion of dredge volumes to shoaling rates (USACE 2006a); and 4) evaluation of sediment radioisotope data (Tierra 2011). All estimates are subject to inherent uncertainty. Radioisotope data in the Phase I and II cores were specifically collected to estimate deposition rates (Tierra 2011) but in some cores, there were some inconsistences in estimates based on the two different isotopes measured (i.e., Cs-137 and Pb-210) and dating methods used. In addition, the dating methods lack sufficient resolution to discern the profiles and rates of change where deposition rates are particularly low.

A comparison of modeled average bed elevation change rates and Phase I and Phase II radio-dated core estimates are presented in Figures 5-MOD-9 and 5-MOD-10. In these two figures, it is important to note that the model output (showing changes in bed elevation in cm/yr) is limited to recent changes between 2004 and 2013, whereas the estimated sedimentation rates derived via the radioisotopes are based on the historical time period of 1963 to either 2005 or 2007 (depending on field program), assuming an undisturbed, continuous rate of long-term net-deposition. In part due to these differences, there are variations between the radioisotope-derived and model-output bed elevation predictions. A comparison of long-term sedimentation rates from different studies in the Bay is presented on Table 3-5. Available data were also used to identify depositional areas in the Bay and estimate the amount of sediment deposition for the 1934 to 2006 time period (Figure 5-ACCUM) (USACE 2006a; Tierra 2011). A detailed analysis of historical deposition patterns in Phase I/II cores is discussed in the Deposition Report (Tierra 2011). This report utilizes the USACE (2006a) report, historical information (i.e., NOAA Nautical Charts), as well as the Phase I and II Sediment Investigation results to define the anthropogenic features such as old channels and cuts that shaped the historical depositional features of the NBSA. The presence of historical structures, such as the dike shown on Figure 5-ACCUM, may also have affected patterns of deposition. Geomorphic changes related to development have influenced sediment deposition rates and depositional areas in the NBSA. For this reason, sedimentation rates derived from long-term observation may not represent current sedimentation rates because of the major changes to the bathymetry – which in turn influence depositional areas and rates – of the NBSA, which are discussed in Section 3. Intrinsic rates of decline in surface sediment concentrations in the subtidal flats can be estimated by the burial rate (nominally 0.2 to 0.5 cm/yr) divided by the BAZ thickness (mean thickness of 5.2 to 5.7 inches, Section 5.4.4), which provides an attenuation rate of 0.013 per year to 0.04 per year (1.3% to 4% per year). Expression of this rate as a half-life suggests that the residence time of the recently deposited sediments in the BAZ layer prior to burial out of the BAZ layer would be approximately 18 to 52 years. The actual half-life will be influenced by factors such as bioturbation depth and intensity, and COPC concentrations of depositing solids. Locations with greater bioturbation would exhibit a longer half-life of persistent chemicals, or slower attenuation rate, compared to other locations with the same long-term average net sedimentation rate. Half-lives would tend to be lengthened by increasing COPC concentrations on depositing solids if continuing inputs occur; estimates of solids concentrations are further discussed in Section 5.5.1.

5.4.6 Sediment Resuspension

Sediment resuspension delivers deposited COPCs back to the water column where transport processes can redistribute. Both cohesive and non-cohesive sediments are mobilized by shear stress from current,

waves, and propwash, after which, the dissolved and sorbed COPCs may be redistributed to other locations. Cohesive sediments may erode when the bed shear stress exceeds the critical shear stress for erosion and the rate of erosion is dependent on the shear stress. Non-cohesive sediments can be eroded when the shear stress exceeds a critical value for incipient motion that is a function of particle size and density. Erosion rate is dependent on applied stress. The net erosion rate depends on the simultaneous rates of gross erosion and deposition that may occurring.

In context of Newark Bay, resuspension by wind waves on the shallow flats and by tidal currents, turbulence from propeller wash and hull displacement flows in the navigational channels are important. Second to inflows, resuspension provides the majority of the remainder of sediment inputs to the water column (~17%) (Figure 5-MOD-3). Examination of model-predicted bed elevation changes and sediment grain size data provides insight to the variation in sediment transport, especially within the subtidal flats. Figures 5-MOD-11 and 5-MOD-12 show sand and silt content, respectively, overlaid on the computed bed elevation change predictions over the 2004 to 2013 period. Figures 5-MOD-13 and 5-MOD-14 show the same data overlaid on 2012 NBSA multibeam bathymetry. These maps show that sediment properties represented in the model, which were initialized based on measured values, portions of the subtidal flats near the port channels and portions of the northeastern subtidal flats have coarser sediments. The presence of coarser material in these areas reflects the model prediction of typically higher bottom shear stresses in these areas compared to shallower near-shore areas. These results also indicate the potential for localized variations in sediment bed dynamics that may differ from the average behavior on the subtidal flats. This imparts uncertainty to conclusions that may be drawn when representing the subtidal flats as individual large model mass balance regions (e.g., SW Subtidal Flat). This uncertainty will need to be considered when evaluating model results for evaluation of remedial options in the FS.

In the display of model results in Figures 5-MOD-11 and 5-MOD-12, a range of +1 to -1 cm/yr is used to illustrate results with a small degree of change. It is judged that the model's ability to predict the difference whether an area is experiencing net erosion or net deposition is subject to more uncertainty when these rates are smaller than 1 cm. The model's ability to predict if net erosion or net deposition is occurring is judged to have less uncertainty when the predicted net changes are greater than +/-1 cm/yr. This value of 1 cm/yr was chosen for illustration purposes for display of the model results in this figure and is not based on a quantitative uncertainty evaluation.

Rare storm events are of interest with respect to sediment stability and sediment loading to the Bay. In Section 5.5.1, the REMAP and RI data bracketing the Hurricane Sandy in 2012 are discussed, showing that influences of the event on COPC concentrations in the NBSA were not apparent in the data. While this does not directly support a finding that the sediments were stable during the event, the data indicate the event did not cause a re-emergence of historically higher concentrations. Modeling results show the discharge from the Passaic River resulted in an annual solids loading for 2011 of approximately 17 times the average of the other years in the 1996 to 2013 simulation period.

As discussed in Section 3, channel deepening in the Bay has affected the hydrodynamics, including tidal energy and has altered sediment resuspension and deposition. Localized resuspension and deposition occur from ships transiting the shipping channels as demonstrated on Figure 3-6. The effects vary considerably depending on vessel type and on the manner of vessel movement (Clarke et al. 2015). Deep-draft navigation contributes appreciably to sediment resuspension, while shallow-draft tug/barge traffic had little effect on resuspension.

To characterize the spatial variation in erosion rates and physical properties of the bed sediments in the NBSA, Sea Engineering, Inc., on behalf of the USEPA, completed a SEDFlume analysis of 29 intact field and 35 laboratory consolidation cores collected from 14 and 5 locations in the NBSA, respectively (Sea Engineering, Inc. 2013). The analysis provides estimates of the erosion rates as a function of bed shear stress and depth within the core. Analysis of the data across the Bay reveals patterns in bed erosion resistance. The SEDFlume critical shear stress data indicate that sediments are relatively the most stable in areas that contain relatively elevated sediment COPC concentrations on the southeast and southwest flats. These areas have relatively low bottom shear stress and thus historically accumulated deposited fine-grained sediment from many sources. The finer sediment likely contributes to greater cohesiveness. This stability together with low rates of burial are apparently why these areas of elevated surface sediment COPC concentrations persist.

5.4.7 NBSA RI/FS Model Results

Model results for the 1996 to 2013 calibration period provide additional perspective to understand the relative importance of fate and transport of COPCs in the sediment bed and water column of the NBSA. For the representative COPCs, mass balances for the sediment bed were prepared for defined zones within the model system (Figure 5-MOD-8). The COPC mass balances around the sediment bed, with results presented on a flux basis (milligrams per square meter per year) are shown in Figures 5-MOD-4A through 5-MOD-4D and summarized in Tables 5-3 through 5-7. These results show the relative importance of sediment transport processes. The largest transfers are associated with sediment resuspension and deposition, and in the navigational channels, ship-activity-related resuspension. Mass of COPCs leaving the sediment bed through diffusion processes is relatively minor in comparison.

NBSA-wide magnitude of key pathways was quantified from the model mass balance results for the four representative COPCs (Figure 5-MOD-5). Results show the major pathways are inflows and outflows and sediment-water exchanges. Sediment-water exchange is dominated by resuspension and deposition – dissolved phase flux is small in comparison. Net inflows and outflows for these four COPCs show the dominant fate of the retained mass is net deposition. For example, during the 1996 to 2013 calibration period, the modeled mass flux estimates that 20.3 g/yr of 2,3,7,8-TCDD is transported from the Passaic River into the Bay, followed by export of 1.9 g/yr to the Hackensack River, 3.0 g/yr to the Arthur Kill, and 3.3 g/year through the Kill Van Kull (Table 5-8). A total of 8.1 g/yr is exported from NBSA; the remaining 12.2 g/yr of 2,3,7,8-TCDD is deposited in the Bay. For tetra-PCB, modeled mass flux estimates indicate that 11.0 kg/yr of tetra-PCB is transported from the Passaic River into the Bay and 7.0 kg/yr is transported from the Kill Van Kull into the Bay, followed by export of 1.7 kg/yr to the Hackensack River and 6.7 kg/yr to the Arthur Kill (Table 5-9). A total of 8.4 kg/yr is exported from NBSA; the remaining 9.6 kg/yr of tetra-PCB is deposited in the Bay. Considering total DDx (4,4’), the model estimates that 3.2 kg/yr of total DDx (4,4’) is transported from the Passaic River into the Bay and 8.1 kg/yr is transported from the Arthur Kill into the Bay, followed by export of 0.3 kg/yr to the Hackensack River and 7.3 kg/yr to the Kill Van Kull (Table 5-10). A total of 7.6 kg/yr is exported from NBSA; the remaining 3.7 kg/yr of total DDx (4,4’) is deposited in the Bay. And for mercury, the modeled mass flux estimates that 77.5 kg/yr of mercury is transported from the Passaic River into the Bay and 40.9 kg/yr is transported from the Kill Van Kull into the Bay, followed by export of 14.9 kg/yr to the Hackensack River and 48.7 kg/yr to the Arthur Kill (Table 5-11). A total of 63.6 kg/yr is exported from NBSA; the remaining 54.8 kg/yr of mercury is deposited in the Bay.

The modeled mass Inventory increases between approximately 1% to 2% for tetra-PCB, mercury, and total DDX (4,4') and approximately 5.4% for 2,3,7,8-TCDD over the period 1996 to 2013 (Figure 5-MOD-15). Because mass inventories show increases over this period, and recent loadings are likely similar, source control (including the remedial action currently in design for the lower 8.3 miles of the Passaic River, which acts as a net source of 2,3,7,8-TCDD and other COPCs to the NBSA; see Figure 5-MOD-2B) will be important in determining the future levels of contaminants in the NBSA sediments. Concentrations of COPCs on incoming solids combined with the local and spatially varying deposition rates control sediment concentrations in the Bay. With the exception of PCBs, particulate COPC concentrations on the incoming tides from the Kill Van Kull (Table 5-10) indicate these sediments will promote further declines in bioavailable surface sediment concentrations of COPCs in the Bay. In depositional areas, surface sediment concentrations will eventually be controlled by incoming particulate COPC concentrations from connected waterways, and as this occurs, rates of decline will slow.

Model results for average surface sediment concentrations of 2,3,7,8-TCDD and tetra-PCBs in zones of the NBSA identified for linkages to exposure areas (i.e., Assessment Zones, see Section 4.6) were provided by USEPA (Figures 5-MOD-16 and 5-MOD-17). These figures show the concentrations over time in comparison to NBSA surface sediment datasets for the period 1995 through 2019, and were developed during the calibration phase of the USEPA CFT model. The original dataset used for model initialization in 1995 is less spatially intensive than the Phase III dataset, which is the most spatially-extensive dataset available. Model results are shown for restarts of the model at several points in time where the sediment conditions were initialized based on the Phase III dataset for both sediment grain size (which affects erodibility of the sediment bed in the model) and surface sediment chemical concentrations. Results for this series of model runs are plotted together on these figures. The difference in concentrations illustrates the uncertainty in specification of model initial conditions; however, the results for each sub-area exhibit similar changes over time. Surface sediment 2,3,7,8-TCDD concentrations decline in all areas of the Bay until 2011, when Hurricane Irene occurred. LPR inputs to NBSA in 2011 including Hurricane Irene were larger than all prior years combined for the period examined by the USEPA model (2004 to 2013). While model results indicate increases in surface sediment concentrations occurred in all exposure areas, the largest increase was noted in the southern channels, where surface sediment 2,3,7,8-TCDD concentrations increased approximately 225% (from 45 ng/kg before Hurricane Irene to 145 ng/kg after). The smallest increases (approximately 18%) occurred in the northern channel (from 87 ng/kg to 103 ng/kg). After Hurricane Irene, predicted declines in surface sediment concentrations resumed the following year. Results for tetra-PCB are similar; however, the impact of Hurricane Irene was smaller for tetra-PCB concentrations, where concentration increases were limited to the southeastern subtidal flats, confined aquatic disposal, and the southern channel cell areas (approximately 1%, 7%, and 24%, respectively). Similarly, surface sediment contaminant concentrations of total DDx (4,4') and mercury increased in response to Hurricane Irene (depending on the exposure area, concentration increases ranged from 2% to 10% for total DDx (4,4') and 1% to 11% for mercury). After Hurricane Irene (and prior to the reset of initial conditions in water year 2017 [HDR 2021b]), predicted surface sediment contaminant concentrations decrease again. The greatest decreases were noted for 2,3,7,8-TCDD and tetra-PCB; depending on exposure area, concentrations decreased over the period January 1, 2012 to September 30, 2016 from 7% to 57% for 2,3,7,8-TCDD and from 4% to 26% for tetra-PCB. Decreases in surface sediment concentrations of total DDx (4,4') and mercury also occurred, ranging from 3% to 9% and 4% to 20%, respectively, depending upon exposure area.

The most recent model results received from USEPA in September 2021 incorporate updates to the CPG model. The updates include: initial chemical concentrations in the Arthur Kill, navigation scour adjustments, and the adjustments based on the reset of chemical concentrations based on Phase III data. These changes are described in the NBSA model documentation (HDR 2021b). Note that while Figures 5-MOD-16 and 5-MOD-17 show tests of multiple potential resets based on the Phase III data, in the model results shown on Figure 5-MOD-18 through Figure 5-MOD-21 the simulation labeled as NBSA Baseline incorporates the reset of initial conditions based on Phase III by resetting the surface concentration at the beginning of water year 2017 (HDR 2021b). A discontinuity in concentrations occurs at this point, observed as either a small sudden increase or decrease in concentrations. Larger decreases in concentration are observed in the confined aquatic disposal (CAD) cell area; this reflects capping completed within that region, with lower concentrations measured in Phase III reflecting the placement of clean cap material. After the reset, concentrations generally follow similar level or declining trends observed prior to the reset. However, in the CAD cell area, concentrations of total DDx (4,4'), tetra-PCB, and 2,3,7,8-TCDD increase, reflecting deposition of contaminants on the clean cap material. The observed trends for tetra-PCB and 2,3,7,8-TCDD are also similar to the trends observed in Figures 5-MOD-16 and 5-MOD-17, with the exception of 2,3,7,8-TCDD in the CAD cell area, which showed a declining trend in Figure 5-MOD-16 and shows a slight increasing trend in Figure 5-MOD-18. Note that the reset of the concentrations based on Phase III data occurs after the 18-year period of model results covered in this section of the RI Report.

5.5 Temporal and Spatial Contaminant Trends

Surface water and sediment concentration data collected during the RI sampling programs were examined for spatial (surface and subsurface) patterns reflecting fate and transport mechanisms and temporal trends. Temporal trends were examined using statistical comparisons of surface sediment concentrations at two (or three) points in time using co-located data from the Phase I, II, and III programs; and by calculating rates of change of contaminant concentrations in co-located cores using both surface and subsurface concentrations in datable cores. Spatial trends were examined by plotting surface sediment concentrations by Bay mile and by graphical depiction of subsurface core data and are examined in terms of contaminant mass inventory. In addition, particulate concentrations in the water column are also examined spatially to determine the potential for circulating solids to influence future surface sediment concentrations.

5.5.1 Surface Sediment Temporal Trends

Temporal trend analyses of COPC concentrations were conducted using surface sediment concentrations from Phases I, II, and III samples from 37 co-located sampling stations. These stations were established in the Phase I and/or Phase II event, and re-occupied/re-sampled during the Phase III sampling event. Estimated precision of location reoccupation was within 14 feet (average distance). This analysis, presented in detail in Section 4.3.1 and summarized below in Table 5-12, indicates that the concentrations for most COPCs—including dioxins, PCBs, PAHs, total DDx (4,4'), and some metals—have shown a statistically significant decline since the RI sampling started in 2005 (Table 4-8). The temporal comparison suggests that arsenic concentrations have increased approximately 22% over this time period. Nickel and zinc showed no significant temporal change.

Table 5-12. Summary of Results of Temporal Comparison of Phase I/II and Phase III Co-located Samples

Observed Change	COPCs
Statistically Significant Decline	Cadmium, Chromium, Copper, Lead, Mercury, Silver, 2,3,7,8-TCDD, BEHP, TPH, Total Aroclor PCBs (Sum of 9 Aroclors), Total PCB Congeners (209), Total DDx (4,4'), Total HMW PAHs, Total LMW PAHs, Total PAHs
Statistically Significant Increase	Arsenic
No Significant Temporal Change	Nickel, Zinc

Historical data were also examined. REMAP surface sediment samples (i.e., top 2 cm of sediment) were first collected in 1993 and 1994 with 5-year re-visits in 1998, 2003, 2008, and 2013. The 2013 sampling program was conducted after Hurricane Sandy. The coordinates for these data were plotted (Figure 2-11) and the distances between stations were calculated. Unfortunately, while some stations have similar station names and appear in the general vicinity of each other on maps, the sampling stations are not co-located (i.e., within 100 feet of another) based on their database coordinates. Therefore, a quantitative co-located analysis similar to the RI data analysis (Phases I, II, and III) could not be conducted for the REMAP data. Within the REMAP dataset, 18 stations were sampled in 1993 and 1994 and 11 to 13 were sampled in subsequent 5-year intervals. Some COPCs were not analysed in all time periods. A comparison of mean COPC concentrations over time is presented in Table 5-13, and while it suggests concentrations may have declined for some COPCs (e.g., 2,3,7,8-TCDD, cadmium, copper, lead, mercury, silver, and zinc) over the period, due to the small sample size, the declines are not statistically significant. Nickel and chromium appear to have increased in concentration in 2013 after previously declining; however, again these comparisons are not statistically significant. The REMAP pesticide data are difficult to interpret due to the low FOD. Most pesticides were rarely detected after 1993. Mean total DDx (4,4') concentrations dropped from 123 µg/kg in 1993/94 to 1.54 µg/kg (2008) and 3.07 µg/kg (2013) in the later REMAP sampling events (Table 5-13). The mean total DDx (4,4') of the Phase III data set is 93.1 µg/kg (Table 4-3), approximately 30 times greater than the 2013 REMAP mean. It is unclear how these extreme changes could occur. While it is noted that REMAP sampling was conducted in the top 2 cm while Phase III sampling was conducted in the top 6 inches of sediment, the differences in sampling depth are unlikely to account for the disparity and a more likely explanation is that the 2008 and 2013 REMAP pesticide data are unrepresentative. Mean arsenic concentrations showed no evidence of a decline over the time period, similar to that observed with the RI data. The highest arsenic concentrations tended to occur in the southern part of the NBSA (stations NB044, NB223, NB309, NB310, and NB413); a pattern similar to that noted in the RI data (Figure F-25 in Appendix F). All other metals also had their highest concentrations in the south (stations NB213, NB223, NB309, NB310, and NB413) consistent with results from the RI data analysis (Figures F-26 through F-35 in Appendix F).

The REMAP data support the temporal declines in COPC concentrations exhibited by the RI data and there is no apparent evidence that Hurricane Sandy caused a measurable increase in COPC concentrations in the NBSA; although, it is acknowledged that surface sediments in the top 2 cm might be more sensitive to storm events. Taken together, these results indicate that sources of COPCs have likely

declined since the 1990s, and that burial processes may have sequestered historically higher concentrations. The exceptions seem to be portions of the southern Bay, particularly in the southwest area in the historically disturbed subtidal flats. Sediment core data from these areas indicate that concentrations of many of the COPCs are particularly elevated in surface sediments. For those locations that exhibited acute toxicity in this area, the concentrations of most COPCs are at the 90th percentile of their Bay-wide concentrations ranges. This is in contrast to much of the rest of the NBSA where the Phase I to III data demonstrate lower overall average concentrations of COPCs in the surface sediments and burial of historically higher concentrations, as discussed in Section 5.5.2. This is also demonstrated by the fact that measured sediment toxicity in most of the NBSA between 2008 and 2015 (from both the RI SQT and REMAP programs) is absent or low with the exception of localized areas in the southwest subtidal flats. These results are in sharp contrast to the historical REMAP data from the 1990s when substantial surface sediment toxicity was measured throughout the Bay. As discussed in the BERA (GSH 2020), a substantial decline in abundance and taxa was noted in the 2013 REMAP data as compared to previous REMAP events. This appears to have been a short-term impact because the 2015 SQT abundance and taxa data were more consistent with long-term trends and were unimpacted throughout the Bay relative to the reference area. This is further indication of the improvement of sediment conditions in recent years.

While the RI data suggest the Bay exhibits long-term declines in surface sediment concentrations, future concentrations are expected to be influenced by COPC concentrations in depositing solids. Water column monitoring data were used to estimate the concentrations of suspended solids in the surface water of the Bay and tributaries (see Section 4.4 for a description of the RI surface water sampling programs and estimations of solids concentrations) and are summarized in Table 5-14. Sampling locations are shown on Figure 2-10. Solid-phase concentrations were estimated from surface water concentrations measured in the Small Volume Chemical Water Column Monitoring (SVCWCM) Program (AECOM 2011) and the High Volume Chemical Water Column Monitoring (HVCWCM) Program data (AECOM 2019b); however, the data from the latter involved measurement of the particulate phase directly and also allowed for the subtraction of the dissolved fraction in the water sample, and thus is more accurate. Mean solid-phase concentrations of 2,3,7,8-TCDD in the NBSA estimated by the SVCWCM did not vary appreciably by station (Table 5-14); however, those measured by the HVCWCM were quite variable and were greatest (157 ng/kg) at a station in the northeast portion of the NBSA (station NNE on Figure 2-10). Concentrations were much lower at stations in the east-central (11.6 ng/kg) and southern (20 ng/kg) parts of the NBSA (stations NBE and NBS respectively, on Figure 2-10). In the SVCWCM program, FODs for 2,3,7,8-TCDD in water were fairly low in the NBSA (40%) and other tributaries (exception is Passaic River with 80% detection rate) and many of the detected values were flagged as estimated maximum possible values, adding uncertainty to the solids concentration estimates. Therefore, while it was a much smaller program, solids concentration estimates from the HVCWCM program are likely to be much more accurate at least for the NBSA and the Kill Van Kull. For the Passaic River, estimates were similar for both programs. Sampling for the HVCWCM program occurred over a five- to eight-hour period, but in the Kill Van Kull was limited to the flood tide period providing a good estimate of the solids coming into the Bay. A similar issue occurs for PCBs where many individual congener results were flagged as estimated maximum possible concentrations and the HVCWCM solids concentration estimates are likely to be more accurate.

Based on these estimates, depositing solids in the NBSA would be expected to have a range of 10 to 157 ng/kg 2,3,7,8-TCDD with the higher end of the range limited to the northern part of the Bay near the mouth of the Passaic River. As such, depositing solids in the lower end of the range as measured in the central

and southern part of the Bay and the Kill Van Kull could result in lower surface sediment concentrations over time in the Bay especially south of Bay mile 1 (Figure 1-1). Total PCBs are expected to range from 53,000 to 883,000 ng/kg in depositing solids with the highest concentrations in the northern part of the Bay. Solids in the lower end of the range such as the central and southern part of the Bay could result in lower surface sediment concentrations; although, solids measured in the incoming tide from the Kill Van Kull (550,000 ng/kg) have a greater total PCB concentration than the average of Phase III surface sediment (480,000 ng/kg). Mercury in solids is expected to range from 917 to 1,520 µg/kg with likely comparatively less contaminated solids coming in from the Kill Van Kull at 756 µg/kg. These concentrations are lower than the average Phase III sediment concentration (2,350 µg/kg). Total DDx (4,4') in solids ranges from 49,600 to 59,900 pg/g, lower than the average Phase III surface sediment concentration (93,000 pg/g). Solids entering from the Kill Van Kull are likely lower; however, solids that may enter from the Arthur Kill (131,000 pg/g) could be a source of total DDx (4,4') in the southern portion of the NBSA.

Solid-phase concentrations measured within the NBSA in the HVCWCM program compare similarly to recently deposited sediments in the navigation channel as described in Section 4.4. Concentrations of 2,3,7,8-TCDD in the solid-phase (Table 4-22), ranging from 11.6 to 157 ng/kg (average 52 ng/kg) are similar to the average concentration of Be-7 bearing sediment samples in the navigation channel (51.7 ng/kg; Table 4-16). Concentrations of total PCBs in the solid-phase (Table 4-22), ranging from 53,000 to 883,000 ng/kg (average 366,000 ng/kg) are similar to the average concentration of Be-7 bearing sediment samples in the navigation channel (534,000 ng/kg; Table 4-16). Therefore, Be-7 bearing channel samples are useful for characterizing recently deposited material. Comparisons of solid-phase concentrations measured in the HVCWCM program and Be-7 bearing sediments are further described in Section 5.5.2 and shown on Figures 5-B7-1 and 5-B7-2.

5.5.2 Surface Sediment Spatial Trends and Recent Deposition

Surface sediment concentrations for key COPCs (i.e., 2,3,7,8-TCDD, total PCB Congeners, total DDx (4,4'), and mercury) in the LPR and the NBSA were plotted as a function of River/Bay mile to examine spatial trends (Figures 5-B7-1 through 5-B7-4). The top graph of each figure shows the data for all surface sediment samples from all NBSA RI programs (i.e., Phase I, Phase II, and Phase III including Crab/Clam and SQT programs) and from all LPRSA RI programs from 2008 through 2013. The bottom graph shows the data for NBSA Phase I/II samples and LPRSA samples that had Be-7 concentrations greater than 0.5 pCi/g. Concentrations greater than 0.5 pCi/g indicate recent deposition. Also shown are the particulate concentrations measured in the high-volume chemical water column monitoring program for 2,3,7.8-TCDD and total PCBs. The Be-7 results were collected from a 0 to 1 inch grab sample that was co-located with the sediment core. The presence of relatively higher Be-7 levels indicates the surface sediment contains more recently deposited particulates than in locations where the surface sediment samples have low levels of Be-7. It is assumed that the sediment chemistry in the co-located sediment core (0 to 6 inches) also represents some relatively recent deposits; however, it does not mean that the entire 0 to 6 inch interval is predominantly comprised of recently-deposited material. Figure 1-1 shows the River and Bay mile designations. For samples that were assigned with Arthur Kill or Kill Van Kull miles, these miles were added to the end of the Bay miles for the purpose of plotting. As an example, a sample designated with AK-1 would appear at a value of 5.5 on the x-axis. Samples in the NBSA located north of the 0-mile mark (0-mile is at the confluence of the Kearny Point Reach of the Passaic River and the Northern Bay channel)

are negative. The LPRSA samples from all programs are represented by inverted black triangles on the plot. The NBSA RI samples are coded by location with respect to channels and tributaries.

The data were examined for insight to fate and transport processes affecting distribution of contaminants in sediments. For 2,3,7,8-TCDD (Figure 5-B7-1a), the top graph, showing all data, demonstrates the maximum surface sediment concentrations are found in the LPRSA and that concentrations trend downward toward the NBSA. The downward trend continues until Bay mile 4. Some higher concentrations near Bay mile 5 are located on the southwestern subtidal flat near the western shoreline and the old railroad bridge alignment. The bottom graph shows the subset of samples with Be-7 greater than 0.5 pCi/g. These data show a downward trend from north to south that levels off after Bay mile 4, particularly among the channel samples, where the data become more variable. Several of the highest concentrations in the NBSA occur between Bay miles 4 and 5.

A similar assessment is provided in Figure 5-B7-1b[49] examining the ratio of 2,3,7,8-TCDD to total TCDD. Ratios are highest in the LPRSA where 2,3,7,8-TCDD comprises 70% or more of the total TCDD. Ratios trend downward in the NBSA. The highest ratios occur between Bay miles 0 and 1. They are somewhat lower and less variable between Bay miles 2 and 4. Ratios are again elevated between Bay miles 4 and 6. The bottom graph of Figure 5-B7-1b shows a similar trend with the ratio generally decreasing from north to south, particularly among the channel samples. The two Be-7 bearing locations between Bay miles 4 and 5 that have ratios exceeding 0.6 are core locations 019 and 020 (Figure 3-7). Be-7 concentrations at these locations were low (i.e., equal to the Be-7 bearing threshold of 0.5 pCi/g) suggesting that recent deposition is low. That fact along with the observed 2,3,7,8-TCDD concentrations (592 ng/kg and 184 ng/kg for 019 and 020, respectively) suggest these samples likely comprise a significant portion of historically deposited sediment (dating to circa 1960) now exposed at the surface. Similar concentrations and ratios can be found throughout the Bay, although more commonly at greater depth. The spatial pattern depicted on Figure 5-B7-1a suggests that the LPR is the predominant source of 2,3,7,8-TCDD in the NBSA. Upland site sources to the NBSA have not been investigated as part of the RI, since this RI was not designed to collect data to identify upland site sources and their magnitude of influence on the NBSA. OCC submitted information to USEPA that may indicate the existence of additional upland site sources of 2,3,7,8-TCDD with similar 2,3,7,8-TCDD to total TCDD ratios. However, that determination is not the focus of this document. Water column particulate concentrations are within a similar range as the Be-7 bearing sediment concentrations.

For total PCBs (Figure 5-B7-2), the top graph (i.e., all data) indicates the highest concentrations are found in the LPRSA. Within the NBSA maximum values occur around Bay mile 0.5 and Bay mile 5.5, with lower concentrations from approximately Bay mile 2 to Bay mile 3.5. The maximum PCB concentration is near Bay mile 5.4. The bottom graph on Figure 5-B7-2 (Be-7 bearing samples) reflects a similar pattern, but with lower variability and a lower overall range. In the bottom graph, based on the pattern of channel concentrations, it appears there may be an ongoing PCB source in the Port Channels. Water column particulate concentrations are within a similar range as the Be-7 bearing sediment concentrations.

[49] Some LPRSA 2,3,7,8-TCDD:Total TCDD ratios exceed one. The reason this occurred is because the USEPA required upward adjustment of the 2008 Low Resolution Core concentrations for 2,3,7,8-TCDD (and other dioxin/furan congeners). In some cases, the adjusted 2,3,7,8-TCDD concentration exceeded total TCDD in the same sample. Ratios exceeding one are plotted at a value of one on Figure 5-B7-1b.

For total DDx (4,4') (Figure 5-B7-3), both graphs show there is a decreasing trend from the LPRSA into the NBSA followed by an increasing trend in the southern Bay. Within the NBSA, the highest concentrations in surface sediments occur between Bay mile 4 and Bay mile 7. This increasing trend from north to south starts around Bay mile 3.5 and extends into the Arthur Kill. This upward trend is also apparent in channel samples after Bay mile 5. In comparison, total DDx (4,4') concentrations are consistently lower from Bay mile 1 to Bay mile 3.5. The bottom graph shows that sediments impacted by recent deposition in the southern part of the Bay and in the Arthur Kill exhibit among the highest total DDx (4,4') concentrations. This observation is consistent with sediment data in the Arthur Kill, which was used to set initial conditions for the USEPA CFT model (HDR 2021b). Total DDx (4,4') concentrations in the Arthur Kill collected during a 2015 sampling program are as high 700,000 µg/kg (DIVER 2020). USEPA CFT model results suggest the Arthur Kill is a likely source of total DDx (4,4') to the NBSA.

Surface sediment mercury concentrations (Figure 5-B7-4) show somewhat similar range and variability across the system from River mile 12 in the LPRSA. In the NBSA, there are generally lower concentrations between Bay mile 2 and Bay mile 3.5 and the maximum concentrations occur between Bay miles 1 and 2 in two co-located samples at the upper end of the Port Newark Channel near the discharge of Pierson's Creek. Pierson's Creek is the location of a designated Superfund site due to elevated levels of mercury and other contaminants. Aside from these samples, the next highest concentrations occur near Bay mile 5. Concentrations in the Arthur Kill appear similar to those in the northern part of the Bay.

5.5.3 Trends in Sediment Core Profiles

5.5.3.1 Recent and Long-term Rates of Contaminant Decline

Estimates of long-term average rates of change in surface sediment concentrations can be computed using radio dating techniques (which provide an estimate over several decades) and then compared to the more recent approximate 10-year trends observable by comparing the Phase I/II surface sediment sample to the Phase III surface sediment sample. Phase I and II core dating was previously conducted using the Cs-137 data collected in a subset of these cores in areas that had not been dredged after 1963. Results of the sediment core dating are reported separately in the Phase I and II Sediment Deposition Report (Tierra 2011). Cs-137 is found in the environment as a result of atmospheric nuclear weapons testing that began in the early 1950s and peaked in 1963. By 1954, Cs-137 was present in measurable amounts and as such the Cs-137 "horizon" and peak values in a core are associated with deposition in 1954 and 1963, respectively. Using these data and the dating methods described in the Deposition Report (Tierra 2011), date intervals were estimated for each of the sampling intervals in the Phase I/II cores. If Cs-137 was not detected or if it was only detected in the surface interval, no dates could be assigned. Table 5-15 shows the sample depths and concentrations of selected COPCs assigned to the 1954 horizon and 1963 peak Cs-137 concentration for all dateable cores. There were 30 in total. Also, shown are the sampling depths and COPC concentrations for the sampling interval in which the year 1980 is estimated to have occurred. After 1980, major sources of contamination are assumed to have been controlled and therefore rates of change after this period would be more reflective of natural recovery processes, such as burial. Concentrations in the dated depth intervals were then compared to the 2016 Phase III surface sediment sample result where available or to the Phase I/II surface interval where no Phase III sample was collected to estimate a long-term annual rate of decline. These long-term rates of decline are based on

dateable cores only and thus are biased toward areas with high deposition rates such as historically disturbed subtidal flats and do not reflect rates of decline in areas with low deposition rates where typically appreciable COPC concentrations are only found in the surface sediment. Further, because the loading of legacy contamination was ongoing before 1980, the rates calculated based on the 1954 and 1963 periods represent a combination of source reduction and natural recovery. Cores in which Be-7 exceeded 0.5 pCi/g, an indicator of recent deposition, are also identified in the table.

Long-term rates of decline were calculated as follows:

$$\text{Annual rate of decline} = [\log_e(\text{concentration at year}_0) - \log_e(\text{concentration year}_t)] \div (\text{year}_t\text{-year}_0)$$

where year_0 is the initial year the concentration was observed (i.e., either 1954, 1963, or 1980), year_t is year the surface interval was collected (i.e., either 2005, 2007, or 2016) and $\log_e$ is the natural logarithm function.

Short term changes (i.e., since 2005/2007) based on the modeled comparisons of co-located cores presented in Section 4 can be converted to an annual rate using the β term provided in Table 4-8 as follows:

$$\text{Annual Short-Term Rate of Decline} = 1 - e^{\beta}.$$

Recent and long-term estimated average annual rates of decline for 2,3,7,8-TCDD, PCBs, total DDx (4,4'), and mercury are summarized in Table 5-16; these are discussed in further detail below.

Table 5-16. Annual Rates of Decline for Selected COPCs

COPC	Since 2005/2007	Since 1980	Since 1963[a]	Since 1954[a]
2,3,7,8-TCDD	3.3%	4.7%	4.4%	3.5%
Total PCB Congeners	5.4%	5.0%	4.0%	2.3%
Total DDx (4,4')	4.6%	2.0%	2.2%	2.3%
Mercury	2.9%	3.7%	3.1%	2.3%

[a]Historical rates of decline are estimated for areas where historical disturbance and subsequent high deposition occurred and is based on datable cores where Cs-137 peaks were observed. Because contaminant loading was ongoing after 1963, these rates may not represent natural recovery rates after sources were controlled.

5.5.3.1.1 2,3,7,8-TCDD

Concentrations of 2,3,7,8-TCDD in dateable cores show a general decline over the last six decades (Table 5-15). Since 1980, when most legacy sources were likely controlled, long-term annual rates of decline ranged from 1 to 10% with an average rate of 4.7% in dateable cores which are generally located in historically disturbed subtidal flats. There were other locations not specifically designated as historically disturbed, but where it is obvious that disturbance had occurred based on the core profiles and depth to Cs-137 horizon (Table 5-15). For example, the location of co-located cores 057/079 was not characterized by USACE as a high net deposition area; however, core dating resulted in an estimated depth of 12.9 feet to the 1940 horizon (Tierra 2011) indicating significant historical deposition had occurred there. The location of core 089 was characterized by USACE as an area of high net deposition, but it was designated with the geomorphic area of transitional slope due to its being at the southern edge of the Shooters Island

channel. In undisturbed areas of the Bay, particularly portions of the subtidal flats where little deposition has occurred and cores were not datable based on Cs-137, core profiles are characterized by appreciable 2,3,7,8-TCDD concentrations (and concentrations of other COPCs) being largely limited to the surface sediment (0 to 0.5 foot). In such areas, estimated long-term rates of decline are not applicable. The average annual short-term (i.e., 2005/2007 to 2016) rate of decline based on the 37 co-located Phase III cores is 3.3% (95% confidence interval [CI]: 0.31%, 6.3%).

5.5.3.1.2 Total PCBs

PCB concentrations have generally declined over the last six decades (Table 5-15). Since 1980, long-term annual rates of decline ranged from 0.9% to 12.5% in dateable cores in historically disturbed areas with an average annual rate of decline of 5%. The average annual short-term rate of decline is 5.4% (95% CI: 2.8%, 7.9%).

5.5.3.1.3 Total DDx (4,4')

Total DDx (4,4') concentrations have also declined over the last six decades (Table 5-15). Since 1980, long-term annual rates of decline ranged from 0 to 5.5% in datable cores in historically disturbed areas with an average rate of 2% (Table 5-15). Concentrations increased at two core locations (i.e., 089 and 082) in the southern Bay. The average annual short-term rate of decline is 4.6% (95% CI: 1.0%, 8.0%).

5.5.3.1.4 Mercury

Concentrations of mercury have also declined over the last six decades. Since 1980, long-term annual rates of decline ranged from 1.1 to 8.6% with an average rate of 3.7% in datable cores in historically disturbed areas (Table 5-15). The concentration increased at core 015 in the southern Bay. The average annual short-term rate of decline is 2.9% (95% CI: 0.43%, 5.3%).

5.5.3.1.5 Summary

For the four COPCs evaluated, long term declines in concentration were observed in dateable cores in historically disturbed areas since 1980 with annual rates ranging from 2 to 5% (Table 5-16). These long-term rates do not apply in low deposition areas such as those discussed in Section 4.3.1.3 where contaminant concentrations are largely found in the surface sediment and long-term changes cannot be evaluated by core data. Based on the comparisons of the 37 Phase III co-located cores presented in Section 4 (Table 4-8), short-term annual rates of decline range from 2.9 to 5.4% (Table 5-16); although, there is significant variability in these estimates. In addition, it is uncertain how rising sea levels will affect rates of change in COPC concentrations.

5.5.3.2 Vertical Contaminant Profiles

Vertical contaminant profiles observed in the Phase I/II cores reflect the depositional environment at each core location and the historical depositional history. Historical deposition rates estimated by the USACE (2006a) for these cores are depicted in Figure 5-ACCUM. Large areas of the subtidal flats in the NBSA are low deposition areas with less than 2 feet of deposition estimated to have occurred over the period from 1934 to 2006 (Figure 5-ACCUM). Cores collected in these locations are characterized by COPC

concentrations highest in the surface sediment (0 to 0.5 foot bss) and limited Cs-137 activity. Historical deposition rates were higher in areas that were historically disturbed. Historical excavation, filling, and construction activities (i.e., piers and bridges) and periods of deposition produced variations in thicknesses of contaminated sediments within the NBSA. A historical dike was constructed in 1923 across the northern boundary of the southern navigation channel north of Shooters Island (Figure 5-ACCUM) and has since been removed. The 3,395-foot dike was installed to promote accumulation of sediment north of the dike rather than in the southern channels of the Bay to reduce maintenance dredging needs (USACE 1997). By 1964, the dike was badly deteriorated and was reconstructed. An inspection in 1984 found that less than 2% of the structure remained; sediment had built up north of the structure; and channel slopes in the vicinity were stable. The dike probably had some effect on sedimentation rates in nearby areas of the southwestern subtidal flats as evidenced in nearby cores. Be-7 was not detected in cores 013, 014, 015, and 018 located just north of the former dike (Figures 3-8 and 5-ACCUM) suggesting no recent deposition. Cs-137 concentrations are limited to surface sediments in cores 013, 014, 018, and 019 (but not 015), suggesting that sediments below the surface interval were deposited prior to 1954. Core 015 is located in an area of a natural tidal channel where at least 3 feet of sediment has been deposited since 1954 based on the Cs-137 horizon in this core. Other historically disturbed areas of the southwestern subtidal flats had considerable deposition after 1954 and 1963 based on core data for the Cs-137 horizon and peak concentrations. For example, cores 012 and 082 located in the abandoned Elizabethport Channel (Figure 5-ACCUM) had Cs-137 horizons at a depth of 5.8 and 9.5 feet and Cs-137 peaks at 1.9 and 7.5 feet, respectively. Similarly core 098, located in the abandoned Allied Signal Channel (Figure 5-ACCUM) had a Cs-137 horizon and peak at depths of 11.5 and 6.5 feet, respectively. Therefore, while the dike may have slowed deposition after the 1950s in undisturbed areas, disturbed areas continued to accumulate sediments after this time.

To further explore the vertical trends in COPC concentrations, five cross-sections through select portions of the southern and northern NBSA were developed. Figures 5-CS-1 through 5-CS-36 cross-sections of the Phase I, Phase II, and Phase III data for arsenic, mercury, 2,3,7,8 TCDD, total PCBs (Aroclors), total PCBs (congeners), total DDx (4,4'), and total PAHs. Samples collected up to 400 feet from the cross-section were depicted at native elevation; therefore, some sample locations project off the sediment surface. In addition, Figures PF-1 through PF-7 (presented in Appendix L) depict the individual sediment concentration/depth profiles for all the Phase I and II sediment cores. These select COPCs were the focus of the sediment profile evaluation and cross-section development as they cover the different contaminant classes.

In the northern Bay, there are areas of both low and high deposition depending on the degree of prior disturbance (Figure 5-ACCUM). Cross-section C-C' (Figures 5-CS-16 through 5-CS-22) runs south to north along the northwestern shore of the NBSA where significant historical disturbance took place followed by infilling (Figure 5-ACCUM). The cut and fill flats south of the I-78 extension bridge (core 076) was an area where a cut was made in the late 1930s as access to piers in the area. It was later expanded and deepened but began to fill in during the 1960s (Tierra 2011). Construction of the Lehigh Valley Railroad bridge and nearby access channels (cores 077 and 078) also affected deposition in the area (Tierra 2011). Contaminated sediments extend to depths up to 25 feet in this area and maximum concentrations of COPCs are found at depths ranging from 5 to 25 feet. For example, in core 078, which is located in an abandoned turning basin (Tierra 2011), the greatest 2,3,7,8-TCDD concentrations (> 8,000 ng/kg) are 25 feet below the sediment surface (Figure 5-CS-18; Figure PF-3G in Appendix L). South

of core 078, cores 076 and 077 have 16 and 11 feet of contaminated sediments, respectively, with maximum 2,3,7,8-TCDD concentrations of 3,360 ng/kg and 2,680 ng/kg at depths of 8 and 4 feet, respectively (Figure 5-CS-18; Figure PF-3G in Appendix L). Similar patterns are noted for the other COPCs, particularly total PCB congeners (Figures 5-CS-16, 5-CS-17, and 5-CS-19 through 5-CS-22).

Cross-section D-D' runs south to north mostly on the historically disturbed flats east of the navigation channel including one location (core 061) in the channel (Figures 5-CS-23 through 5-CS-29). The area was also influenced by construction of the Lehigh Valley Railroad bridge (Figure 5-ACCUM). Contaminated sediments extend to depths of approximately 13 feet on the flat. The depth of the maximum concentrations vary by location. The maximum concentration of 2,3,7,8-TCDD (1,440 ng/kg) occurs at a depth of 10 feet in core 080 while in core 093, the maximum concentration (1,850 ng/kg) is at 1 foot (Figure 5-CS-25; Figure PF-3H in Appendix L). Core 094, although technically located within the navigation channel boundary, has a surface elevation at least 20 feet above the depth of the channel and likely represents a transitional slope environment (Tierra 2011). It is characterized by fairly uniform 2,3,7,8-TCDD concentrations ranging from 70 to 243 ng/kg throughout its vertical extent of 29 feet (Figure 5-CS-25; Figure PF-3H in Appendix L). Relatively lower concentrations were observed in the channel in core 061, which penetrated native materials at a depth of 1 foot. Other COPCs display similar vertical patterns in cross-section D-D' (Figures 5-CS-23, 5-CS-24, and 5-CS-26 through 5-CS-29).

In undisturbed areas of the northern Bay, particularly in USEPA Subunit 6 (Figure 2-8), very little deposition has occurred. For example, 2,3,7,8-TCDD has the highest concentrations in the surface samples in the cores located on the subtidal flats in USEPA Subunit 6 (i.e., 045, 050, 053, 054, 062, 064, and 065) (Figure PF-3K). The observed sediment profiles within the undisturbed subtidal flats in USEPA Subunit 6 are consistent with the noted low deposition rates within these areas (Tierra 2011) and the fact that there is no evidence of recent deposition at these core locations (Figure 3-7).

The occurrence of accumulated contaminated sediments in the central part of the Bay (USEPA Subunit 5) is dependent on the degree of historical disturbance. A study of historical bathymetric maps (Tierra 2011) indicated various dredging and filling activities took place on the subtidal flats east of the navigation channel. These are identified as Accumulation Areas 8, 9, 11, and 12 on Figure 5-ACCUM. This activity resulted in the accumulation of contaminated sediments of varying thicknesses. For example, in cores located in the most historically disturbed areas in USEPA Subunit 5 (e.g., 044, 071, 074, 091, and 092), up to 20 feet of contaminated sediments have accumulated with 2,3,7,8-TCDD concentrations peaking at depths of 5 to 13 feet bss (Figure PF-3J in Appendix L). By contrast, for cores located in the undisturbed subtidal flats in USEPA Subunit 5 (e.g., 038, 039, and 041), with no evidence of recent deposition (Figure 3-7), the highest 2,3,7,8-TCDD concentrations, along with other COPCs, occurred at the sediment surface (Figure PF-3I, Figure PF-3J in Appendix L). Cross-section E-E' runs along subtidal flat east of the navigation channel (Figures 5-CS-30 through 5-CS-36). Moving south along this cross-section, beginning around core 037, there is a trend of deeper contamination that corresponds to areas of increased historical deposition due to prior disturbance (Figure 5-ACCUM). For example, see the profile for core 091 on Figure 5-CS-32 where the maximum 2,3,7,8-TCDD concentration is found at a depth of 5 feet bss and is detected to at least 20 feet bss.

Cross-sections A-A' and B-B' illustrate vertical patterns of contaminants in the southern Bay particularly in historically disturbed areas. Cross-section A-A' (Figures 5-CS-2 through 5-CS-8) runs south to north along the southwestern shoreline of the Bay and traverses several historically disturbed areas (Figure 5-

ACCUM) such as the abandoned Elizabethport channel (cores 012 and 082), the old Bay railroad bridge (core 019), and the abandoned Allied Signal channel adjacent to and south of the South Elizabeth Channel (core 098). The Elizabethport channel and associated ports appeared on nautical charts by 1917, was expanded over time through the 1930s, and was closed and abandoned by 1940 (Tierra 2011). Based on the core profiles, at least 8 to 12 feet of contaminated sediments have been deposited within the abandoned Elizabethport channel. Maximum 2,3,7,8-TCDD concentrations were observed at 3 (555 ng/kg, core 012) to 8 (688 ng/kg, core 082) feet below the surface (Figure 5-CS-4) in the channel. Concentrations of other COPCs are relatively elevated in these deposits including arsenic at up to 155 mg/kg (Figure 5-CS-2), mercury at up to 100 mg/kg (Figure 5-CS-3), total PCB congeners at up to 32,000,000 ng/kg (Figure 5-CS-6), total DDx (4,4') at up to 1,000 µg/kg (Figure 5-CS-7), and total PAHs at up to 520,000 µg/kg (Figure 5-CS-8). The Elizabethport channel is still discernable on bathymetry (Figure 3-3) and the bottom of the channel is 5 to 10 feet below the surrounding subtidal flats: therefore, deposition in the channel is likely to continue. Estimated historical deposition rates range from 0.022 to 0.61 foot per year in core 012 and from 0.11 to 0.22 foot per year in core 082. The abandoned Allied Signal channel first appears on the 1967 nautical chart (Tierra 2011). Approximately 12 feet of contaminated sediments have been deposited in this channel, but COPC concentrations are much lower than in the Elizabethport channel likely due to the later time frame of its construction and abandonment. The maximum 2,3,7,8-TCDD concentration (115 ng/kg) is observed at a depth of 8 feet below the surface (Figure 5-CS-4; Figure PF-3C in Appendix L). The old Bay railroad bridge first appears on the 1917 nautical chart and was removed in 1980 (Tierra 2011). The historical disturbance of its construction and removal does not seem to have resulted in deep deposits of contaminated sediments as evidenced by the core profiles in cores 019 and also 020 (located east of 019 and not shown on the cross-section) where contaminants are confined to the top 2 feet (Figures 5-CS-2 through 5-CS-8; see also Figure PF-3B in Appendix L for 2,3,7,8-TCDD concentrations in core 020).

Cross-section B-B' traverses the southern shoreline south of Shooters Island from west to east (Figures 5-CS-9 through 5-CS-15) through historically disturbed areas (Figure 5-ACCUM) associated with the Shooters Island channel and the Richmond terrace cut (core 090). Core 089 is located on the transitional slope of the South Shooters Island channel where more than 20 feet of contaminated sediments have been deposited. The maximum 2,3,7,8-TCDD concentration (3,750 ng/kg) is found at a depth of 12 feet (Figure 5-CS-11). Other COPCs are similarly elevated in this core (Figures 5-CS-9 through 5-CS-15). Co-located cores 009/097, located west of Shooters Island, do not appear to indicate significant accumulation of high concentrations of COPCs in this area. Concentrations of 2,3,7,8-TCDD, total PCBs, and total DDx (4,4') are fairly low at this location (Figures 5-CS-11, 5-CS-13, and 5-CS-14, respectively). However, arsenic and mercury are somewhat elevated (Figures 5-CS-9 and 5-CS-10, respectively). More deposition occurred east of Shooters Island as shown in cores 005/070 where there are approximately 14 feet of contaminated sediments. The maximum mercury (16 mg/kg), 2,3,7,8-TCDD (1,010 ng/kg), and total PCB congener (7,530,000 ng/kg) concentrations occur at a depth of 2 feet (Figures 5-CS-10, 5-CS-11, and 5-CS-13, respectively). Maximum concentrations of arsenic and PAHs were found deeper within this core (Figures 5-CS-9 and 5-CS-15, respectively). Core 090 is located near the southern shoreline in an area of historical disturbance related to channel and shoreline development (Figure 5-ACCUM). Approximately 12 feet of contaminated sediments were deposited here with maximum concentrations of all COPCs occurring at depths of 5 to 9 feet (Figures 5-CS-9 through 5-CS-15). Based on cores 004 and 08A, at least 3 feet of contaminated sediments have been deposited in the channel south of Shooters Island (Figures 5-CS-9 through 5-CS-15).

In undisturbed areas of the southern Bay (USEPA Subunit 1), where little deposition has occurred and Be-7 concentrations indicate no recent deposition as of 2007, the maximum COPC concentrations are found in the surface samples, e.g., see the profiles for cores 003, 013 (Figure PF-3a), 014, and 025 (Figure PF-3b). As discussed, core 014 is located just north of the historical dike where deposition may have slowed after an initial period of infilling following construction.

Within the dredged navigation and port channel areas (USEPA Subunit 2), review of the sediment core profiles indicated lower concentrations of COPCs that are generally not elevated below 3 or 4 feet below the sediment surface (Figures PF-1 through PF-7 in Appendix L) likely attributable to periodic dredging activities. Within the formerly dredged channel (USEPA Subunit 3), some cores indicate some accumulation of COPCs in sediments that generally increase with depth. For example, in core 063, located in USEPA Subunit 3 near the mouth of the Passaic River, 4 feet of sediment has accumulated above the red clay layer[50] and 2,3,7,8-TCDD concentrations peaked at the bottom of the core (Figure PF-3F in Appendix L). Less accumulation (i.e., 1 to 3 feet) is noted in cores 055 and 061 located south of core 063 in the formerly dredged channel (Figure PF-3F in Appendix L).

5.5.4 Spatial Patterns in Contaminant Inventory

Contaminant distributions in the Bay can be examined by calculating a contaminant mass per unit area (MPA) to examine contaminant distributions in the Bay. The MPA calculation for each core estimates the mass of contaminant present based on the core length-weighted contaminant concentration for each core and the thickness of COPC-containing sediments. The MPA was calculated for TCDD, mercury, total DDx (4,4'), and total PCBs for cores collected during the Phase I and II investigation and are reported in milligrams per square foot. In areas where sediment thickness is high and contaminant concentrations are high – the MPA values will be highest, and vice versa. The MPA results are shown in Figures 5-INVEN-1a through 5-INVEN-1d, and distributions by USEPA subunit and geomorphic area on Figure 5-INVEN-2a through 5-INVEN-2d and are discussed in further detail below.

On both an USEPA subunit and a geomorphic area basis, MPA results for all contaminants exhibit similar spatial patterns in the Bay. This is expected due to the influence of core length on the calculation of the value. However, examination of the relative MPA values for each contaminant reveals subtle differences driven by the COPC concentrations within cores. 2,3,7,8-TCDD, PCBs, and mercury exhibit similar spatial patterns in the Bay, with lowest MPA values in the eastern subtidal flats south of the I-78 bridge, and highest in the northeastern subtidal flat area of the Bay, north of the I-78 bridge. MPA values for these contaminants tend to be highest in the northern portion of the Bay, show decreasing values in the central portion of the Bay, then increasing values in the southwestern subtidal flat areas. The MPA results are similar, except for the presence of relatively elevated (upper quartile) MPA values in the southwestern subtidal flats. These observations are consistent with the model results, which indicate the Arthur Kill is an ongoing source of total DDx (4,4') to sediments in the Bay.

[50] The native red clay layer was used as an indicator of the maximum depth of deposited sediments (Tierra 2011).

5.6 Contaminant Bioavailability

The potential risks from contaminants in the NBSA system to ecological receptors (i.e., invertebrates, fish, and wildlife) and humans are a function of site-specific exposures in the Bay. The extent and magnitude of exposure is, in turn, a function of a number of contaminant transport and storage factors that control the bioaccessability and bioavailability (i.e., as the term is used herein, the degree to which a substance is absorbed into a living system) of COPCs in surface water, sediments, porewater, and the food web (i.e., biological tissues). These include factors such as:

- Affinity of various COPCs for solids/fines, or to form complexes with other chemicals
- Concentrations of COPCs in the dissolved phase of surface water and porewater available for uptake through respiration by invertebrates and fish
- Burial of COPCs in sediments below the zone of invertebrate bioturbation (or potential for resuspension)
- Types of organisms present and their foraging and other life history habitats
- Ability of COPCs taken up by organisms to be metabolized and excreted, or preferentially stored in fat or other tissues/organs.

This section discusses the factors that may control bioavailability and fate in the NBSA.

5.6.1 Bioavailability Assessment Overview

It is important to evaluate the potential bioavailability of contaminants in the system to explain: 1) any observed toxicity or direct impacts to benthic communities from COPCs in sediments of the NBSA; and 2) the measured bioaccumulation of COPCs in biota at different trophic levels and feeding guilds in the Bay food web. The latter is the fate endpoint of most concern for many organic and inorganic COPCs, as it can influence long-term risks to humans and wildlife that consume aquatic organisms.

Direct toxicity to benthic and demersal (near bottom-dwelling) organisms is considered to be a function of factors that control the concentrations of contaminants present in the dissolved phase of porewater and overlying surface water (USEPA 2005a). Bioaccumulation, on the other hand, is a function of the integrated uptake of contaminants from water, sediment, and food ingestion. The proportional contribution of these sources of COPCs to the bioaccumulation in a given type of organism is dependent on its feeding strategy and food sources, and the levels of contamination present in water, sediments, and prey items (Iannuzzi and Ludwig 2000). For fish, the simplest and most rapid pathway for uptake of contaminants is via respiration of water through the gills. If COPCs are not present in appreciable concentrations in the dissolved phase of water, then food ingestion pathways are likely to be the more important influence on bioaccumulation.

A number of studies were designed and conducted under the NBSA RI and risk assessments to collect data sufficient to help quantify and characterize factors that control biological exposure and fate. These include:

- A characterization of the BAZ to evaluate the depth of likely sediment exposure for benthic (infaunal) organisms, and to help inform the characterization of likely bioturbation of COPCs in sediments (see Sections 5.4.4 and 5.4.5)
- Quantification of COPC, solids, and OC concentrations in both whole and filtered surface water samples
- Quantification of COPCs, OC, and sulfide concentrations, and grain size data in sediments samples
- Quantification of COPCs concentrations for the porewater within the interstitial spaces of surface sediments
- Quantification of COPCs and lipid concentrations in samples of the whole body and fractional portions of representative invertebrates (i.e., polychaetes, softshell clam, and blue crab) and fish (forage and predatory species from different feeding guilds and levels of the food web).

An integrated evaluation of these datasets was used to provide a characterization of bioavailability and fate of COPCs for the NBSA. A conceptual model for the likely transport and partitioning of COPCs between sediments, water, and biota is provided in Figure 5-BIOAV. This diagram provides a broad depiction of the general habitat types, potential sources of COPC exposure, and overall food web interactions for the Bay. Data were collected to evaluate the COPC distributions in select representative organisms of invertebrates and fish (as described above) for evaluation in the RI and the risk assessments. Grass shrimp, while noted in Figure 5-BIOAV as present in the NBSA food web, were not collected. Despite the fact that they have been shown to accumulate contaminants when present in the system (Pruell et al. 1993), their reported seasonal presence in the Bay is sporadic and, as such, it is likely that their relative contribution as the overall food source for fish in the NBSA is limited.

Statistical evaluations were conducted as part of this RI and the risk assessments to evaluate potential relationships between the COPC concentrations in these different media, and with respect to potential normalizing factors in sediments and tissue (e.g., OC, sulfides, lipid) and their ability to describe spatial variability in the COPC data. Summaries of key findings from these analyses are provided to help characterize bioavailability and fate of COPCs in the NBSA.

5.6.2 Organic COPCs Bioavailability

Benthic infaunal organisms are exposed to chemicals dissolved in the interstitial waters in sediment (i.e., porewater) and via ingestion of sediment particles and food sources (e.g., detrital material, plankton). Organic COPCs were detected in the 30 porewater samples collected in the NBSA (Table 4-25). The porewater concentrations, as measured by passive samplers, represent the freely dissolved concentrations in interstitial waters. Many COPCs such as 2,3,7,8-TCDD, PCBs, pesticides DDx, dieldrin, chlordane, and hexachlorobenzene), and PAHs[51] were detected in all samples indicating that they are bioavailable.

[51] PAH concentrations in tissues may be underestimated based on a comparison to USEPA split sample results. Corrective action was implemented by GSH and sediment samples were reanalyzed; however, tissue samples were not reanalyzed and the tissue data likely are biased low.

Figures 5-BIO-1 through 5-BIO-4 (upper left graph) show the relationships between concentrations of COPCs in porewater versus sediment (dry weight basis) for selected COPCs (i.e., 2,3,7,8-TCDD, total PCBs, total DDx (2,4' and 4,4'), and total PAHs). (See Figures PWSED-1 through PWSED-3 of Appendix M for a complete set of organic COPCs on both a dry weight and an OC-normalized basis.) For most organic COPCs (i.e., 2,3,7,8-TCDD, total PCBs, and total DDx (2,4' and 4,4')), porewater concentrations are correlated with sediment concentrations (Figures 5-BIO-1 through 5-BIO-3, upper left graphs). Normalization of sediment concentrations to OC does not improve this relationship or reduce the variability in the relationship. For PAH concentrations however, there is no apparent relationship between porewater and sediment (Figure 5-BIO-4; Figure PW-SED-3 in Appendix M). Under the assumptions of equilibrium partitioning theory, PAHs in porewater should be predictable from sediment concentrations and OC content; however, in application, large variation in partitioning is associated with the type of OC that is present, whether it be natural (i.e., plant-based) or anthropogenic, such as coal, soot (black carbon[52]), tars, etc. (USEPA 2017). Lambert et al. (2011) compared the distribution of PAHs, PCDDs, and PCDFs in the Passaic River and NBSA to the distribution predicted by an OC partitioning model and a black carbon-inclusive Freundlich distribution model. PAH, PCDD, and PCDF distributions were underpredicted by the OC model by 10 to 100-fold, whereas the black-carbon inclusive Freundlich model predictions were within a factor of two to three of measured PAH concentrations. Lambert et al. (2011) found the presence of black carbon may significantly reduce porewater concentrations, and therefore the bioavailability, of PCDDs, PCDFs, and PAHs. The nature of the OC was not assessed in the NBSA sediment samples; therefore, it is unclear what role other forms of carbon play in the PAH porewater-sediment relationship. While organic COPCs were detected in porewater, as discussed in the BERA for the NBSA (GSH 2020), their concentrations were generally low with respect to the New Jersey saline WQC for aquatic life and other screening criteria. The following exceptions were noted. Total DDx (4,4') exceeded the chronic WQC for 4,4'-DDT in 14 of 30 porewater samples; although, among the observed concentrations of the single isomer on which the criteria are based, there were no exceedances. There is no specific WQC for total DDx (4,4'). Total PCB congeners exceeded the chronic WQC in three of the 30 porewater samples.

To help assess exposure and uptake (or fate) of sediment bound contaminants, a laboratory bioaccumulation study was performed by exposing the polychaete test species, *Nereis virens*, to eight surface sediment samples from the NBSA. After a 28-day exposure, tissue samples were analyzed for a suite of chemicals to examine uptake by a representative benthic invertebrate organism that lives in the sediments of the NBSA (GSH 2017d). Many COPCs such as 2,3,7,8-TCDD, PCBs, and pesticides (total DDx (2,4' and 4,4'), dieldrin, chlordane, heptachlor epoxide, and hexachlorobenzene) were detected in all eight polychaete tissue samples. In contrast, PAHs had lower detection rates[53]. A few high molecular weight PAHs were detected in six of the eight samples. Alkylated PAHs were only detected in one of the eight samples. No LMW PAHs were detected. Figures 5-BIO-1 through 5-BIO-4 (upper right graph) show the relationships between concentrations of selected organic COPCs in tissue versus sediment. (See

[52] Lambert et al. (2011) found the presence of black carbon may significantly reduce porewater concentrations, and therefore the bioavailability, of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDDs/PCDFs) and PAHs.

[53] PAH concentrations in tissues may be underestimated based on a comparison to USEPA split sample results. Corrective action was implemented by GSH and sediment samples were reanalyzed; however, tissue samples were not reanalyzed and the tissue data likely are biased low.

Figures SEDPOLY-1 through SEDPOLY-3 in Appendix M for a complete set of organic COPCs on both a wet weight and lipid normalized basis for tissue and both dry weight and OC-normalized basis for sediment and for tissue versus porewater concentrations.) For most organic COPCs, tissue concentrations increase with concentrations in sediment and porewater. Lipid normalization does not appear to reduce the variability in the relationships. For many COPCs, porewater concentrations show a better relationship than sediment concentrations (e.g., PCBs, dieldrin). For others, the relationship has similar variability (e.g., 2,3,7,8-TCDD). It should be noted that individual PAH compounds or PCB congeners may exhibit different relationships between sediment and tissue than summations of these chemicals. However, the NBSA BERA was conducted using toxicity reference values (TRVs) that are based on groupings and summations of PAHs and PCBs; therefore, these summations were also evaluated for polychaete bioaccumulation.

Eighteen softshell clam (*Mya arenaria*) tissue samples were collected from intertidal areas within the NBSA along with co-located sediment (GSH 2017a). Most organic COPCs such as 2,3,7,8-TCDD, PCBs, pesticides (total DDx (2,4' and 4,4'), dieldrin, chlordane, heptachlor epoxide, and hexachlorobenzene) and PAHs were detected in all 18 softshell clam tissue samples (Table 4-27). Figures 5-BIO-1 through 5-BIO-4 (lower left graph) show the relationships between concentrations of selected organic COPCs in softshell clam tissue versus sediment. (See Figures CLAMSED-1 through CLAMSED-3 in Appendix M for a complete set of organic COPCs on both a wet weight and lipid-normalized basis for tissue and both dry weight and OC-normalized basis for sediment.) For most organic COPCs, tissue concentrations increase with concentrations in sediment. Lipid normalization does not appear to reduce the variability in the relationships. The relationship between COPC concentrations in sediments and softshell clam tissues is expected, as these organisms live in close association with the sediments and feed by filtering suspended sediment particles, plankton, and detritus from the overlying water.

Seventeen samples of resident forage fish (mummichog, and striped killifish) of the genus *Fundulus* were collected in the NBSA along with co-located sediment. These species have small home ranges and therefore might be expected to have COPC concentrations that track the co-located sediment concentrations. Most organic COPCs such as 2,3,7,8-TCDD, PCBs, and pesticides (total DDx (2,4' and 4,4'), dieldrin, chlordane, heptachlor epoxide, hexachlorobenzene, and BHC compounds) were detected in all forage fish tissue samples (Table 4-30). PAHs were detected less frequently, which might be expected because PAHs are metabolized in fish and typically excreted as polar metabolites; however, this may also be due to potential bias[54]. Figures 5-BIO-1 through 5-BIO-4 (lower right graph) show the relationships between concentrations of selected organic COPCs in tissue versus sediment. (See Figures FISHSED-1 through FISHSED-3 in Appendix M for a complete set of organic COPCs on both a wet weight and lipid-normalized basis for tissue and both a dry weight and OC-normalized basis for sediment.) Tissue concentrations tend to increase with sediment, but there is much variability in the relationship. Lipid normalization does not appear to improve the relationship.

As described in the BERA (GSH 2020), for higher trophic level shellfish, fish, and wildlife that utilize the Bay, the food web exposure pathways are the primary influence on bioaccumulation. Surface water concentrations of COPCs in the NBSA are generally low compared to WQC for aquatic life; however, 24%

[54] PAH concentrations in tissues may be underestimated based on a comparison to USEPA split sample results. Corrective action was implemented by GSH and sediment samples were reanalyzed; however, tissue samples were not reanalyzed and the tissue data likely are biased low.

of surface water samples exceeded the chronic total DDx (4,4') criteria (Table 4-19). Direct exposure to porewater is not a significant pathway for mid- to high-trophic level fish. Sediment ingestion is incidental and accounts for a low overall portion of the diet of fish and wildlife receptors. In addition, most of these organisms are migratory and are only exposed in the Bay for portions of their lives. Therefore, the CFT pathways that control the uptake of COPCs into the resident lower trophic-level organisms on which they feed while in the NBSA are primarily responsible for their exposure. These include the depth of the BAZ, burial and flushing processes, bioturbation, and COPC inputs from ongoing sources.

5.6.3 Inorganics/Metals Bioavailability

Most inorganic COPCs (except for chromium and mercury), had low FODs in porewater (Table 4-25). In addition, there were no strong associations between porewater and sediment concentrations for inorganic COPCs (Figure 5-BIO-5; Figure PWSED-4 in Appendix M). This indicates that inorganics/metals bioavailability is low and that metal fate and transport are governed by sediment processes, similar to organic COPCs. Both mercury and methylmercury had high FODs in porewater and as discussed in Section 4.5, close to 100% of mercury in porewater appears to be in the methylated form making it more bioavailable to benthic organisms. The methylation process can occur either in sediments/porewater (i.e., via microbial activity) or within organisms themselves (i.e., fish). The bioavailability that results from the methylation process is accounted for in the risk assessments via direct measures of mercury bioaccumulation and exposure. As discussed in Section 6.2.4.2, mercury did accumulate in some benthic receptors and fish to levels suggesting ecological risk.

In the polychaete laboratory bioaccumulation study, most inorganic COPCs were fully detected in tissue. Cadmium was detected in seven of eight samples and chromium in six of eight. There was no strong association between polychaete tissue and sediment or porewater concentrations for inorganic COPCs (Figure 5-BIO-5; Figure SEDPOLY-4 in Appendix M); although, this was expected given that invertebrates (and all organisms) regulate tissue concentrations of essential metals and where regulated, metals will remain constant over a range of sediment or porewater concentrations. For example, copper in tissue may be constant over a range of values within which regulation can be maintained by the organism and then beyond that range, begin to increase with exposure (Paquin et al. 2007). Given that such a relationship was not observed, may indicate that copper exposure was within the range of regulation and/or that copper is not bioavailable in the sediments. As described further below, metal sulfide complexes likely rendered divalent metals (i.e., cadmium, copper, nickel and zinc) non-bioavailable. Organism size is not likely a factor since polychaetes were from a similar source and randomly selected.

Most inorganic COPCs had a 100% FOD in softshell clam tissue (Table 4-27). Tissue concentrations tended to increase with sediment concentrations, but there is much variability in the relationship (Figure 5-BIO-5; Figure CLAMSED-4 in Appendix M). Invertebrates may regulate their body burdens of some metals; although, metals regulation, and the strategy thereof, is species and metal specific (Adams et al. 2011; USEPA 2007b). This adds a source of variability in establishing relationships between concentrations in invertebrate tissue and sediments, thus analyses are presented on a species- and metal-specific basis.

Most inorganic COPCs had high FOD in forage fish tissue (Table 4-30). Nickel had 40% FOD and cadmium was not detected in any forage fish. Tissue concentrations tended to increase with sediment concentrations, but there is much variability in the relationship (Figure 5-BIO-5; Figure FISHSED-4 in

Appendix M). All fish actively regulate the uptake and distribution of essential metals (e.g., copper and zinc) necessary for normal metabolic function, and non-essential metals may also be regulated by these systems because they mimic essential elements (Bury et al. 2003). This adds a source of variability in establishing relationships between concentrations in fish tissue and sediments.

For higher trophic level fish and wildlife, inorganic/metals exposure is a function of the relative bioaccumulation potential of a COPC and the physiological regulation of the metals as essential elements needed by these organisms for metabolic processes (USEPA 2005a; Bury et al. 2003). Thus, as discussed in the BERA (GSH 2020), concentrations in tissues or diets of these organisms as they relate to potential risk, need to be considered on a chemicals-specific basis. The factors controlling the exposures/uptake of these COPCs in migratory fish and wildlife that utilize the Bay are variable and hard to quantify. As with the organic COPCs, those factors that control the uptake of inorganics/metals into the resident lower trophic-level prey organisms in the NBSA may be the most important distinguishing factor to differentiate incremental site-related exposures from background.

Potential bioavailability was also evaluated specifically for divalent metals in sediment using equilibrium partitioning theory (USEPA 2005a). A total of 61 surface sediment samples collected during the Crab/Clam (GSH 2017a) and SQT (GSH 2017d) sampling programs were analyzed for AVS and SEM. Under the equilibrium partitioning theory, divalent metals partition in sediment between AVS, interstitial water (i.e., porewater), benthic organisms, and other sediment phases such as OC (USEPA 2005a). Sulfides are typically present in sediments under relatively anoxic and reducing conditions. The divalent metals (i.e., cadmium, copper, lead, nickel, and zinc) bind to available sulfides in the sediments and are precipitated as metal sulfide solids/complexes. These metal sulfide complexes are not bioavailable in sediments and, therefore, are non-toxic to benthic organisms (USEPA 2005a). In addition, total OC contributes to the lack of bioavailability (USEPA 2005a). To evaluate the bioavailability of divalent metals, SEM concentrations are summed and the AVS concentrations are subtracted to give the value ∑SEM-AVS. If the value is negative, it is inferred that the metals are bound to the AVS in sediment and not bioavailable (USEPA 2005a). Further, ∑SEM-AVS is divided by the fraction (f) of OC in the sample giving the quantity (∑SEM-AVS)/f_{OC}. Based on toxicity experiments, when (∑SEM-AVS)/f_{OC} is less 130 micromoles per gram of OC, no toxicity is expected (USEPA 2005a) because of the lack of bioavailability. Eleven of the 61 samples have values exceeding 0 for ∑SEM-AVS (Table 5-17). Of those 11, only two have (∑SEM-AVS)/f_{OC} values that exceed 130, location NB03SED123BCL (134 micromoles per gram OC (µmol/g-oc)) and location NB03SED129CL (189 µmol/g-oc). None of the eight sediment samples from the bioaccumulation study indicated bioavailability of divalent metals. Therefore, in general, according to equilibrium partitioning theory, these metals should not be bioavailable or toxic to benthic organisms and stay associated with the sediment in the NBSA. The porewater data also suggest low bioavailability of the divalent metals. Cadmium and nickel (along with monovalent silver, which also binds to sulfide) were not detected in any of the porewater samples. The FOD was low for copper, lead, and zinc (17%, 21%, and 10% respectively). However, as discussed in the BERA (GSH 2020), there were a few exceedances of acute WQC for zinc (3) and copper (1) in porewater samples for which their sediment ∑SEM-AVS values do not predict bioavailability. It is unknown why metals were detected in porewater where it is not predicted, but one possible explanation is that oxidation had occurred.

5.6.4 Biologically Active Zone Depth Assessment for Risk Characterization

A study conducted in October 2005 at 14 stations in the Bay utilized sediment profile imagery and supplemental grab samples to determine the BAZ (Tierra 2008a). Results of the study indicate that the surface sediment is structured by physical (e.g., currents and sediment movement) and biological processes (e.g., movement of infaunal organisms), both of which can affect the bioavailability and transport of chemical constituents. The fauna and biogenic structures observed in the images and grab samples were sufficient to bioturbate sediment to the estimated total BAZ depths of 5.4 to 6.5 inches (average of approximately 6 inches or 0.5 foot). Therefore, this sediment interval was the focus of the risk characterization.

5.6.5 Benthic Invertebrate Community and Toxicity Assessment

A number of historical studies have been conducted on the benthic invertebrate communities of the NBSA. These studies typically demonstrated that the benthic invertebrate communities throughout the Bay were characterized by relatively low diversity and abundance, and that the benthic environment was stressed from various pollutants and anoxic conditions. Most notably, in 1993/94, 1998 to 1999, 2003, 2008, and 2013, USEPA (under REMAP) collected benthic invertebrate samples throughout the NBSA (Adams 2016; USEPA 2003a). A summary of the benthic community indices calculated under the REMAP by year are presented in Table 5-18. The pre-NBSA RI period (i.e., before 2004) REMAP studies concluded that the overall benthic invertebrate communication was characterized by low abundance and diversity and dominated by pollution-indicative species. The 1993 to 2003 B-IBI values, an index calculated based on various structure and abundance metrics, indicated that as much as 90% of the Bay was classified as moderately to highly impacted. In the 1998 study, all but one station within the NBSA boundaries was considered highly impacted (USEPA 2003a).

Table 5-18. Historical Benthic Community Indices from REMAP

Metric	REMAP Study Year					BERA
	1993/94	1998	2003	2008	2013	2015
Number of NBSA Stations	**18**	**13**	**11**	**11**	**11**	**30**
Species Richness						
Number of Species	73	53	73	71	22	106
Means of Benthic Variables (± 90% confidence interval)						
Species Richness (as number species/sample)	19 (±2.5)	14 (±2.4)	22 (±4.8)	22 (±3.5)	6.7 (±1.2)	23 (±2.9)
Pollution-Sensitive Species (%)	0.5 (±0.5)	1.7 (±1.8)	2.4 (±2.2)	3.5 (±3.4)	0	1.7 (±0.8)
Pollution-Indicative Species (%)	57 (±7.5)	47 (±13)	42 (±8.5)	20 (±9.2)	41 (±12)	31.2 (±4.9)
Species Diversity (Shannon-Wiener)*	1.5 (±0.14)	1.8 (±0.21)	1.8 (±0.19)	1.9 (±0.13)	1.3 (±0.16)	2.2 (±0.10)

Notes:
* Natural Log Calculation
All values calculated from raw data.
NBSA = Newark Bay Study Area
SQT = sediment quality triad

More recent studies on infaunal benthic communities conducted during the period of the NBSA RI—which include the 2008 and 2013 REMAP studies, and surveys conducted in 2015 as part of the SQT and Porewater Study for the BERA—have shown a substantial improvement in benthic community conditions in the Bay. An apparent downward trend in the species diversity (richness) and B-IBI values for the 2013 REMAP dataset may be due to the short-term effects of Superstorm Sandy on benthic communities. The values from the 2015 SQT program show a return to the relatively unimpacted conditions similar to those from the 2008 REMAP study. In the 2015 SQT and porewater investigation, a cumulative total of 106 individual taxa were found throughout the Bay, with a range between 8 and 46 taxa identified per individual sample location.

Metrics on the diversity and abundance of invertebrates have also improved (i.e., more diversity and evenness of species found) in recent years. Compared to historical REMAP studies, the B-IBI for the 2015 surveys indicates that the majority of the Bay benthos are considered to be not impacted. Improvements to benthic community conditions are likely due to improving conditions in the Bay in terms of water and sediment quality, and a decrease in bioavailability of COPCs.

Improvements in the incidence of acute toxicity, defined as 10-day amphipod survival significantly different from control in laboratory tests, have also been observed. In a toxicity study conducted by NOAA (1995), 88% of samples in the NBSA were toxic. The percentage of toxic samples generally declined over the years of the REMAP studies: 22% in 1993/1994, 54% in 1998, 9% in 2003, 9% in 2008, and 0% in 2013. Laboratory toxicity testing results with NBSA sediments indicate most of the Bay is non-toxic (GSH 2020). Where acute toxicity was observed, most COPCs were at their highest (i.e., 90th percentile) concentrations in surface sediments and porewater.

5.7 Summary

Multiple lines of evidence available from a series of sampling events and fate and transport modeling provide a good understanding of the sediment transport and CFT processes affecting COPC concentrations in surface sediments over time. Declines in bioavailable concentrations of COPCs in surface sediments leading to risk reduction, is driven by a combination of reduction of external sources to the Bay, natural recovery processes (including burial), and subsequent reduction of resuspension and dissolved phase flux to the water column and redistribution within the system. Data trends show long-term declines in COPC concentrations in surface sediment, increases in benthic invertebrate diversity and abundance, and declining sediment toxicity to benthos. Model predictions developed by USEPA corroborate these empirical lines of evidence by showing declining trends in surface sediment COPC concentrations over the historical model simulation period (1996 to 2013), but also illustrate the importance of controlling sources of COPCs from tributaries and other sources to enhance and sustain these declines over time. The following summary lists key information concerning CFT processes and observed declines of COPCs in the NBSA sediments:

- Findings of trend analysis from co-located surface sediment samples repeatedly sampled over an 11-year period
- Comparison of changes in COPC concentrations from USEPA REMAP surface sediment sampling data sets spanning a 20+-year period

- Improvements in the overall health (e.g., diversity and abundance) of the benthic invertebrate communities in the NBSA, and substantial declines in surface sediment toxicity to benthic invertebrates based on datasets (USEPA REMAP and BERA SQT) spanning a 20+ year period, likely due to declines in COPC concentrations and bioavailability
- Calculated rates of decline in surface sediment COPC concentrations from radio-dated sediment core profiles collected between 2005 and 2007
- Influence of particulate concentrations of COPCs on reductions in bioavailable surface sediment concentrations in the Bay
- Importance of source control to reduce COPC inputs to the Bay to enhance further reductions in bioavailable surface sediment concentrations
- Stability of existing sediment deposits in subtidal flats and historically disturbed areas, and influence of ongoing deposition on natural recovery processes
- Impact of maintenance dredging activities on mass inventory of COPCs and reductions in bioavailable surface sediment concentrations in the Bay.

These findings are discussed in further detail in the following sections.

5.7.1 COPC Concentration and Toxicity Declines in Surface Sediments

While there is some spatial heterogeneity among locations, trend analyses of co-located samples from the Phase I, II, and III data presented in Section 4 and Section 5.5.3 show that concentrations of COPCs have declined across the NBSA. These datasets are the best available direct LOE as to the reduction in surface sediment COPC concentrations over time; although, human health and ecological risks are still present due to contaminant levels in fish and crab tissues in the Bay. The sampling approach and methods were developed specifically to assess changes in COPC concentrations in the bioavailable zone. The data comparisons show that concentrations of most COPCs except arsenic have declined in the NBSA. Average rates of decline are nominally 3 to 5% per year for 2,3,7,8-TCDD, PCBs, total DDx (4,4') and mercury between 2005 and 2016. Rates of decline estimated from the RI sediment data are subject to uncertainty and may not be predictive of future conditions. At a few locations, an increase in COPC concentrations between 2005 and 2016 was noted, suggesting that declines may not be universally present at all areas of the Bay, particularly where deposition rates are very low or where particulate concentrations suggest ongoing inputs of COPCs. Heterogeneity in sediment concentrations may also cause variability in comparing resample results near a single location. The proposed USACE channel deepening and widening project (USACE 2020) is likely to expose legacy sediments in the historically disturbed areas of the subtidal flats, which may influence future rates of changes in COPC concentrations in the NBSA. Actual effects of this project will be further evaluated in the FS.

Comparison of datasets from USEPA's REMAP program from 1993 through 2013 show that concentrations of several COPCs in the top 2 cm are declining; however, the datasets are too limited to conclude statistical significance of differences and the pesticide data appear to be unreliable for assessing a trend. In the REMAP dataset, arsenic levels did not show declines. The REMAP concentrations of some COPCs in 2013 were nominally two orders of magnitude lower than the Phase III data, which may reflect a difference in concentrations in the top 2 cm versus the top 6 inches, or some other factor.

The declines in COPC concentrations in the surficial sediments are congruent with observations from data collected in 2015 of no or low toxicity to benthic invertebrates, and the establishment in recent years of unimpaired benthic communities (relative to reference) as described in the BERA (GSH 2020) and Section 5.6. A small number of the sample locations (2 of 30, Figure 4-28) exhibited acute toxicity (based on 10-day amphipod survival) in conjunction with relatively elevated concentrations of multiple COPCs in the surficial sediments and these occurred in the southwest area of the Bay within the historically disturbed subtidal flats. While acutely toxic, these samples had only slightly impacted benthic communities according to B-IBI scores. One other location in the southern Bay had an impacted benthic community according to B-IBI score but did not exhibit toxicity. For those locations that exhibited acute toxicity in this area, the concentrations of most COPCs are at the 90th percentile of their Bay-wide concentration ranges. In addition to those locations, chronic toxicity (based on 28-day amphipod survival) was observed at four additional locations, two in the north and two in the central part of the Bay (Figure 4-28).

Future reductions of COPC concentrations in fish and crab tissue are expected to follow reductions of bioavailable concentrations of COPCs in surface sediments; however, exposures derived outside of the NBSA may cause lags in the rate of decline of COPC concentrations in some species (for example migratory species that accumulate portions of their body burden outside of the NBSA). Conversely, any future increases in concentrations that may take place in the system (for example, from uncontrolled tributary inputs or industrial releases) could lead to an increase in sediment toxicity and bioaccumulation at locations that currently exhibit limited impacts. Even if temporary increases occur, the USEPA CFT model results spanning the 2011 Hurricane Irene event show that declining trends in surface sediment concentrations resume relatively quickly after increases associated with episodic COPC loading events.

5.7.2 Historical and More Recent Declines in Sediment COPCs

Estimated historical mean annual rates of decline in COPC concentrations since 1980 range from 2% to 5% (Table 5-16). These estimates are based on dateable Phase I/II cores which are biased towards areas with high deposition rates such as historically disturbed subtidal flats. More recent rates of sediment burial are slower yet are still indicative of the importance of long term sedimentation in driving continued reductions in surface sediment concentrations. The presence of historical structures, and geomorphic changes related to development, may also have affected patterns of deposition in the Bay.

5.7.3 Influence of Incoming Contaminated Particulates

Particulate concentrations in the water column of the NBSA and tributaries (Table 5-14) suggest the potential for ongoing sources of contaminated sediment, but also point toward deposition of new sediments as a contributor to future declines in surface sediment concentrations due to the lower COPC concentrations on incoming particulates in comparison with current surface sediment concentrations. With the exception of PCBs, particulate COPC concentrations on the incoming tides from the Kill Van Kull suggest a source of comparatively less contaminated sediments that could promote natural recovery processes. Total PCB concentrations in particulates are similar among tributaries to the NBSA (Table 5-14); however, the Kill Van Kull, being the largest source of solids (Figure 5-MOD-2A), is a slightly larger source of PCB mass flux to the NBSA than the Passaic River in non-hurricane years (1996-2010, 2012, and 2013). Greater particulate COPC concentrations in other tributaries suggest potential sources. The Passaic River may be an ongoing net source of COPCs to the NBSA, which is expected to be reduced by

implementation of the remedy selected by USEPA for the lower 8.3 miles of the LPR. The Arthur Kill is likely an ongoing source of total DDx (4,4'). The model results suggest that the Hackensack is a net sink of mercury from the Bay. However, based on annual loads measured at the head of tide (Table 5-14), the Hackensack is potentially an ongoing source for mercury. In addition, the Pierson's Creek Superfund site is a source of mercury into the NBSA via the Port Newark Channel.

5.7.4 Mass Balance Analysis of Connected Waterway Exchanges

From the USEPA CFT model results for the period 1996 to 2013, analysis of sediment and COPC mass fluxes between the NBSA and connected waterways show that, due to bi-directional tidal currents, the Bay is a source of sediments and COPCs to connected waterways, and all connected waterways are sources of sediments and COPCs to the Bay. The export of sediments and COPCs to connected waterways from the Bay can be increased during periods of low freshwater discharge. High freshwater discharge from rainfall runoff can increase contaminant loadings to the Bay, and flushing of the Bay, which can have short-term effects on both solids and contaminant fluxes at the boundaries of the NBSA. This illustrates the importance of source controls to reduce COPCs inputs from adjacent waterways to facilitate further reductions in bioavailable surface sediment concentrations of the Bay. However, net flux determines the role each waterway plays in determining the inventory of contaminants in the Bay and relative importance of the different mechanisms supporting these reductions. Summary findings include:

- For the period from 2004 through 2013, outflows remove 80% of the suspended solids from the water column of the NBSA.
- Deposition accounts for 20% of the loss of solids from the NBSA water column, but approximately 80% of the sediments deposited in the Bay are captured in the Port Channels.
- COPC discharges to the Bay during the Hurricane Irene event in 2011 were larger than all prior years combined of the model period; however, the model showed declines in surface sediment concentration trends resumed after the event.
- During the 2011 hurricane event, the Passaic River was a large source of both COPCs and sediments to the NBSA, and surface sediment COPC concentrations increased in response to the event, showing the importance of remediation of the Passaic River to facilitate reductions in bioavailable surface sediment concentrations in the Bay.
- The Arthur Kill is shown to be an ongoing source of contamination, including total DDx (4,4'), to the sediments in the Bay. Reduction of total DDx (4,4') inputs from Arthur Kill may be needed to ultimately achieve remedial goals in the NBSA.
- The Kill Van Kull is shown to be an ongoing source of solids, tetra-PCB and mercury to the sediments in the Bay. The Kill Van Kull acts as an export pathway for total DDx (4,4') and 2,3,7,8-TCDD from the Bay.

5.7.5 Recovery Processes in the Subtidal Flats

The subtidal flats are of key importance and natural recovery processes in these large shallow areas include deposition and bioturbation, which add sediment and OC to the sediment bed. As external and internal sources to the NBSA are reduced, these additions will contain lower concentrations of COPCs.

Sediment burial occurs at slow rates, but gradually sequesters historical contamination out of the BAZ. Sediment-water transfer via resuspension and diffusion result in a portion of the inventory being exported from the subtidal flats into the navigational channels or removed via outflows from the Bay. Of these, long-term burial and sequestration is likely most important in governing future declines of COPC concentrations in the BAZ of the subtidal flats, understanding that for this mechanism to improve surface sediment quality, the depositing solids must be less contaminated than the existing surface sediment and the areas would need to remain net depositional in the future. The RI data indicate that some locations in the Bay have these characteristics.

Intrinsic rates of decline in surface sediment concentrations in the subtidal flats can be estimated by the burial rate (nominally 0.2 to 0.5 cm/yr) divided by the mean BAZ thickness (5.2 to 5.7 inches), which provides an attenuation rate of 0.013 per year to 0.04 per year (1.3% to 4% per year). The actual half-life at specific locations will be influenced by factors such as the actual bioturbation depth and intensity. Locations with greater bioturbation may exhibit a longer half-life of persistent chemicals, or slower attenuation rate, compared to other locations with the same long-term average net sedimentation rate and the same particulate chemical concentrations on the depositing solids. Expression of this rate as a half-life, and assuming relatively clean solids, suggests that the lower bound recovery half-life in the subtidal flats due to burial would be approximately 18 to 52 years. However, half-lives would tend to be lengthened by increasing COPC concentrations of depositing solids (see Section 5.5.1 and Table 5-14). As summarized in Section 5.5.3, observed rates of decline from 2005/2007 to 2016 ranged from 2.9% to 5.4% (most of the 2016 cores were from the subtidal flats). These rates are equivalent to half times of 12 to 23 years. Interpretation of model results for 2,3,7,8-TCDD concentrations in the top 6 inches for the period 1995 through 2019 (see Section 5.4.7) show similar rates of decline, but with variation by sub-area.

Available critical shear stress data (presented in Section 5.4.6) suggest the southwest subtidal flat area is relatively stable – this, in addition to low rates of burial, contributes to persistence of sediment COPC inventories in these areas.

5.7.6 Maintenance Dredging Removal of Sediment

The periodic removal of sediment from the navigational channels, which continue to be dredged by the USACE to maintain navigational depths, will aid further reductions in bioavailable surface sediment concentrations of COPCs in the NBSA by removing these inventories from potential export out of the NBSA via flushing, or to other areas of the Bay. The frequency of maintenance dredging and the impact of this dredging will likely be a dominant process governing temporal trends of COPCs in the navigational channels. A harbor widening and deepening project to be implemented over a period of 14 years has been proposed (USACE 2020) with a tentative date of construction beginning 2024. The proposed harbor deepening project is expected to increase the federal navigational channel (south of Port Elizabeth) to a depth of -55 feet MLLW and also widen the channel (USACE 2020). This widening would result in the removal of sediments west of the channel on the southwestern subtidal flat and on the subtidal flats east of the channel from Bayonne Point to the Elizabeth Channel. The proposed widening of the channel may impact previously identified high net depositional areas where varying thicknesses of contaminated sediments have accumulated depending on the degree of disturbance. Concentrations of 2,3,7,8-TCDD in these historical depositional zones can extend up to 18 feet bss. Mercury extends up to 22 feet bss in these historical depositional zones. Recognizing that the subtidal flats have an elevation of about -10 feet MLW, the 2,3,7,8-TCDD and mercury contamination may extend to about -30 feet MLW; therefore, the

side slopes in the widened channel following construction will intersect a swath of the high net depositional area. Removal and exposure of these contaminated sediments in the historically depositional areas may affect estimated rates of decline in surface sediment COPC concentrations presented in the RI; actual effects of this project will be further evaluated in the FS.

6 RISK ASSESSMENT SUMMARY

6.1 Baseline Human Health Risk Assessment Summary

This section summarizes the USEPA-approved BHHRA that was prepared as part of the RI/FS for the NBSA (GSH 2019b) and is included as Appendix A to this RI Report. The BHHRA meets the requirements of the AOC and National Contingency Plan (NCP) (USEPA 1990).

The BHHRA was performed in accordance with applicable USEPA risk assessment guidance (USEPA 1989, 1991a, 1991b, 2001, 2004b, 2009, 2014b). The BHHRA presents the methods and procedures used and reflects USEPA Region 2 and GSH agreements and agency directives for conducting baseline risk assessments. The BHHRA was conducted in accordance with the following four-step paradigm for human health risk assessments developed by USEPA (1989):

1. Data evaluation and hazard identification
2. Exposure assessment
3. Toxicity assessment
4. Risk characterization.

Each step is summarized in the following subsections.

6.1.1 Data Evaluation and Hazard Identification

The purpose of the data evaluation and hazard identification process is twofold: 1) to evaluate the nature and extent of the release of chemicals present within the NBSA; and 2) to identify a subset of these chemicals as COPCs for quantitative evaluation in the BHHRA. This step of the risk assessment involves compiling and summarizing the data and identifying COPCs and is fully detailed in Sections 3.1 and 3.2 of the BHHRA (Appendix A).

6.1.1.1 Data Evaluation

As described in Section 2.1, several USEPA-approved sample collection programs have been conducted in support of the RI/FS. The relevant datasets used in the BHHRA are summarized in the following subsections for each medium of interest (surface sediment, surface water, and fish and crab tissue).

6.1.1.2 Surface Sediment Dataset

The BHHRA includes surface sediment sample data from the following sampling programs between 2014 and 2015:

- Crab and Clam Sampling Program (Crab/Clam) (see Section 2.1.3.3; sampling locations on Figure 2-3)
- SQT Program (see Section 2.1.3.5; sampling locations shown on Figure 2-7).

To assess the impact of direct human contact with sediment (dermal and incidental sediment ingestion), sediment samples at human-accessible points along the shoreline were evaluated.

The BHHRA includes sediment sample data from 16 accessible locations from the Crab/Clam program and 23 accessible locations from the SQT program, as shown on Figure 6-1. Additional sediment samples were collected in the Phase III Sediment Investigation (Section 2.1.3.6); however, because none of the locations were considered accessible, no samples from this investigation were evaluated as part of the BHHRA.

6.1.1.3 Surface Water Dataset

The BHHRA includes data from the Small Volume Chemical Water Column Monitoring Sampling Program, performed as part of the RI/FS for the LPRSA (AECOM 2019b). Data were collected during five rounds of routine sampling and two high-flow sampling events (see Section 2.1.3.7) and included six locations within the NBSA. To reflect likely human interaction with surface water (i.e., wading, swimming, or boating), the BHHRA evaluated only samples that were collected at a depth of 3 feet or less (depth rounded to a single significant figure) for a total of 131 samples over the seven events at the six NBSA locations.

6.1.1.4 Fish and Crab Tissue Dataset

The BHHRA includes data from the fish and crab tissue collection programs conducted in the NBSA (see Sections 2.1.3.4 and 2.1.3.3, respectively). Fish sampling activities were conducted within the three Newark Bay (Bay) geographic zones (North, Central, and South) during three fish sampling events: fall 2014, spring/summer 2015, and spring 2016. Blue crab (*Callinectes sapidus*) sampling activities were conducted in September and October 2014. Blue crab samples were collected from 12 intertidal areas; further blue crab samples were collected from each of the three Bay geographic zones (eight locations in North, eight locations in Central, and nine locations in South Newark Bay) (Figure 2-3).

The BHHRA includes data only for fish species from which fillet samples were collected: American eel (*Anguilla rostrate*), bluefish (*Pomatomus saltatrix*), striped bass (*Morone saxatilis*), summer flounder (*Paralichthys dentatus*), and white perch (*Morone americana*). Blue crab tissue samples included separate muscle and hepatopancreas samples. Although no combined muscle/hepatopancreas samples were collected directly, combined muscle/hepatopancreas results were calculated mathematically from the separate muscle and hepatopancreas results for each analyte. Specifically, muscle and hepatopancreas samples collected at the same location at the same time were from the same crab. Based on precise weight measurements of hepatopancreas, muscle and carcass of 34 individual crabs from station 129 (all crabs in composite measured) and station 131 (five of the crabs in the composite measured), it was estimated that 74% of the combined tissue mass for each crab was composed of muscle, and 26% was composed of hepatopancreas. Accordingly, the combined value was a weighted average of the separate muscle and hepatopancreas values, with weight 0.74 for muscle and 0.26 for hepatopancreas. Although blue crab carcass samples were collected, these were not analyzed as part of the BHHRA because they are not considered relevant to human ingestion patterns.

Table 6-1 summarizes the number of tissue samples collected for each fish species and crab tissue type used in the BHHRA.

Table 6-1. Summary of Tissue Samples used in the BHHRA

Matrix	Species	Tissue	Number of Samples
Fish	American eel	Fillet	18
Fish	Bluefish	Fillet	18
Fish	Striped bass	Fillet	21
Fish	Summer flounder	Fillet	18
Fish	White perch	Fillet	22
Crab	Blue crab	Hepatopancreas	37
Crab	Blue crab	Muscle	37

6.1.1.5 Constituent of Potential Concern Selection

A total of 82 chemicals (Table 6-2) were identified as COPCs in one or more of these media based on a screening process that considered carcinogen status, essential nutrient status, FOD, and comparison of maximum concentrations (the higher of the maximum detected concentration or maximum detection limit) to risk-based screening levels, similar to the Revised Pathways Analysis Report (Battelle 2018). These included PCDDs/PCDFs, PCBs, PAHs, various pesticides and inorganics, a few TPH ranges (PHC as gasoline and TPH [C9-C40]), VOCs, and SVOCs. An additional 56 chemicals were evaluated qualitatively in the uncertainty evaluation. The COPC screening process was designed to ensure that chemicals not identified as COPCs are only minor contributors to overall site risks and noncancer hazards. Selection of COPCs is fully detailed in Sections 3.3 and 3.4 of the BHHRA (Appendix A).

6.1.2 Exposure Assessment

The human health CSM is depicted in Figure 6-2 and identifies the sources, media, and exposure pathways by which humans are exposed to COPCs in the NBSA. The objective of the exposure assessment was to estimate the magnitude, frequency, duration, and routes of current and reasonably anticipated future human exposure to COPCs associated with the NBSA. The extent of a receptor's exposure was estimated by identifying exposure scenarios that describe the potential pathways of exposure to COPCs and the specific activities and behaviors (e.g., swimming, wading, boating, and fishing) that may lead to contact with COPCs in the environment. A combination of site-specific data representing the conditions and local population in the NBSA and USEPA default input values were used in the calculations to estimate exposures. The outcome of the exposure assessment is exposure point concentrations (EPCs) and subsequent human receptor intakes of COPCs for all complete exposure pathways associated with current and reasonably anticipated future human exposures at the NBSA. The exposure assessment methods are fully described in Section 4 of the BHHRA (Appendix A).

6.1.2.1 Identification of Exposure Scenarios

Human use of the NBSA is primarily industrial and commercial. Recreational use is more limited due to access limitations from the shoreline types (i.e., bulkhead, bridges, sheet piling, and mudflats) and

surrounding urban/industrial/commercial land use. Access for recreation is through available public access areas (e.g., parks along the shoreline) and pleasure boating (i.e., launches from marinas inside and outside of the NBSA). Some consumption of fish and crab from the Bay has been reported, despite consumption advisories for certain fish species and a ban on the harvest and consumption of blue crab from the NBSA. Fishing has been reported along the Bayonne waterfront on the eastern side of the Bay; on the pilings of the Central Railroad of New Jersey/Newark Bay Bridge (also known as Old Bay Bridge), which was demolished in the 1980s; and at other piers, exposed rocky shorelines, pilings, and docks.

Potential receptors and exposure pathways identified for quantitative evaluation in the human health CSM for the NBSA include the following:

- Anglers/sportsmen who may be exposed via fish or shellfish ingestion, dermal contact with sediment and surface water, and incidental ingestion of sediment and surface water
- Swimmers, waders, and boaters who may be exposed via dermal contact with sediment and surface water, and incidental ingestion of sediment and surface water
- Workers who may be exposed via dermal contact with sediment and incidental ingestion of sediment.

Potential exposure via inhalation of vapors in outdoor air as a result of volatilization of VOCs and SVOCs from sediment and surface water was shown to pose negligible risks (i.e., cancer risks less than 10^{-6} and noncancer hazards less than 1) to all receptors by a quantitative screening-level evaluation; therefore, this pathway was excluded from the final cumulative risk estimates in the BHHRA (inhalation screening assessments were conducted in the BHHRA for sediments [BHHRA Appendix C-1] and surface water [BHHRA Appendix C-2]).

Exposure by ingestion of waterfowl or species other than fish and crabs (e.g., turtles, frogs) was not included in the quantitative risk assessment calculations because ingestion of other species appears to be minimal relative to fish and crab consumption. Residential receptors were not included as an exposed population in the quantitative risk assessment calculations because access to the Bay from residential properties was limited by physical barriers. Transient persons potentially inhabiting areas near and along the NBSA were not evaluated because the assumed exposures by long-term recreators and anglers/sportsmen were anticipated to be higher than those of a transient individual.

6.1.2.2 Quantification of Potential Exposures

Consistent with USEPA guidance for Superfund risk assessments, two exposure scenarios were evaluated in the BHHRA: a reasonable maximum exposure (RME) scenario and a central tendency exposure (CTE) scenario. The intent of the RME scenario was to estimate a conservative exposure case that was above the average case, but still within the range of possible exposures. The CTE scenario used average exposure parameters to calculate the average exposure of an individual. While risk management decisions are based on the RME, the purpose of evaluating both an RME and a CTE scenario in the BHHRA is to provide risk managers and stakeholders with an estimate of the range of risks from average to upper-bound. The RME and CTE exposure parameters are presented in the BHHRA and include conservative estimates of fish tissue and crab consumption rates that were developed by USEPA Region 2, independently of GSH, based on consideration of a wide range of creel-angler surveys (USEPA 2012b). The ingestion rates were based on two published surveys conducted in the NY/NJ Harbor estuary with

enough information to calculate statistical distributions of ingestion rates for anglers who consume their catch (Burger 2002 for fish and crab ingestion; Connelly et al. 1992 for fish ingestion).

Exposure to fish and crab tissue, as well as accessible surface sediment and surface water, was evaluated on a Bay-wide basis. In addition, the EPC for both the RME and CTE scenarios was the lower of the 95UCL of the arithmetic mean or the maximum concentration, consistent with USEPA guidance (USEPA 1989).

The BHHRA evaluated a “mixed fish” diet to account for the presence of multiple fish species in the Bay that may be consumed by anglers, which was assumed to comprise equal amounts (20%) of the five species collected as part of the RI/FS (American eel, bluefish, striped bass, summer flounder, and white perch). A supplemental analysis of individual fish species diets was included in an uncertainty evaluation. Similarly, the BHHRA evaluated crab muscle and hepatopancreas tissues combined, to account for the possibility that the crab was cooked before the hepatopancreas was removed. A supplemental analysis of a crab-muscle-only diet was included in an uncertainty evaluation. Risks/hazards for hepatopancreas only are also presented in appendices to the BHHRA. Finally, no cooking loss was considered in the RME scenario for both fish and crab consumption, which assumes that fat, pan drippings, and cooking juices were consumed. For the CTE scenario, cooking loss was included for fish consumption (insufficient data were available for crab consumption).

6.1.3 Toxicity Assessment

The purpose of the toxicity (or dose-response) assessment is to identify the types of adverse health effects a chemical may potentially cause and to define the relationship between the dose of a chemical and the likelihood or magnitude of an adverse health effect (response; USEPA 1989). Adverse effects are classified by USEPA as potentially carcinogenic or noncarcinogenic (i.e., endpoints other than cancer). Combining the results of the toxicity assessment with information on the magnitude of potential human exposure provides an estimate of potential risk or hazard.

The toxicity criteria used in the BHHRA were selected according to USEPA guidance (USEPA 1997, 2003c, 2003d, 2019a, 2019b; ATSDR 2019), including cancer and noncancer criteria for oral and dermal exposures. USEPA default dermal absorption factors were used to adjust oral toxicity criteria for evaluating dermal exposure. In addition, USEPA’s age-dependent adjustment factors were used to evaluate early-life exposures for chemicals believed to act by a mutagenic mode of action. Blood lead models, for adults and children, were used to evaluate potential exposure to lead in fish, crabs, and sediment. The toxicity assessment methods are fully described in Section 5 of the BHHRA (Appendix A).

For PCDDs/PCDFs and dioxin-like (DL) PCBs (collectively referred to as dioxin-like compounds), cancer risks and HIs were estimated for the individual congeners, as well as in terms of a total toxic equivalent (TEQ) for PCDDs/PCDFs and PCBs (TEQ DF and TEQ PCB, respectively). The toxicity criteria for these compounds are based on the cancer and noncancer criteria for 2,3,7,8-TCDD and congener-specific toxicity equivalency factors. The TEQ DF and TEQ PCB were calculated by two methods: (1) using USEPA’s Kaplan-Meier (KM) calculator (Version 9.1; issued July 2014), and (2) manually based on the TEQ concentration for each congener. The first method is denoted as “based on KM TEQs” and the second method is denoted as “excluding KM TEQ.” The remaining non-DL PCB congeners were evaluated as a group (Total non-DL PCBs) using toxicity criteria for PCBs (high risk) and Aroclor 1254 for cancer and noncancer effects, respectively. Cumulative risk/hazard estimates are presented based on KM

TEQs, as well as based on TEQs calculated manually. There was essentially no difference in the risk/hazard estimates between the two methods; however, the latter method allows for identification of the specific congeners that contribute most to the overall risk/hazard.

6.1.4 Risk Characterization

In the risk characterization step of the BHHRA, possible threats to human health related to potential exposure to COPCs in environmental media were determined. Specifically, the quantitative exposure factors were combined with the chemical-specific toxicity factors for COPCs. In assessing carcinogenic effects, estimated intakes and cancer toxicity factors were integrated to calculate the probability that a person will develop cancer; in determining noncarcinogenic effects, projected intakes of COPCs were compared to the noncarcinogenic toxicity factor. Cancer risk was determined by averaging exposure over a 70-year lifetime; noncarcinogenic hazard was assessed by averaging exposure over the exposure duration. The potential carcinogenic risks and noncarcinogenic hazards calculated for each receptor scenario were summed to yield cumulative risks and hazards by receptor.

For each receptor, the cumulative potential carcinogenic risks were compared to the NCP risk range, which refers to a range of cancer risks representing one potential excess cancer incidence per population of 10,000 (i.e., one in ten thousand or 10^{-4}) to one potential excess case of cancer incidence per population of 1,000,000 (i.e., one in a million or 10^{-6}). Noncarcinogenic hazards were evaluated based on the HI and were compared to the protection goal of an HI equal to 1. The HI represents the ratio of the exposure dose to the reference dose, below which adverse noncarcinogenic health hazards are not expected to occur. HI values below 1 indicate that potential exposures are below the reference dose, while HI values above 1 indicate that potential exposures are above the reference dose. However, the magnitude of the hazard cannot be directly equated to a probability or effect level. Noncancer HIs greater than 1 were further evaluated on a target-organ-specific basis.

Per USEPA guidance, when the cumulative carcinogenic site risk to an individual based on RME for both current and future land use is less than 10^{-4}, and the noncarcinogenic hazard quotient (HQ) is less than 1, action generally is not warranted. The risk characterization is fully described in Section 6 of the BHHRA (Appendix A).

6.1.4.1 Risk Characterization Results

Tables 6-3 through 6-6 present the RME and CTE cumulative cancer risks and total noncancer hazard indices for all receptors and exposure pathways quantitatively evaluated in the BHHRA; additional details for the receptor age group with the highest potential cancer risk and noncancer hazard are presented following the tables.

6.1.4.2 Potential Constituents of Concern Identification

Potential COCs were identified in cases where the potential cumulative cancer risk or noncancer HI for a receptor exceeds 10^{-4} or 1, respectively. In these cases, potential COCs were any COPC with an individual pathway cancer risk greater than 10^{-6} or noncancer HI greater than 0.1. Table 6-7 summarizes the potential COCs for the RME scenario (no potential COCs were identified for surface water for either

the RME or CTE scenario). COC identification is fully described in Section 6.4 of the BHHRA (Appendix A).

6.1.5 BHHRA Conclusions

Consumption of self-caught fish or crab from the NBSA presents the primary source of potential risk to human health. For the RME scenario, which was intended to represent a conservative exposure case that was above the average case but still within the range of possible exposures, the potential cancer risk and noncancer hazards to anglers/sportsman who are assumed to routinely consume their catch (34.6 grams per day [g/day] for an adult and 11.5 g/day for a child for fish, or 21 g/day for an adult and 7 g/day for a child for crab, over a period of 26 years) exceeded the NCP risk range of 10^{-6} to 10^{-4} and a noncancer protection goal of an HI of 1. The RME cancer risk for the combined adult/child angler/sportsman was 8×10^{-4} for both fish consumption and crab consumption, and the noncancer HIs for the child angler/sportsman were 40 for fish consumption and 50 for crab consumption.

For the CTE scenario, which was based on average exposure levels (3.9 g/day for an adult and 1.3 g/day for a child for fish, or 3 g/day for an adult and 1 g/day for a child for crab, over a period of 12 years), the potential cancer risks for the combined adult/child angler/sportsman who consumes fish or crab from the NBSA were within the NCP risk range; however, noncancer HIs for the child angler/sportsman were above the noncancer protection goal of 1 (i.e., 4 for fish consumption and 7 for crab consumption).

The primary COPCs for fish and crab ingestion were 2,3,7,8-TCDD, PCB-126, and non-DL PCBs, with some pesticides, inorganic arsenic, copper[55], and/or methyl mercury also contributing to the cumulative risks/hazards for both the RME and CTE scenarios. The proportional contribution of 2,3,7,8-TCDD and total PCBs (includes both DL and non-DL risk) to risk is given in Table 6-8.

Table 6-8. Summary of Risk Human Health Risk and Proportional Contribution

Risk Type	Diet	Central Tendency Exposure	Reasonable Maximum Exposure	Contribution from Primary Risk Drivers	
				2,3,7,8-TCDD	PCBs
Cancer Risk	Fish	$<10^{-4}$	$8x10^{-4}$	28%	56%
	Crab	$<10^{-4}$	$8x10^{-4}$	52%	31%
Noncancer Hazard Index	Fish	4	40	19%	58%
	Crab	7	50	33%	29%

The cumulative potential cancer risks and noncancer HIs associated with direct contact with accessible surface sediment and surface water in the NBSA while angling, swimming, wading, or boating were much

[55] The BHHRA identified copper as contributing to an unacceptable noncancer hazard from blue crab consumption. Due to the toxicity value and uncertainty factors used to estimate the noncancer hazards associated with copper, and considering that copper is an essential nutrient, USEPA determined that a preliminary remedial goal (PRG) does not need to be calculated for copper.

lower than those associated with fish or crab consumption and were within or below the NCP risk range of 10^{-6} to 10^{-4} and below the noncancer protection goal of an HI of 1.

6.2 Baseline Ecological Risk Assessment Summary

The BERA (GSH 2020) was conducted as part of the RI/FS for the NBSA and pursuant to the AOC. The objectives of the BERA are to evaluate potential exposure risks for aquatic organisms and wildlife (i.e., representative benthic invertebrates, fish, birds, mammals, and reptiles) that inhabit or utilize the Bay environs, and provide a risk characterization that can be used to make informed risk management decisions for the NBSA. The BERA is included as an Appendix B to this RI Report and summarized here.

Chemistry data from surface sediment (0 to 6 inches below sediment surface), porewater, surface water and biota tissue samples, collected under the following RI sampling programs were used in the BERA (Section 4.3 of BERA; Appendix B):

- Crab and Clam and Sediment Sampling Program (Crab/Clam) (see Section 2.1.3.3)
- SQT and Porewater Sampling Program (see Section 2.1.3.5)
- Phase III Sediment Sampling Program (see Section 2.1.3.6)
- Chemical Water Column Monitoring Program (see Section 2.1.3.7).

The SQT program also included toxicity testing *(L. plumulosus*) and BIC taxa enumeration.

6.2.1 Problem Formulation and Data Evaluation

The Problem Formulation report for the NBSA BERA was completed in 2013 (Tierra 2013a) and guided the collection of data and identification of receptors and assessment endpoints used in the NBSA.

6.2.1.1 Ecological Receptor Groups

Representative receptor groups were selected based on available reports, biological surveys, habitat data, and other information (as described in Section 3 of BERA; Appendix B). The following factors were considered:

- Potential for exposure to sediment associated chemicals through direct and incidental ingestion of sediment, sediment-exposed prey or direct contact with sediments and whether species is a year round resident or migratory
- Relative ability to bioaccumulate/biomagnify site-related chemicals
- Societal and cultural significance such as threatened and endangered species or species of commercial and recreational importance
- Ecological significance such as species that serve a unique ecological function
- Sensitivity among species to site-related chemicals.

The receptor groups that may be exposed to constituents of potential *ecological* concern (COPECs) in sediment, surface water, and/or tissue from the NBSA include benthic invertebrates, fish, birds, mammals, and reptiles. The representative organisms selected for each receptor group are presented in Table 6-9.

Table 6-9. Representative Ecological Receptors

Receptor Group	Receptor Guild and Habitat	Site Use	Species
Benthic Invertebrates	Benthic, deposit/filter-feeders, marine	Resident	Infaunal inverts./ polychaete worms
	Benthic, filter-feeder, marine	Resident	Softshell clam
	Benthic omnivore, marine	Resident	Blue crab
Fish	Forage fish	Resident	Mummichog/killifish (*Fundulus* spp.)
	Forage fish	Migratory	Atlantic menhaden/silverside
	Benthic omnivore	Migratory	Summer/winter flounder
	Pelagic invertivore/piscivore	Migratory	White perch
	Pelagic piscivore	Part Resident	American eel
Birds	Benthivore/sediment-probing	Migratory	Spotted sandpiper
	Subtidal piscivore	Part Resident	Great blue heron
	Pelagic piscivore	Part Resident	Double-crested cormorant
	Omnivore	Migratory	Lesser Scaup
Mammals	Piscivore	Transient	River otter
	Omnivore	Resident	Muskrat
	Piscivore	Transient	Harbor seal

6.2.1.2 Assessment and Measurement Endpoints

Risk evaluation in the BERA used assessment endpoints, risk questions, and measurement endpoints consistent with the Problem Formulation report (Tierra 2013a).

The following community- or population-level assessments were included:

- **Invertebrates** – Survival, growth and/or reproduction of invertebrates that form the base of the food web for fish and other upper-trophic level organisms.
- **Fish** – Survival, growth and/or reproduction of fish in the NBSA including species at various trophic levels of the food web. They consume invertebrates and other lower-trophic level organisms but, in turn, are fed upon by upper-trophic level birds and mammals.
- **Birds** – Survival, growth, and/or reproduction of birds that are part of the upper trophic levels of the food web and include the following feeding guilds: benthivores (consume benthic invertebrates), omnivores (consume plant and animal matter), and piscivores (consume fish).
- **Mammals** – Survival, growth, and/or reproduction of mammals that are part of the upper trophic levels of the food web and include the following feeding guilds: omnivores (consume plant and animal matter) and piscivores (consume fish).

- **Reptiles** – Survival, growth, and/or reproduction of reptiles. Reptiles were evaluated qualitatively by discussing the possibility of reptiles inhabiting the NBSA.

6.2.1.3 Ecological Conceptual Site Model

A conceptual food web diagram is depicted in Figure 6-3. The specific ecological exposure pathways are depicted on Figure 6-4. Following discharge to the NBSA, contaminants can partition between the dissolved- and particulate-phase in the water column. Chemicals in the particulate-phase can then be transferred to the sediment bed by settling or be resuspended from the bed to the water column. The estimated depth of the biologically active zone, the area where biological activity and benthic exposures to contaminants occur, is approximately 6 inches throughout the Bay (Tierra 2008a). Bioaccumulation of contaminants is dependent on a variety of factors including contaminant type and speciation, metabolism, lipid content of the organisms, and physicochemical attributes of the sediment and porewater (e.g., OC and sulfide content). Contaminants can enter the food web via accumulation in tissues of biota exposed directly to contaminants in the water column, sediments/porewater, and/or in the tissues of prey items. Food web interactions are likely the most significant exposure pathways for wildlife that forage in the NBSA. Because the Bay surface water is saline, ingestion of water, other than incidental ingestion during foraging, not an exposure pathway for wildlife.

For aquatic organisms, such as fish and invertebrates, exposure to contaminated media (i.e., sediment and surface water) occurs via direct contact (e.g., absorption) or ingestion/uptake. Although birds and mammals are in direct contact with contaminated media, exposure via direct or dermal contact is negligible due to the presence of feathers and fur. Field reconnaissance of the NBSA (Tierra 2015b) indicated little evidence of reptile use in the NBSA. Similarly, inhalation of contaminants, such as VOCs in sediment or surface water by wildlife, is negligible.

Risks under the BERA were estimated both on a NBSA-wide basis, and for a series of assessment zones to evaluate relative risks on more localized areas of potential exposure (Figure 4-35). There were three primary assessment zones for which risks were quantified in the BERA: North, Southeast, and Southwest Zones. The regularly dredged navigation channel zone was treated qualitatively in the BERA, as only limited data were collected from this zone for risk assessment purposes, and the contamination in these areas was evaluated and addressed by the United States Army Corps of Engineers (USACE) as part of the permitting process for the navigation dredging events. The limited intertidal mudflat habitats that are present in the NBSA were evaluated in the BERA in terms of the specific risk potential from localized sediment contamination to organisms that preferentially forage in these areas.

6.2.2 Identification of Contaminants of Potential Ecological Concern

Pursuant to CERCLA ecological risk assessment guidance (USEPA 1997), the process of identifying COPECs for the BERA was conducted and presented in the Screening-Level Ecological Risk Assessment Report for the Newark Bay Study Area (SLERA; Battelle 2008, provided as an attachment to the BERA). The SLERA indicated that the average and/or upper-bound concentrations of a variety of contaminants in sediments exceeded conservative screening guidelines and/or benchmarks throughout the NBSA. In addition, preliminary screening-level food web model results for fish, birds, and mammals indicated that the upper-bound tissue and exposure-modeled concentrations of bioaccumulative contaminants exceeded conservative tissue benchmarks derived from the scientific literature. From the SLERA, a preliminary list of

COPECs was identified for sediments and the different types of organisms. These included PCDDs/PCDFs, metals, PAHs, PCBs, pesticides, and other SVOCs. As part of the Problem Formulation development (Tierra 2013a), a revised screening-level assessment was performed using the surface sediment chemistry data collected during the Phase I and II RI investigations. The results of the updated screen confirmed the list of primary chemical groups retained as COPECs for the BERA and helped to identify the most important individual chemicals or compounds in those groups.

All chemical data collected under the Phase III sampling programs (i.e., 2014 to 2016 datasets) were evaluated with respect to their potential for risk. In the SQT assessment, all detected analytes in surface sediments (regardless of prior COPEC status) were included in the statistical evaluations to determine if there was a relationship between the analyte and potential effects on the BIC. In the tissue and food web modeling analyses for shellfish, fish, birds, and mammals, a group of widely detected COPECs with known potential for toxicity were evaluated (Table 6-10).

6.2.3 Risk Analysis

6.2.3.1 Exposure Assessment

Ecological receptors were evaluated in terms of exposure to contaminated surface sediment, exposure to contaminated prey and and/or body burden of contaminants as appropriate. The EPC within these media was represented by the 95UCL on the mean of the available chemical data for the media and assessment area that was evaluated. For datasets with fewer than six detected samples, a UCL was not calculated, and instead the maximum concentration was used to represent an EPC. EPCs were calculated using USEPA's ProUCL statistical package (Version 5.1.00; USEPA 2015a). For the BIC, the exposure was described in terms of distribution and co-occurrence with COPECs.

6.2.3.2 Effects Assessment

COPECs were evaluated for the potential for adverse effects for each assessment endpoint. Each COPEC was evaluated for adverse effects based on survival, growth, or reproduction. For the BIC, an SQT assessment was conducted, a method that incorporates both qualitative and quantitative analyses to identify potential cause and effect relationships such as determining if there was correlation between COPECs in sediment and porewater and effect endpoints such as toxicity metrics (e.g., amphipod survival) or community metrics (e.g., abundance, number of taxa). For other receptors, EPCs measured or modeled in tissue were compared to TRVs, which are concentrations or dose levels used to determine the potential for unacceptable risk. The TRVs were incorporated to the extent feasible and appropriate from the BERA for the LPRSA (Windward 2019). This included incorporation of the TRVs developed by the USEPA for the Focused Feasibility Study Report for the Lower Eight Miles of the Lower Passaic River (LPR FFS; USEPA 2014a) for risk bounding purposes. The list of TRVs include both no-observed-adverse-effect level (NOAEL) and lowest-observed-adverse-effect level (LOAEL) values.

COPECs in surface water were evaluated by direct comparison of surface water concentrations to water quality criteria (Section 5 of the BERA; Appendix B).

6.2.3.3 Risk Characterization, Uncertainty Analysis, and Identification of Contaminants of Concern

In the risk characterization, the estimation of risk is determined by comparing the COPEC concentration or dose level developed in the exposure analysis to the adverse effects level (TRV) developed in the effects assessment. The result of this comparison is quantified as the HQ. All COPECs with a LOAEL HQ ≥ 1 in any of the available HQ LOE (including sensitivity analyses) were identified as a COPC (i.e., having potentially unacceptable risk). Each COPC was then evaluated using all available LOEs and consideration of the factors above to reach a risk conclusion for that receptor-COPEC pair based on the cumulative weight of evidence (WOE). Only receptor-COPEC pairs with a LOAEL HQ ≥ 1 and factors supporting the conclusion of unacceptable risk were recommended as risk drivers/COCs. In cases where no risk conclusion could be made, risk was considered uncertain and these COPECs were also recommended as COCs. In the SQT assessment, COPECs that were significantly correlated with benthic effect measures were also identified as COPCs. A summary of the WOE for the receptors evaluated is provided in Table 6-11a for dietary and tissue assessments and in Table 6-11b for the SQT evaluation. COPCs and BERA uncertainties are summarized in Section 6.2.9. All COPECs with LOAEL-based HQs greater than 1 will be carried into the FS for risk management consideration. Selection of COCs for evaluation in the FS will be completed in consultation with USEPA and based on the findings of the BERA.

6.2.4 Benthic Invertebrate Assessment

Benthic invertebrates in the NBSA include both infaunal communities and several epibenthic shellfish such as softshell clam (*Mya arenaria*), Baltic clam (*Macoma balthica*), eastern oyster (*Crassostrea virginica*), and blue crab. There are a variety of taxonomic feeding guilds for benthic and epibenthic invertebrates including filter-feeders, deposit-feeders, detritivores, and omnivores. These organisms live in close association with the sediments in the Bay and, therefore, represent some of the highest potential for exposure to COPECs in sediments. Invertebrates also form the base of the food web for fish and other upper-trophic level organisms such a birds and mammals. The BIC was evaluated using the SQT assessment methodology described in Section 6.2.4.1 (additional details can be found in Section 6.1 of the BERA; Appendix B).

6.2.4.1 Benthic Invertebrate Community Assessment

The SQT program was designed to support an effects-based, WOE assessment to evaluate risks to benthic invertebrate communities using three primary lines of evidence (LOEs): 1) sediment chemistry, 2) sediment toxicity, and 3) BIC metrics. Sediment grab samples from each of 30 locations were prepared for the following analyses: sediment and porewater chemistry, toxicity testing (10 and 28-day *L. plumulosus* whole sediment bioassays), and benthic invertebrate taxa enumeration. The methods used to evaluate SQT data fall into two major categories:

- The SQT evaluation is an objective method of comparing sediment and porewater chemistry concentrations, sediment toxicity endpoints, and BIC metrics to screening, control, or reference values with the objective of categorizing each sampling station with respect to the degree of potential impact.

- The quantitative effects assessment incorporates bivariate and multivariate statistical methods to evaluate the association of sediment and porewater chemistry with effects measures (i.e., toxicity endpoints and BIC metrics).

6.2.4.1.1 SQT Evaluation

This evaluation was used to classify each of the 30 SQT stations with respect to degree of potential impact. Three categories (i.e., the triad) were evaluated: BIC composition, sediment toxicity, and sediment/porewater chemistry. Each category has equal weighting in the evaluation and was assigned a score ranging from 0 (unimpacted) to 1 (most impacted). The scores for each category were summed (maximum possible score = 3) and the final score was used to categorize each station with respect to degree of impact.

Five benthic metrics and indices (abundance, number of taxa, diversity, dominance, and the NY/NJ Harbor B-IBI) were evaluated with respect to reference conditions for scoring the BIC. Most BIC metrics indicated little to no impact to the benthic community.

Four toxicity endpoints were evaluated for toxicity scoring: 10-day survival, 28-day survival, growth, and reproduction. The results of the survival endpoints are depicted on Figure 4-28. Based on 10-day survival, two of 30 SQT stations were acutely toxic. Based on 28-day survival, six of 30 SQT stations exhibited chronic toxicity. Eighteen stations exhibited 28-day growth statistically significantly different than laboratory control. Thirteen stations exhibited 28-day reproduction significantly different from laboratory control.

Sediment chemistry concentrations were compared to sediment screening values from literature (Long et al. 1995; USEPA 2005c; Buchman 2008). Porewater concentrations were preferentially compared to New Jersey saline WQC. For detected compounds in porewater without WQC, screening values found in the literature (Buchman 2008) were used for comparison and scoring. These comparisons resulted in a combined sediment/porewater chemistry score.

Based on the combined SQT scoring, two SQT stations were classified as medium impact; 18 as low impact and 10 as no impact relative to the Jamaica Bay reference area.

6.2.4.1.2 Quantitative Effects Assessment

Spearman rank correlation analysis was used to determine the association with chemicals in sediment and porewater with toxicity endpoints and BIC metrics. A list of benthic COPECs was developed based on the results of the correlation analysis, the FOD and exceedances of sediment benchmarks and WQC. The following chemicals were subsequently incorporated into a multivariate analysis: 2,3,7,8-TCDD, total PCBs, pesticides (total DDx (2,4’ and 4,4’), dieldrin, chlordanes, hexachlorobenzene), and metals (antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc).

Multivariate dose-response modeling was conducted to quantify the relationship between effects measures (e.g., 10-day survival, number of taxa) and concentrations in sediment and porewater and to predict where toxicity or benthic impairment might occur in the NBSA. The Phase III sediment data set was transformed using PCA. Eighty-three percent of the variance was explained by the first three PCs. PC1 explains 67% of the variance of the COPECs in sediment and all COPECs were highly correlated with PC1. Therefore, PC1 scores indicate where the highest concentrations of COPECs tend to occur.

Higher positive scores indicate higher COPEC concentrations. Sample scores for PC1 are depicted on Figure 4-27.

Principal component (PC) scores for the first three PC scores of 30 SQT stations were used to conduct dose-response modeling of all toxicity and benthic metrics. Ten-day amphipod survival was significantly associated with PC1. The resulting dose-response model was used to predict where the potential for acute toxicity exists in the NBSA (Figure 6-5). Twenty-eight day survival was significantly associated with PC1 and PC2. Predicted chronic toxicity, based on this endpoint, is depicted in Figure 6-6. Acute toxicity was predicted in 21 samples (8.2%) in areas on the southwest subtidal flat and southern shoreline and to a lesser extent in the north (Figure 6-5). Chronic toxicity was predicted in 45 samples (17.7%) located mostly in the same areas as for acute toxicity (Figure 6-6).

PCA and dose-response modeling was also conducted using the porewater data. Porewater PCs were not used for prediction in the NBSA because porewater chemistry was only measured in the SQT samples. However, similar relationships were found for porewater chemistry and toxicity as for sediment chemistry.

Sediment PCs were not predictive of benthic impairment.

6.2.4.1.3 Benthic Invertebrate Community Assessment Summary

Table 6-11b presents the WOE summary of the SQT evaluation. There was no evidence that chemical concentrations are affecting the BIC. Acute and chronic toxicity was observed in SQT samples and based on associations with chemical concentrations, was predicted to occur in 8.2% and 17.7% of sampled areas, respectively. Sediment concentrations exceeded many screening benchmarks; however, these benchmark values were not predicative of toxicity. Porewater concentrations exceeded WQC for total PCBs, total DDx (2,4' and 4,4'), arsenic, copper, and zinc. The sum of toxic PAH units in porewater exceeded one at the two acutely toxic stations. Although fully detected in porewater, 2,3,7,8-TCDD did not exceed the chronic screening value from the literature (i.e., 10 pg/L).

Potential risk to the benthic community is possible in localized areas due to elevated concentrations of multiple co-occurring COPECs including PCDDs/PCDFs, total PCBs, pesticides, PAHs, and metals.

6.2.4.2 Benthic Invertebrate Tissue Assessment

As an additional LOE, the potential for risk to benthic invertebrates was also characterized for three species (polychaete worm, softshell clam, and blue crab) using benthic tissue chemical concentrations compared to TRVs based on the literature to derive risk estimates (i.e., HQs; additional details can be found in Section 6.2 of the BERA; Appendix B). Risk to the three representative benthic invertebrate species was evaluated in various exposure areas, including Bay-wide and the following assessment zones: North, Southeast, and Southwest Zones (Figure 4-35).

The range of HQs for the aggregate invertebrate tissue samples (i.e., all species) with HQs ≥ 1 are depicted in Figure 6-7. The following were recommended as COCs for benthic invertebrates (Table 6-11a):

- Polychaete worm – 2,3,7,8-TCDD, total PCBs, arsenic
- Softshell clam – 2,3,7,8-TCDD, total PCBs, arsenic, lead, mercury

- Blue crab – 2,3,7,8-TCDD, total PCBs, total DDx (2,4' and 4,4'), mercury, methylmercury.

6.2.5 Fish Assessment

The fish tissue assessment and dietary assessment were conducted for the following fish species: combined mummichog/striped killifish (i.e., *Fundulus* sp.), summer and winter flounder, American eel, and white perch. In addition, risk to *Fundulus* species (mummichog and striped killifish) were characterized using modelled fish egg concentrations as an additional LOE to characterize risk from maternal dietary exposure. Tissue chemical concentrations and dietary doses were compared to TRVs based on the literature to derive risk estimates (i.e., HQs). Risk to fish species was evaluated based on various exposure areas, including Bay-wide and within the following assessment zones: North, Southeast, and Southwest Zones (Figure 4-35).

In addition, several qualitative LOEs were evaluated that involved the assessment of NBSA data for fish community data (based on 10 years of USACE Aquatic Biological Survey data; USACE 2015a, 2015b) and gross external and internal health observations. As part of the uncertainty evaluation, dietary risk estimates for fish were also evaluated for: (1) different proportions of large fish (i.e., > 30 cm) in the diets of American eel and summer/winter flounder, (2) site use factors for summer/winter flounder and white perch, and (3) the use of the full quantitation limit for non-detects. Further details on the fish risk assessment can be found in Section 7 of the BERA (Appendix B).

The range of HQs for the aggregate whole-body fish tissue samples (i.e., all species) with HQs ≥ 1 are depicted in Figure 6-8. Overall, unacceptable risk is predicted for fish potentially exposed to a limited number of COPECs in the NBSA (Table 6-11a). Based on the WOE, potential for unacceptable risk was identified for PCDDs/PCDFs and TEQ (2,3,7,8-TCDD, total PCDD/PCDF TEQ fish, PCDD/PCDF/PCB TEQ fish) for all fish receptors, total PCBs for forage fish in the Southwest Zone only, and total DDx (2,4' and 4,4') for white perch. Copper was recommended as a COC due to the substantial uncertainty associated with the risk estimates for white perch[56].

Fish community monitoring data from the Aquatic Biological Survey (ABS; USACE 2015a, 2015b) found that fish abundance and diversity in the Arthur Kill/Newark Bay were similar or greater than other locations in the NY/NJ Harbor Estuary and are comparable. The ABS studies were not designed to evaluate the potential effects of contamination in the NBSA on fish communities. Without comparative long-term data for an appropriate reference estuary or defined statistical power, it is not possible to determine from these historical datasets whether or not COPECs in the Bay are impacting the NBSA fish community. However, this uncertainty is diminished by the collection of multiple years of data in the same areas, as was the case with the USACE ABS study. Additionally, the fish pathology investigation found abnormalities in 12 of the 145 fish (8%) collected and necropsied; although, gross health examinations have limited ability to assess potential sublethal (i.e., growth and reproductive) effects, and cannot identify potential risk associated with specific COPECs in environmental media.

Conclusions for the fish evaluations are based on the WOE evaluation and are summarized below. Further details on the fish evaluation can be found in Section 7.7 of the BERA. :

[56] During discussions regarding the uncertain COC status for copper and with consideration of its essential mineral status for both human and ecological organisms (including fish) and the magnitude of the risk estimates, USEPA determined that copper was not an ecological risk driver requiring PRG development for Newark Bay.

- For localized forage fish (mummichog/killifish):
  - COPCs included PCDDs/PCDFs and TEQ (2,3,7,8-TCDD, total PCDD/PCDF TEQ fish, PCDD/PCDF/PCB TEQ fish), total PCB TEQ, total PCBs[57], total DDx (2,4' and 4,4'), cadmium, copper, mercury, methylmercury, and silver (based on sensitivity analyses only) based on tissue, dietary, and/or egg LOAEL HQs ≥ 1 estimated for at least one scenario evaluated in the BERA.
  - Recommended COCs are TEQ (2,3,7,8-TCDD, total PCDD/PCDF TEQ fish, PCDD/PCDF/PCB TEQ fish) and total PCBs.
- For predatory fish (American eel, flounder, and white perch):
  - Fish community monitoring data for these three species (USACE 2015a, 2015b) found no impairment relative to other locations in the NY/NJ Harbor Estuary.
  - Fish pathology investigation found abnormalities in 12 of the 145 fish (8%) collected and necropsied.
  - COPCs, identified based on tissue or dietary LOAEL HQs ≥ 1 for any scenarios evaluated in the BERA, include:
    - For American eel: PCDDs/PCDFs and TEQ (2,3,7,8-TCDD, total PCDD/PCDF TEQ fish, PCDD/PCDF/PCB TEQ fish), total PCB TEQ, total PCBs, total DDx (2,4' and 4,4'), cadmium, copper, mercury, methylmercury, and selenium.
    - For summer and winter flounder: PCDDs/PCDFs and TEQ (2,3,7,8-TCDD, total PCDD/PCDF TEQ fish, PCDD/PCDF/PCB TEQ fish), total PCBs, cadmium, copper, mercury, and methylmercury (based on sensitivity analyses only).
    - For white perch: PCDDs/PCDFs and TEQ (2,3,7,8-TCDD, total PCDD/PCDF TEQ fish, PCDD/PCDF/PCB TEQ fish), total PCB TEQ, total PCBs, total DDx (2,4' and 4,4'), cadmium, chromium, copper, mercury (based on sensitivity analyses only), selenium, and silver. Additionally, arsenic and zinc were identified as recommended final COPCs based only on liver LOAEL HQs ≥ 1; whole body tissue and dietary LOAEL HQs <1 were predicted for arsenic and zinc in all scenarios.
  - Unacceptable risk is considered possible for PCDDs/PCDFs and TEQ (all predatory receptors) and for total DDx (2,4' and 4,4') (white perch only) based primarily on LOAEL HQs greater than 1.
  - Unacceptable risk is considered unlikely for the remaining COPCs (total PCB TEQ, total PCBs and some metals [arsenic, cadmium, chromium, mercury/methylmercury, selenium, silver, and zinc]) based primarily on dietary and/or tissue HQs < 1 for most scenarios.
  - For copper, unacceptable risk is considered uncertain for white perch and unlikely for American eel and summer/winter flounder. For white perch, tissue LOAEL HQs ≥ 1 were predicted in all scenarios and the tissue LOAEL HQs approach or exceed 10 in many cases; however, dietary LOAEL HQs <1 were estimated using conservative dietary assumptions. There is substantial

[57] The identification of Total PCB risks to forage fish in the Final BERA was mistakenly listed for only the Southwest Zone. This has been corrected here and will be evaluated accordingly in the FS.

uncertainty related to both the tissue and dietary TRVs; although, both sets of HQs likely overestimate risk. For American eel and summer/winter flounder, NBSA tissue and dietary LOAEL HQs < 1 were estimated and LPR FFS tissue LOAEL HQs ≥ 1 were low in magnitude and were estimated only in the North Zone (flounder) or Southwest Zone (eel).

In conclusion, potential exposures to most COPECs in the NBSA are not expected to pose unacceptable risk to fish. The potential for unacceptable risk (identified based on LOAEL HQs ≥1 and WOE supporting the conclusion of unacceptable risk) was identified for PCDDs/PCDFs and related TEQ compounds (2,3,7,8-TCDD, total PCDD/PCDF TEQ fish, PCDD/PCDF/PCB TEQ fish) for all fish receptors, total PCBs for forage fish in the Southwest Zone, and possibly for total DDx (2,4' and 4,4') for white perch in the NBSA. Unacceptable risk is uncertain for white perch exposed to copper[58].

6.2.6 Bird Assessment

The potential for unacceptable risk to aquatic birds was characterized using NBSA tissue and sediment chemistry to estimate dietary doses of COPECs for four bird species (spotted sandpiper [*Actitis macularius*], great blue heron (*Ardea herodias*), double-crested cormorant [*Phalacrocorax auritus*], and lesser scaup [*Aythya affinis*]). Risks to double-crested cormorant from maternal dietary exposure were characterized using modelled bird egg tissue concentrations as an additional LOE. In addition, the results of a reproductive study of double-crested cormorants in the NBSA (Shooters Island) by Parsons (2003) was included as a qualitative LOE. Dietary doses and modeled bird egg concentrations were compared to a range of TRVs to derive risk estimates (HQs). Risk to the four representative aquatic bird species was evaluated based on foraging in various exposure areas, including the Bay-wide and by the following assessment zones: North, Southeast, and Southwest (Figure 4-35). As part of the uncertainty evaluation, dietary risk estimates for birds were also evaluated for: (1) different proportions of large fish (i.e., > 30 cm) in the diets of double-crested cormorant and great blue heron, (2) different proportions of diet components for great blue heron and lesser scaup, (3) site use factor (SUF) for spotted sandpiper, and (4) the use of the full quantitation limit for non-detects. Further details on the bird risk assessment can be found in Section 8 of the BERA (Appendix B).

The range of HQs for the aggregate bird dietary exposure estimates (i.e., all species) with HQs ≥ 1 are depicted in Figure 6-9. Overall, no unacceptable risk to birds potentially exposed to COPECs in the NBSA is expected as summarized below and in Table 6-11a. Further details on the bird evaluation can be found in Section 8.4 of the BERA.

- For spotted sandpiper (benthivorous bird):
  - Using primary exposure and toxicity assumptions, dietary LOAEL HQs < 1 were estimated for all COPECs using all exposure area and TRV assumptions, except for lead and mercury using LPR FFS TRVs.
  - Uncertainty analyses, including evaluation of a SUF of 1 and calculation of total concentrations using the full quantitation limit for NDs, resulted in identification of total PCDD/PCDF/PCB TEQ

[58] During discussions regarding the uncertain COC status for copper and with consideration of its essential mineral status for both human and ecological organisms (including fish) and the magnitude of the risk estimates, EPA determined that copper was not an ecological risk driver requiring PRG development for Newark Bay.

and total HMW PAH as additional COPCs based on LOAEL HQs equal to 1 for the NBSA-wide area and/or one or more individual assessment zones.

- Unacceptable risk is considered unlikely for lead, mercury, total PCDD/PCDF/PCB TEQ, and total HMW PAH based primarily on the following: (1) LOAEL HQs < 1 using NBSA TRVs, (2) the low magnitude of the LPR FFS LOAEL HQs ≥ 1, and (3) the use of exposure assumptions that likely overestimate risk to spotted sandpiper populations.

- For great blue heron (piscivorous bird):
  - Using primary exposure and toxicity assumptions, dietary LOAEL HQs < 1 were estimated for all COPECs using all exposure area and TRV assumptions, except for total DDx (2,4' and 4,4') and using LPR FFS TRVs.
  - Sensitivity analyses related to evaluation of alternate diets resulted in identification of total PCB TEQ, total PCDD/PCDF/PCB TEQ, mercury, and methylmercury as additional recommended final COCs based on LOAEL HQs ≥ 1 for the NBSA-wide area and/or one or more individual assessment zones.
  - Unacceptable risk is considered unlikely for total DDx (2,4' and 4,4'), total PCB TEQ, total PCDD/PCDF/PCB TEQ, mercury, and methylmercury based primarily on LOAEL HQs < 1 using NBSA TRVs, the low magnitude of the LPR FFS LOAEL HQs ≥ 1, and the use of exposure assumptions that likely overestimate risk to great blue heron populations.

- For double-crested cormorant (piscivorous bird):
  - Using primary exposure and toxicity assumptions, dietary LOAEL HQs < 1 were estimated for all COPECs using all exposure area and TRV assumptions, except for total PCDD/PCDF/PCB dioxin TEQ, total PCB TEQ, total PCBs, total DDx (2,4' and 4,4'), and methylmercury using LPR FFS TRVs only.
  - Sensitivity analyses related to evaluation of alternate diets resulted in identification of copper and mercury as additional COPCs based on dietary LOAEL HQs ≥ 1 for the NBSA-wide area and/or one or more individual assessment zones.
  - Egg tissue LOAEL HQs ≥ 1 were predicted for total PCDD/PCDF/PCB TEQ, total PCB TEQ, total PCBs, and total DDx (2,4' and 4,4') in the NBSA-wide area using both sets of TRVs, and mercury and methylmercury in the NBSA-wide area using LPR FFS TRVs only. Quantitative sensitivity analyses were not conducted for egg tissue HQs.
  - Unacceptable risk is considered unlikely for total PCDD/PCDF/PCB TEQ, total PCB TEQ, total PCBs, total DDx (2,4' and 4,4'), copper, mercury, and methylmercury based on LOAEL HQs less than 1, the results of a site-specific study (Parsons 2003) that found no effects on COPECs in double-crested cormorants, and the use of exposure parameters that overestimated risk.

- For lesser scaup (omnivorous bird):
  - Using primary exposure and toxicity assumptions, dietary LOAEL HQs < 1 were estimated for all COPECs using all exposure area and TRV assumptions, except for lead using LPR FFS TRVs.
  - Sensitivity analyses related to evaluation of alternate diets did not result in identification of additional COPCs.

- Unacceptable risk is considered unlikely for lead based primarily on LOAEL HQs < 1 using the NBSA TRVs; low magnitude of the LOAEL HQs ≥ 1; and conservative assumptions used in the risk estimates (e.g., maximum EPCs, conservative TRVs).

In conclusion, potential exposures to most COPECs in the NBSA are not expected to pose unacceptable risk to birds. For birds, exceedances of dietary LOAEL TRVs were found for TEQs and total DDx (2,4' and 4,4') in double-crested cormorants using only the LPR FFS TRVs, and the HQs for these were at or near 1. For cormorants, egg tissue LOAEL HQs ≥ 1 were also predicted using both sets of tissue TRVs; however, given the low HQs, conservative TRVs relative to cormorant-specific toxicity data for eggs, and lack of evidence on reproductive success from the Parsons (2003) study, risks to cormorants are unlikely. The potential for unacceptable risk (identified based on LOAEL HQs ≥1 and WOE supporting the conclusion of unacceptable risk) was not identified for birds.

6.2.7 Mammal Assessment

The potential for unacceptable risk to mammals was characterized using NBSA tissue and sediment chemistry to estimate dietary doses of COPECs for three mammal species (river otter [*Lontra canadensis*], muskrat [*Ondatra zibethicus*], and harbor seal [*Phoca vitulina*]). Dietary doses were compared to a range of TRVs to derive risk estimates (HQs). As with the aquatic bird dietary LOE evaluation, risk to the three representative mammal species was also evaluated based on foraging in various exposure areas, including the intertidal zone and shoreline, Bay-wide and by the following assessment zones: North, Southeast, and Southwest (Figure 4-35). As part of the uncertainty evaluation, dietary risk estimates for mammals were also evaluated for: (1) different proportions of large fish (i.e., > 30 cm) in the diets of river otter and harbor seal, (2) different proportions of diet components for river otter, (3) SUF for river otter and harbor seal, and (4) the use of the full quantitation limit for non-detects. Further details on the mammal risk assessment can be found in Section 9 of the BERA (Appendix B).

The range of HQs for the aggregate mammal dietary exposure estimates (i.e., all species) with HQs ≥ 1 are depicted in Figure 6-10. Overall, no unacceptable risk to populations of mammals potentially exposed to COPECs in the NBSA is expected. Conclusions for the mammal evaluations are summarized below and in Table 6-11a:

- For harbor seal (piscivorous aquatic mammal): LOAEL HQs < 1 were predicted for all scenarios evaluated in the NBSA-wide and assessment zone areas and the uncertainty evaluation.
- For muskrat (omnivorous/herbivorous mammal): LOAEL HQs < 1 were predicted for all scenarios evaluated in this BERA except for mercury in the southwest zone using LPR FFS TRVs.
- For river otter:
  - Using primary exposure and toxicity assumptions, LOAEL HQs < 1 were predicted for all scenarios evaluated in the BERA except for PCDDs/PCDFs and TEQ using LPR FFS TRVs.
  - Uncertainty analyses, including evaluation of a SUF of 1 and calculation of total concentrations using the full quantitation limit for non-detects, resulted in identification of total PCBs as an additional COPC based on LOAEL HQs equal to 1 for the NBSA-wide area and/or one or more individual assessment zones.

- Unacceptable risk to these COPECs is unlikely based on the following: (1) LOAEL HQs < 1 using most realistic assumptions for river otter populations (NBSA TRVs and both sets of TRVs in NBSA-wide area), (2) conservative assumptions used in the risk estimates (e.g., conservative TRVs and SUFs), and (3) low magnitude of the LOAEL HQs ≥ 1.

In conclusion, potential exposures to COPECs in the NBSA are not expected to pose unacceptable risk to mammals. The potential for unacceptable risk (identified based on LOAEL HQs ≥1 and WOE supporting the conclusion of unacceptable risk) was not identified for mammals.

6.2.8 Reptile Assessment

The evaluation of the potential for unacceptable risk to amphibian and reptile populations in the NBSA was based on a qualitative risk assessment for diamondback terrapin (*Malaclemys terrapin*), the only reptile species with the potential to occur in the NBSA. A qualitative assessment was conducted because diamondback terrapin have limited potential occurrence in the NBSA and the lack of available species-specific TRVs. Available field survey data were insufficient to determine the presence or absence of a diamondback terrapin population in the Bay, as only a single terrapin was observed. Further details on the reptile qualitative risk assessment can be found in Section 10 of the BERA (Appendix B).

The exposure of terrapins or other reptiles in the NBSA would likely be comparable to that for the mammals assessed in Section 6.2.7. Available terrapin habitat, saltmarsh and estuarine habitats with sandy uplands for egg laying (Hart and Lee 2006) in the Bay are small, representing only 0.7% of the total area of the NBSA. As such, it is likely that they would be exposed only on a limited basis. Exposures for reptiles would be from surface water, sediments, and the food web. Risks to reptile receptors in the NBSA are expected to be de minimis based on the following:

- The surface water assessment found no unacceptable concentrations of COPECs in the NBSA either spatially, temporally, or seasonally
- No risks (i.e., LOAEL HQs ≥1) were found for any of the mammal species assessed in the BERA
- In a quantitative assessment of risks to reptiles for the LPRSA BERA (Windward 2019; Appendix N) for COPECs that had sufficient toxicological data (chromium, copper, lead, mercury, nickel, silver, and zinc), all HQs were less than 1.

6.2.9 BERA Conclusions

The NBSA BERA evaluated five assessment endpoints that addressed the protection and maintenance of communities or populations of benthic/epibenthic invertebrates, fish, birds, mammals, and reptiles (Table 6-9). These assessment endpoints were evaluated within a NBSA-specific risk analysis framework using the data and information collected under the Phase III RI/BERA sampling programs, and integrated site and ecosystem history information to inform the CSM and provide perspectives on potential changes in risk over time. Further details on the BERA WOE can be found in Section 11 of the BERA (Appendix B).

The potential for unacceptable risk was assessed using standard risk assessment practices and through development of LOEs to develop a WOE assessment for each receptor type. The LOEs were based on each measurement endpoint evaluated for the selected assessment endpoints, and associated strengths and uncertainties. The design of this risk assessment was focused on minimizing uncertainties, to the

extent practicable, by being reasonably conservative in the exposure assumptions that were made and conducting sensitivity analyses using alternative assumptions for key input parameters to the exposure-risk models and calculations described above. In addition, conservative TRVs were generally used for all of the COPECs, and bounding of the potential effects was conducted by evaluating HQs calculated using both the NBSA TRVs and the TRVs developed by the USEPA (2014a) for use in the LPR FFS. In addition, available site-specific ecotoxicity studies conducted in the NBSA were used for invertebrates, fish, and birds to quantify risks and/or inform the risk assessment.

Based on the integrated risk management findings in the NBSA BERA (GSH 2020), unacceptable risk was considered possible for the following COPECs, which are recommended as risk drivers/COCs:

- PCDDs/PCDFs and TEQ (i.e., 2,3,7,8-TCDD, total PCDD/PCDF TEQ fish, PCDD/PCDF/PCB TEQ fish) – for shellfish (2,3,7,8-TCDD only), forage and predatory fish (Table 6-11a) and benthic communities (2,3,7,8-TCDD only; Table 6-11b)
- PCBs (i.e., total PCBs based on sum of 209 congeners) – for shellfish, forage fish, and benthic communities (Table 6-11b)
- Pesticides (total chlordane, total DDx (2,4' and 4,4'), dieldrin, and hexachlorobenzene) for benthic communities (Table 6-11b), and total DDx (2,4' and 4,4') for blue crab and white perch (Table 6-11a)
- PAHs (total PAH, HMW PAH, LMW PAH, alkylated PAH) – for benthic communities (Table 6-11b)
- Inorganics (arsenic, cadmium, chromium, copper[59], lead, mercury/methylmercury, nickel, silver, and zinc) – for benthic communities (Table 6-11b), arsenic, lead, mercury, and/or methylmercury for shellfish (Table 6-11a), and copper, based on uncertain risk to white perch (Table 6-11a).

As summarized in the bullets above, these COPECs are recommended as COPCs primarily based on their potential local risk to benthic infaunal communities from the sediment toxicity endpoint in the SQT assessment. PCDDs/PCDFs, PCBs, and total DDx (2,4' and 4,4') were also identified based on the WOE evaluation for shellfish and fish. PCDDs/PCDFs, PCBs, total DDx (2,4' and 4,4'), and mercury/methylmercury also showed some potential for risk in one or more of the tissue-based and/or dietary-based assessments for birds and mammals (summarized in Table 6-11a); however, unacceptable risk was considered unlikely in the NBSA for these COPECs and receptors based on the WOE. The final determination of which COCs are ecological risk drivers requiring risk management consideration and preliminary remedial goal development will be made during the FS in consultation with USEPA. This assessment will be based on further consideration of the relative WOE uncertainties described in the BERA.

[59] During discussions regarding the uncertain COC status for copper and with consideration of its essential mineral status for both human and ecological organisms (including fish) and the magnitude of the risk estimates, USEPA determined that copper was not an ecological risk driver requiring PRG development for Newark Bay.

7 CONCEPTUAL SITE MODEL

The NBSA CSM (GSH 2019a) summarized the understanding of relationships between development of the NBSA area and sources, hydrodynamics, nature and extent, fate and transport, exposures and receptors, and trends of key contaminants in the NBSA. The CSM also provided preliminary (i.e., pre-RI Report) evaluations of the spatial and temporal datasets, which provided a means to evaluate potential key findings and trends in the data to inform further analyses presented within this document, including a summary of the extent and distribution of representative organic and inorganic COPCs. While the key findings presented in the 2019 CSM have not significantly changed, the following provides additional information to augment the CSM:

- The Phase III database has been finalized[60], along with analyses supporting the discussion of nature and extent of key contaminants (Section 4)
- Additional information regarding the fate and transport of a subset of COPCs is now available from modeling work completed by the USEPA (Section 5)
- A BHHRA and a BERA have been completed (Section 6).

This additional information provides a basis to update the NBSA CSM and identify linkages between contaminant sources, exposure pathways, and remaining risks to human health and the environment in the NBSA. This RI Report in its entirety presents a detailed update to the CSM, and this section provides an integrated CSM description.

7.1 Fate and Transport of COPCs in the NBSA

Following historical and current discharges of contaminants to the NBSA from point and non-point sources (Figures 5-SC-1 and 5-SC-2), the chemicals partition between the dissolved- and particulate-phase in the water column according to the amount of suspended solids and OC in the water column – which subsequently plays a dominant role in their transport and ultimate disposition throughout the NBSA. Chemicals in the particulate-phase are transferred to the sediment bed by settling where these particles undergo cohesive bonding processes with other fine-grained sediments. Subsequently, contaminated sediments may be resuspended to the water column if forces exceeding critical shear stresses occur (Figure 5-CFT). Available data indicate most COPCs in the NBSA are bound to sediment particles; therefore, the fate and transport of fine-grained sediments in the NBSA governs their movement and long-term fate. If COPC-containing deposits are resistant to erosion, the long-term fate is burial; although, the rate of burial can be limited by either sediment supply, bioturbation, or by a balance between deposition and resuspension processes that does not favor high rates of sedimentation. Particles that are not resistant tend to eventually be focused into the deep channels where they are more susceptible to transport out of the NBSA in tidal flows or may be removed out of the NBSA via maintenance dredging events.

[60] Some minor changes were made to the Phase III database after the CSM was submitted. The changes were based on comments from USEPA and mostly affected the detection limits used for reporting non-detect results.

- As discussed in Section 5, analysis of sediment and COPC mass fluxes from the USEPA CFT model results for the period from 1996 to 2013 show that, due to bi-directional tidal currents, the Bay exchanges sediments and COPCs with connected waterways, and all connected waterways are sources of sediments and COPCs to the Bay. However, net flux determines the role each waterway plays in determining the inventory of contaminants in the Bay and mechanisms of recovery. The export of sediments and COPCs to connected waterways from the Bay can be increased during periods of low freshwater discharge, while high freshwater discharge from rainfall runoff can increase both contaminant loadings to the Bay and flushing of the Bay. Each of these mechanisms can have short-term effects on both solids and contaminant fluxes at the boundaries of the NBSA. Dredging in the adjacent waterways can also alter the magnitude and direction of net flow. For example, dredging planned in the lower reaches of OU2 may increase import of sediment from the Bay into the Passaic River.
- Figures 7-1 through 7-4 illustrate the impact of storm events on net contaminant fluxes at the boundaries of the Bay. For key COPCs, these figures show a comparison of net mass exchange with the Bay for the 2011 Hurricane Irene year and that combined for the remaining years (the non-hurricane years 1996 to 2010, 2012, and 2013) in the modeled period (1996 to 2013). The combined total for the non-hurricane years represents the summation of the net mass exchange for those years. During the 2011 Hurricane Irene event, model results indicate the Passaic River was a large source of COPCs to the NBSA, and predicted surface sediment COPC concentrations in the Bay show an increase in response to the event with predicted declines resuming after 2011 (Figures 5-MOD-18 through 5-MOD-21). The model suggests that reduction of sources from the Passaic River should assist in further reduction of bioavailable surface sediment concentrations of COPCs and tissue COPC concentrations in the Bay. However, the degree of assistance would be expected to be unique to each COPC.
- There is an apparent decreasing trend in observed sediment (Figure 5-B7-1) and tissue 2,3,7,8-TCDD concentrations (Figure 4-36) from north to south, with higher concentrations proximal to Passaic River sources. However, patterns for other COPCs are different. The sediment trends for total PCBs and mercury (Figures 5-B7-2 and 5-B7-4) are relatively uniform along the Bay while that for total DDx (4,4') shows an increasing trend toward the south (Figure 5-B7-3). In tissue, while some species have higher PCB and mercury concentrations in the north assessment zone (e.g., blue crab) other species have no observable north-south trend (Figures 4-37 and 4-39). Total DDx (2,4' and 4,4') in tissue is most elevated in the southwest assessment zone (Figure 4-38), which is consistent with the higher DDx concentrations in sediment in the southern Bay (Figure 5-B7-3).
- Overall, the USEPA CFT model results for the period between 1996 and 2013 (presented in Section 5) (HDR 2021b) show that on a net mass flux basis, the Passaic River is computed to be a net source of 2,3,7,8-TCDD to the Bay. The model results also show the Passaic River is a source of tetra-PCB to the NBSA (61% of the total net loading), followed by the Kill Van Kull (39% of the total net loading). The model shows the Passaic River and the Arthur Kill are important sources of total DDx (4,4') to the NBSA, contributing 28% and 72% of predicted total net loadings for that time period, respectively, and the Passaic River and the Kill Van Kull are important sources of mercury contributing 65% and 35% of the total net loadings, respectively over the same period. The Hackensack is potentially an ongoing source for mercury, based on annual loads measured at the head of tide, although model results

suggest the Hackensack is a net sink of mercury. The Pierson's Creek Superfund Site is an ongoing source of mercury via the Port Newark Channel.

- While model results show net export of 2,3,7,8-TCDD, tetra-PCB, total DDx (4,4'), and mercury occurs between the NBSA and connected waterways (Figures 7-1 through 7-4), the importance of source controls to reduce COPC inputs from adjacent waterways to enhance continued declines in bioavailable surface sediment concentrations of COPCs in the Bay is evident, as connected waterways are sources of both sediments and COPCs to the Bay. Measured particulate concentrations in the water column of the Bay and tributaries (Table 5-14) indicate that concentrations are on average lower than existing surface sediment concentrations in the Bay for most COPCs but are contributing to the chemical inventory in the Bay via deposition. With the exception of PCBs, particulate COPC concentrations on the incoming tides from the Kill Van Kull indicate these sediments will promote further declines in bioavailable surface sediment concentrations of COPCs in the Bay. Model results show the Kill Van Kull is the largest net source of solids to the NBSA (Figure 7-1 through 7-4).

7.2 Exposure Pathways for COPCs in the NBSA

Contaminants enter the food web via accumulation in tissues of biota exposed directly to contaminants in the water column, sediments/porewater, and/or in the tissues of prey items (Figure 6-3). Food web interactions are the most significant exposure pathways for wildlife (i.e., mammals and birds) that forage in the NBSA. For aquatic organisms, such as fish and invertebrates, exposure to contaminated media (i.e., sediment and surface water) occurs via direct contact (e.g., absorption) or ingestion/uptake (bioaccumulation). The estimated depth of the BAZ, the area where biological activity and benthic exposures to contaminants occur, is approximately 6 inches throughout the Bay (Tierra 2008a). Bioaccumulation of contaminants is dependent on a variety of factors including contaminant type and speciation, metabolism, lipid content of the organisms, and physicochemical attributes of the sediment and porewater that control bioavailability (e.g., OC and sulfide content). Risks to human health are due to the consumption of contaminated fish and crab. A conceptual diagram of these source to pathway and exposure risk linkages is provided in Figure 7-5.

The BHHRA and BERA identify two sets of primary risk drivers: 1) Bay-wide risk drivers associated with bioaccumulation into fish and shellfish tissue that pose potential human health risks (cancer and noncancer) from ingestion of fish and blue crab, and ecological risks from accumulated body burdens of these contaminants; and 2) localized risk drivers in sediments that appear to be associated with direct toxicity risks to the benthic (infaunal) community. The focus of this updated CSM is on the characterization of these risk drivers, in terms of their distribution and exposure pathways related to risk, as described in Sections 7.3 and 7.4, respectively.

7.3 Bioaccumulation-based Human Health and Ecological Risk Drivers

The risk drivers for human health are defined as any contaminant with individual cancer risk greater than 10^{-4} or a noncancer HI greater than 1. The risk drivers for ecological risk are defined by the WOE

approach summarized in Table 6-11a. These risk drivers and their associated potential risks are summarized in Table 7-1.

Table 7-1. Summary of Human Health and Ecological Risk Drivers

Risk Driver	Receptors
2,3,7,8-TCDD	Human: Cancer and noncancer risk due to the consumption of fish and crab
	Ecological: Softshell clam, blue crab, and fish (mummichog, American eel, summer/winter flounder, and white perch)
Total PCBs	Human: Cancer and noncancer risk due to the consumption of fish and crab
	Ecological: Softshell clam, blue crab, and fish (mummichog)
Total DDx[a]	Human: Noncancer risk due to the consumption of fish
	Ecological: Blue crab and fish (white perch)
Mercury/ Methylmercury[b]	Human: Noncancer risk due to the consumption of fish
	Ecological: Softshell clam and blue crab
Arsenic, Lead, Nickel[c]	Ecological: Softshell clam

Human health risk for fish assumes consumption of a mixed fish diet comprised of equal parts of five species: American eel, bluefish, striped bass, summer flounder and white perch.
[a]Human health risk is specifically due to 4,4'-DDD. Ecological risk is evaluated as total DDx (2,4' and 4,4').
[b]Human health risk is specifically due to methylmercury.
[c]Subsequent to submittal of the final BERA, nickel was added as a risk driver for softshell clam because it had a LOAEL HQ greater than 1.

With respect to copper, due to the magnitude and uncertainties in risk estimation and in consideration of its essential mineral status for both human and ecological receptors, USEPA determined that copper was not a COC that requires development of a preliminary remedial goal for Newark Bay (USEPA 2021). Updates to the CSM components provided herein focus on the distribution, spatial and temporal trends, and fate and transport of the primary drivers of risk via bioaccumulation pathways – specifically 2,3,7,8-TCDD, PCBs, total DDx (4,4'), and mercury.

7.3.1 PCDDs/PCDFs

2,3,7,8-TCDD was detected at all stations in the NBSA during surface water sampling conducted as part of the RI; although, at concentrations an order of magnitude lower than those found in the Passaic River (AECOM 2011, 2019; USGS 2015)[61] (Section 4.4). While inputs of 2,3,7,8-TCDD to the NBSA continue, comparison of the Phase I/II and Phase III co-located sediment samples indicates that a statistically

[61] PCDDs/PCDFs were also detected in effluent samples from the Joint Meeting of Essex/Union POTW (GLEC 2008).

significant decline in surface sediment 2,3,7,8-TCDD concentrations of 31% (95% CI: 3%, 51%) occurred between the 2005 and 2016 RI sampling events with an estimated average annual rate of 3.4%. The average long-term rate of decline, since 1980 when significant source reduction began, in historically disturbed sediments is estimated at 4.7%. Recent and long-term rates of decline vary by location and are mostly positive (28 of 37 co-located cores; 24 out of 24 long-term datable cores)[62].

The most elevated surface concentrations (i.e., the top 10% of concentrations) in sediments are often associated with the historically disturbed subtidal flats, and the highest subsurface 2,3,7,8-TCDD concentrations also tend to occur within these areas. The Phase III sampling event surface sediment mean 2,3,7,8-TCDD concentration in the historically disturbed subtidal flats is statistically significantly greater than the Bay-wide mean and the mean in the subtidal flats. However, the comparison is not significant after controlling for TOC, suggesting the differences in 2,3,7,8-TCDD concentrations between these areas are likely governed by sediment transport dynamics. This may reflect the higher infilling rates of these areas with finer sediment. On a USEPA subunit basis, the mean 2,3,7,8-TCDD concentration for Phase III surface sediments in USEPA Subunit 4 (comprising primarily the historically disturbed portions of the subtidal flats in the northern NBSA) is statistically significantly greater than the Bay-wide mean and the mean in USEPA Subunit 1 (comprising primarily the southwest subtidal flat areas). After controlling for TOC variability, the finding is the same, reflecting the differences in deposition in the historically disturbed subtidal flats in the northern Bay compared to the complex history of the southwest subtidal flats, which, in addition to channel excavation and filling, was also influenced by the historical dike that was built to prevent sedimentation in the southern channel. Concentrations of 2,3,7,8-TCDD exhibit a decreasing trend from north to south in NBSA surface sediments (Figure 5-B7-1a).

The presence of freely dissolved 2,3,7,8-TCDD in porewater indicates bioavailability to benthic (infaunal) invertebrates; however, the freely dissolved concentrations are well below literature-based threshold toxicity levels. Qualitative comparisons suggest that the mean 2,3,7,8-TCDD concentration in softshell clam is somewhat (1.25 to 1.5 times) higher in the North Zone of the Bay compared to the other BERA assessment zones (Table 4-25). Tissue concentrations for several species exhibit a decreasing trend from north to south (Figure 4-36) and statistical comparisons for blue crab and fish (American eel, flounder, white perch, and mummichog) indicate mean concentrations of 2,3,7,8-TCDD in whole body tissues are significantly greater in the North Zone. Unacceptable risks from 2,3,7,8-TCDD include Bay-wide cancer and noncancer risks to human health from consumption of fish and/or blue crab tissue, and bioaccumulation risks to fish and shellfish (i.e., softshell clam and blue crab).

7.3.2 PCBs

PCBs were detected at all stations in the NBSA during surface water sampling conducted as part of the RI; although, at concentrations three times lower than those found in the Passaic River (AECOM 2011, AECOM 2019a, USGS 2015). Comparison of Phase I/II and Phase III co-located sediment samples

[62] Rates of decline estimated from the RI sediment data are subject to uncertainty and may not be predictive of future conditions. And at a few locations, an increase in COPC concentrations between 2005 and 2016 was noted, suggesting that the average rate of decline may not apply in all areas of the Bay, particularly where deposition rates are very low or where particulate concentrations suggest ongoing inputs of COPCs. In addition, the proposed USACE channel deepening and widening project may also impact surface sediment COPC concentrations in the Bay. Actual effects of this project will be further evaluated in the FS.

indicates that a statistically significant decline in surface sediment PCB concentrations of 46% (95% CI: 27%, 60%) occurred between the 2005 and 2016 RI sampling events with an estimated average annual rate of 5.6%. The average long-term rate of decline, since 1980 when significant source reduction began in historically disturbed sediments is estimated at 5.0%. Recent and long-term rates of decline vary by location and are mostly positive (30 of 37 co-located cores; 24 out of 24 long-term datable cores).[63]

The most elevated surface concentrations (i.e., the top 10% of concentrations) of sediments are often associated with the historically disturbed subtidal flats, and the greatest subsurface PCB concentrations also tend to occur within these areas. The Phase III surface sediment mean total PCB concentration in the historically disturbed subtidal flats is statistically significantly greater than the overall Bay-wide mean and the mean in the subtidal flats. However, the comparison is not significant after controlling for TOC, suggesting the differences in PCB concentrations between these two areas are likely governed by sediment transport dynamics. For Phase III surface sediment, there were no significant differences in mean total PCB concentrations among USEPA subunits or geographic areas. While there are higher PCB concentrations in surface sediments of the LPR, there is no strong north to south trend within the NBSA (Figure 5-B7-2).

Freely dissolved PCBs are present and bioavailable to benthic (infaunal) invertebrates in porewater, with concentrations that exceed WQC. Qualitative comparisons of softshell clam samples suggest that the mean total PCB concentration is 2.5 times higher in the Southwest Zone of the Bay compared to other BERA assessment zones (Table 4-25). Statistical comparisons for blue crab indicate that mean concentrations of PCBs are highest in the North Zone. PCB concentrations were not significantly different among assessment zones in fish tissue and no consistent north-south trends were observed in species other than blue crab (Figure 4-37). Unacceptable risks from PCBs include Bay-wide cancer and noncancer risks to human health from consumption of fish and/or blue crab tissue, and bioaccumulation risks to fish and shellfish (i.e., softshell clam and blue crab).

7.3.3 Total DDx (4,4')

Total DDx (4,4') was detected at all stations within the NBSA during surface water sampling conducted as part of the RI. Surface water concentrations in the Arthur Kill are twice as high as those observed in the NBSA (AECOM 2011, 2019a; USGS 2015). Comparison of Phase I/II and Phase III co-located surface sediment samples indicates that a statistically significant decline in total DDx (4,4') concentrations of 40% (95% CI: 11%, 60%) occurred between the 2005 and 2016 RI sampling events with an estimated average annual rate of 4.3%. The average long-term rate of decline, since 1980 when significant source reduction began, in historically disturbed sediments is estimated at 2.0%. Recent and long-term rates of decline vary by location but are mostly positive (17 of 31 co-located cores; 22 out of 24 long-term datable cores).[64]

The current spatial distribution of DDx in the sediments of the NBSA appears to be influenced in part by the contribution of total DDx (4,4') from the Arthur Kill to the NBSA. Total DDx (4,4') concentrations in surface sediments have declined over time, but remain elevated in the southwest area of the Bay – including the southern subtidal flats and the confluence of Arthur Kill to the NBSA. Model results (1996 to

[63] See Note 62 on page 7-5.

[64] See Note 62 on page 7-5.

2013) indicate that a portion of the total DDx (4,4') flux from the Arthur Kill is offset by transport of total DDx (4,4') out of Newark Bay via the Kill Van Kull. However, the Arthur Kill remains a net source to the Bay, as a portion of the total DDx (4,4') flux from the Arthur Kill is predicted to remain in the Bay. An increasing trend is observed from north to south starting around Bay mile 3.5 (Figure 5-B7-3). For Be-7 bearing channel samples, the trend is only apparent after Bay mile 5 and extends into the Arthur Kill (Figure 5-B7-3). The most elevated surface concentrations (i.e., the top 10% of concentrations) are found in the southwest subtidal flats and the adjacent areas of the Arthur Kill near the confluence with the Bay. Surface concentrations were not found to be significantly greater in the historically disturbed subtidal flats however, the highest subsurface concentrations are found in the historically disturbed subtidal flats. For Phase III surface sediment, the mean total DDx (4,4') concentration in USEPA Subunit 1 (comprising primarily the southwest subtidal flat areas, Figure 2-8) is statistically significantly greater than the Bay-wide mean and the mean in USEPA Subunit 4 (comprising primarily the historically disturbed portions of the subtidal flats in the northern NBSA), USEPA Subunit 5 (subtidal flats along the eastern shore in the southern portion of the Bay), and USEPA Subunit 6 (north and central subtidal flats). After controlling for TOC, the finding is the same, suggesting the differences in total DDx (4,4') concentrations between these areas are not solely governed by sediment transport dynamics, but also reflects the differences in the depositional history in the southwest subtidal flats. For Phase III surface sediment, there were no significant differences in mean total DDx (4,4') concentrations among geomorphic areas.

Freely dissolved total DDx (2,4' and 4,4') is present and bioavailable to benthic (infaunal) invertebrates in porewater, with concentrations that exceed WQC. Qualitative comparisons of softshell clam samples suggest that the mean total DDx (2,4' and 4,4') concentration is 4.5 times higher in the Southwest Zone of the Bay compared to the other BERA assessment zones (Table 4-25). In contrast to the distribution of 2,3,7,8-TCDD and total PCBs, total DDx (2,4' and 4,4') concentrations in biota show an increasing trend from north to south (Figure 4-38). Statistical comparisons for blue crab and fish (American eel, white perch and *Fundulus* spp.) indicate the total DDx (2,4' and 4,4') concentrations are significantly greater in the Southwest Zone. Unacceptable risks from total DDx (2,4' and 4.4') include Bay-wide noncancer risks to human health from consumption of fish (specifically 4,4'-DDD), and bioaccumulation risks to fish and blue crab.

7.3.4 Mercury

Mercury was detected at all stations during surface water sampling conducted as part of the RI, with the highest mean concentrations in the Passaic River, which were three times higher than the NBSA. The highest concentration of mercury on suspended solids were found in the Passaic River and the Hackensack River. Comparison of Phase I/II and Phase III co-located surface sediment samples indicates that a statistically significant decline in mercury concentrations of 28% (95% CI: 5%, 45%) occurred between the 2005 and 2016 RI sampling events with an estimated average annual rate of 3.2%. The average long-term rate of decline, since 1980 when significant source reduction began in historically disturbed sediments is estimated at 3.7%. Recent and long-term rates of decline by location vary but are mostly positive (27 of 37 co-located cores; 23 out of 24 long-term datable cores; Figure 5-DEC).[65]

[65] See Note 62 on page 7-5.

The most elevated surface concentrations (i.e., the top 10% of concentrations) of mercury are found in the southern subtidal flats. For Phase III surface sediment, there were no significant differences in mean mercury concentrations among geomorphic areas, and no consistent north-south trend (Figure 5-B7-4) but on a USEPA subunit basis, the mean mercury concentration in USEPA Subunit 1 (comprised primarily of the southwest subtidal flat areas, Figure 2-8) is statistically significantly greater than the Bay-wide mean and the mean in USEPA Subunit 6 (comprised primarily of subtidal flats in the northern portion of the NBSA). After controlling for aluminum, the finding is the same reflecting the differences in the depositional histories of these areas of the Bay. The maximum surface and subsurface mercury concentrations were observed in cores at the upper end of the Port Newark Channel near the discharge of Pierson's Creek. Pierson's Creek is the location of a designated Superfund site, due to elevated levels of mercury and other contaminants, and may be a source of mercury to the NBSA.

Freely dissolved mercury is bioavailable to benthic (infaunal) invertebrates with more than 98% of mercury in porewater being present in the methylated form. Qualitative comparisons of softshell clam samples suggest that the mean mercury concentration is 1.2 to 1.6 times higher in the North Zone of the Bay compared to other BERA assessment zones (Figure 4-35). Similar to 2,3,7,8-TCDD and total PCBs, statistical comparisons for blue crab samples indicate the highest concentrations are found in the North Zone. Analyses of benthic forage fish (i.e., *Fundulus* spp.) also found the highest mean concentrations of mercury in the North Zone. There were no consistent north-south trends for other species (Figure 4-39). Unacceptable risks from mercury include Bay-wide noncancer risks to human health from consumption of fish (specifically methylmercury), and bioaccumulation risks to softshell clam and blue crab.

7.4 Benthic Invertebrate Community Risk Drivers

A sediment quality triad investigation was conducted to evaluate risks to the benthic (infaunal) invertebrate community from direct exposure to COPCs in sediments within the NBSA. Sediment samples from 30 locations were evaluated for sediment and porewater chemistry, toxicity testing (i.e., *L. plumulosus*), and benthic invertebrate taxa quantification/characterization. The benthic invertebrate community data indicated no impact compared to reference communities from Jamaica Bay. Based on 28-day survival, chronic toxicity was observed at six of 30 locations in the NBSA (Figure 4-28); although, there is uncertainty due to high variability in control survival, which was often less than 80%. Growth and reproductive endpoints were statistically significantly different than control at 18 and 13 of 30 stations, respectively, and these endpoints were also subject to high variability. Based on 10-day survival, acute toxicity was only observed at two locations in the southwest subtidal flats (Figure 4-28) where the highest concentrations of most chemicals were also found. In multivariate analyses and dose-response modeling of toxicity data, multiple co-occurring contaminants in sediment and porewater were correlated with and found to be predictive of acute and chronic toxicity in the NBSA including: PCDDs, PCDFs, PCBs, pesticides, PAHs, and metals. Based on the application of dose-response models to all Phase III sediment data, acute and chronic toxicity is predicted to occur in localized areas of the Bay, particularly in the southwest subtidal flats and near the I-78 bridge crossing in the northern Bay (Figures 6-5 and 6-6). Samples in these areas have the highest (i.e., upper 90th percentile) chemical concentrations in sediment. While many contaminants were correlated with toxicity endpoints (and each other), likely risk drivers are those contaminants for which WQC (or other toxicity benchmarks from literature [Buchman 2008; USEPA 2017] where WQC were unavailable) were exceeded in porewater samples, particularly at stations exhibiting toxicity. The contaminants for which both porewater exceedances and toxicity were observed

are as follows (along with total number of porewater exceedances in parentheses): PCBs (3), total DDx (4,4') (14), PAHs (2), and arsenic (3). While 2,3,7,8-TCDD was fully detected in porewater, it did not exceed the chronic screening value from literature (10 pg/L). Similarly, while lead, mercury, and nickel were found to be risk drivers due to bioaccumulation in softshell clam, their concentrations in porewater did not exceed screening values.

PCBs and total DDx (4,4') are discussed as Bay-wide risk drivers in Sections 7.3.2 and 7.3.3 above, respectively. PAHs and arsenic are only risk drivers due to direct exposure in localized areas where sediment toxicity to benthic invertebrates was found, and their occurrence in porewater in those areas is the primary basis for differentiating them from other potential sediment contaminants that may contribute to such risks. There are no New Jersey WQC for PAHs; therefore, PAH concentrations in porewater were evaluated in two ways: 1) comparison to marine screening values from the literature (e.g., 300 µg/L for total alkylated PAHs) which were not exceeded, and 2) calculation of the sum of toxic units of 34 PAHs (including alkylated PAHs) related to the narcosis model of toxicity (USEPA 2017). The sum of toxic units was greater than or equal to one (indicating potential for toxicity) at the two acutely toxic stations (both located in the southwest subtidal flats), and alkylated PAHs contributed the most to the sum of toxic units at those stations. Arsenic was detected in porewater at one of the acutely toxic stations in the southwest subtidal flats at a concentration above the acute WQC. PAHs (alkylated PAHs in particular) and arsenic are also most elevated in sediments in the two acutely toxic stations and the southwest subtidal flats in general.

PAHs in sediment are found throughout the Bay and mean concentrations in sediments for all summations (i.e., total PAHs, total HMW PAHs, total LMW PAHs, and total alkylated PAHs) were not found to be significantly different among the spatial units evaluated in the RI. However, the majority of the most elevated total alkylated PAH concentrations (i.e., the top 10% of concentrations) were found in the southwest subtidal flats (Figure 4-22). The most elevated surface concentrations (i.e., the top 10% of concentrations) of arsenic are found in the southwest subtidal flats (Appendix F; Figure F-25) and the mean concentration of arsenic is significantly greater in USEPA Subunit 1 (comprising primarily the southwest subtidal flat areas) compared to other subunits and the overall Bay-wide mean (Table 4-14).

8 SUMMARY AND CONCLUSIONS

The RI goals, as defined in the AOC (CERCLA; Index 02-2004-2010; USEPA 2004a) are to determine the horizontal and vertical distribution and concentrations of COPCs, determine the primary human and ecological receptors (endpoints), and determine the significant direct and indirect continuing sources of COPCs in the NBSA. This RI Report for the NBSA documents accomplishment of these goals and contains an integrated evaluation of the history, physiography, hydrodynamics, and sources, nature and extent, fate and transport, and risk of contaminants in the Bay. The characterization is primarily based on investigations and data collections in the Bay under the RI program and is supplemented by secondary data as appropriate (see Section 2). From this process, a CSM has been developed for the NBSA (see Section 7), and the information has been synthesized and arranged to support remedial decision-making in the FS. This section provides a brief overview of the key findings of the RI.

Under the NBSA RI/FS program, extensive sampling, analysis, survey, and testing activities have been conducted throughout the NBSA in three phases, each informed by prior phase(s) results and advancement of the NBSA CSM. A robust data set was collected in the following categories:

- Sediment chemistry (surface layer and deep cores)
- Sediment profile imaging and related studies to define the BAZ
- Surface water chemistry
- Porewater chemistry
- Sediment toxicity testing (laboratory)
- Sediment bioaccumulation testing (laboratory)
- Fish and shellfish (blue crab/softshell clam) tissue chemistry
- Benthic (infaunal) invertebrate community surveys
- Bathymetric surveys
- Habitat and shoreline surveys
- Secondary data/information compilation and evaluation
- Physical water column measurements for model calibration, including: currents, salinity, temperature, water depth, turbidity/acoustic backscatter, velocity transects, and water sample measurements of total suspended solids.

The sampling and activities conducted under the three phases of the RI informed the assessment of the nature and extent of contamination in the NBSA. Contaminants in the Bay include PCDDs/PCDFs, VOCs, SVOCs, PCBs, pesticides, chlorinated herbicides, TPH, metals[66], butyltins, and cyanide. Temporal, spatial, and statistical analyses were performed on sediment data grouped by geomorphic areas, USEPA-

[66] As noted in Section 4.1.1, “metals” also includes other inorganic compounds, such as arsenic and antimony; metals are listed in Table 4-1.

defined subunits, depth, and depositional environment. Station-specific observations were assessed using principal component analysis and comparisons of sediment COPC concentrations to urban reference values. Fate and transport modeling of the sediment and CFT processes of contaminants driving risk (modeling completed by USEPA) provided insight to factors controlling changes in contaminant surface sediment concentrations over time and illustrate the role of source control in enabling continued declines in exposure concentrations. The BHHRA and BERA have determined the level of risks associated with existing contamination in the NBSA.

The information summarized above supports the following conclusions:

Sediment data show surface sediment COPC concentrations in the Bay are declining. Comparison of 37 temporally co-located surface sediment samples suggest contaminant concentrations for most COPCs (except arsenic) have declined over the recent period between 2005 and 2016. In historically disturbed subtidal flats, historical declines are evident over the period between 1980 and 2016 after significant source reduction had taken place. These findings reflect infilling of historically disturbed areas of the subtidal flats with comparatively less contaminated sediments resulting from concurrent reductions in historical COPC inputs. And while USEPA's CFT model results indicate some increases in surface sediment concentrations of COPCs occurred in the Bay after Hurricane Irene, model-predicted surface sediment concentrations began declining the following year.

Some sediment core profiles show the declines in contaminant concentrations are driven by burial of older sediments and deposition of sediment with lower contaminant concentrations than historical legacy sediment. However, the rates of decline estimated from the RI sediment data are subject to uncertainty and may not be predictive of future conditions. And at a few locations, an increase in COPC concentrations between 2005 and 2016 was noted, suggesting that the average rate of decline may not apply in all areas of the Bay, particularly where deposition rates are very low or where particulate concentrations (as described below) suggest ongoing inputs of COPCs. Heterogeneity in sediment concentrations may also cause variability in comparing resample results near a single location. More recent rates of sediment burial appear slower (Section 5.4.5); however, it is unknown if rates would continue to be slower due to rising bed elevations coming into dynamic equilibrium with erosive stresses (e.g., wind waves and tidal flows) or if sea level rise may offset these such that similar rates occur going forward. The observed declines in sediment concentrations reflects not only burial, but also reductions in external sources of contaminants; these two processes continue to facilitate reduction of concentrations of risk-driving contaminants in surface sediments. This decline in contaminant input is reflected in lower concentrations of contaminants in depositing sediments in the Bay.

Benthic toxicity has declined and benthic community health is improving. Declines in surface sediment toxicity to the benthic community have been measured, based on datasets spanning a 20+ year period. Over this time, benthic community diversity and abundance metrics have increased along with favorable changes to the benthic index of biotic integrity metric.

The NBSA both contributes and receives contaminant loads from connected waterways. Analysis of sediment and mass fluxes of risk-driving contaminants between the NBSA and connected waterways show that, due to bi-directional tidal currents, bi-directional tidal fluxes of sediments and contaminants are exchanged with connected waterways. The direction of net transfer varies among the individual compounds and waterway interfaces. All connected waterways are sources of sediments and risk-driving contaminants to the Bay, and depending on the COPC evaluated, the Bay is a source of sediments and

contaminants to some connected waterways; and for other contaminants, the Bay is a net source to specific waterways. The difference between particulate contaminant concentrations in the water column compared to waterways flowing into the NBSA and contaminant concentrations in surface sediments of the NBSA will play a role in determining how quickly concentrations of the risk drivers decline, and ultimately, the extent to which background levels limit declines. Planned remedial efforts for the lower 8 miles of the Passaic River will reduce inputs of contaminants to the NBSA and is anticipated to promote further decline of COPC levels in NBSA surface sediment. Particulate contaminant concentrations in Kill Van Kull inflows indicate comparatively less contaminated incoming sediment from this source, with the exception of PCBs. The Kill Van Kull is the largest net source of sediment loading to the Bay, based on modeling results. Particulate concentrations and the USEPA CFT model show the Kill Van Kull to be an ongoing source of PCBs to the Bay, while the Arthur Kill is an ongoing source of total DDx (4,4') to the sediments in the Bay. These have the potential to restrict future declines in concentrations of these risk drivers in the NBSA.

Bioaccumulation-based risks to human and ecological receptors remain. 2,3,7,8-TCDD, PCBs, total DDx (particularly 4,4'-DDD), copper[67], and mercury (as methylmercury) are associated with Bay-wide human health risks in the NBSA associated with consumption of fish and blue crab. In addition, there are bioaccumulation-based ecological risks to softshell clam (2,3,7,8-TCDD, PCBs, arsenic, lead, mercury, and nickel), blue crab (2,3,7,8-TCDD, PCBs, total DDx (2,4' and 4,4'), and mercury), and fish (2,3,7,8-TCDD and total DDx (2,4' and 4,4')). Other COPCs contribute to overall risks in the system at lower relative magnitudes than those discussed above. Ongoing reductions in COPC inputs and deposition of comparatively less contaminated sediments in the Bay may further reduce future bioaccumulation risks.

Localized risks for direct sediment exposure/toxicity for the benthic (infaunal) community remain. Based on porewater concentrations, PCBs, total DDx (4,4'), PAHs, and arsenic are the primary COPCs associated with direct sediment toxicity risk to benthic (infaunal) invertebrates in localized areas of the NBSA – particularly in the southwest subtidal flats and near the I-78 bridge crossing in the northern Bay. Other contaminants may also contribute to observed toxicity in the system, but their likelihood as toxicological drivers in sediments is substantially less than those discussed herein. For example, 2,3,7,8-TCDD, lead, and nickel are associated with risk to softshell clam; however, porewater concentrations were below toxicity thresholds. Reduction of source(s) of total DDx (4,4') from Arthur Kill may be needed to ultimately achieve reduction in direct toxicity risks in the NBSA.

Shipping channel maintenance dredging is supportive of long-term risk reduction goals. Periodic removal of sediments and associated COPC mass in the channels via maintenance dredging will tend to lead to gradual declines in the overall mass of COPCs within the Bay. This will further reduce already lower concentrations of risk-driving contaminants in recently-deposited sediments in the navigational channel areas. The USEPA CFT model results for the 10-year simulation period indicates these channels capture 80% of the sediments and associated contaminants deposited in the Bay. Sediments currently accumulating in these channels have lower concentrations of risk-driving contaminants in comparison to historical sediments. Periodic removal of this inventory of low-level risk driver-contaminated sediment from

[67]The BHHRA identified copper as contributing to an unacceptable noncancer hazard from blue crab consumption. Due to the toxicity value and uncertainty factors used to estimate the noncancer hazards associated with copper, and considering that copper is an essential nutrient, USEPA determined that a PRG does not need to be calculated for copper.

the navigational channels by maintenance dredging will prevent their remobilization and potential export to areas of the Bay outside of the navigational channels. This may promote further declines in sediment contaminant levels in non-dredged areas in the Bay and in water column contaminant concentrations. The USACE proposed deepening and widening of the navigation channel may alter sediment inventories and sediment transport processes in the Bay. Potential effects of this project will be further evaluated in the FS.

9 REFERENCES

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TABLES

Table 1-1
History of Dredging Activities within Newark Bay

Area	Year	New Dredge Depth (feet Mean Low Water)	Wetlands and Channel Widths
Newark Bay	Mid-19th century	< 10	The bay was bordered by extensive wetlands in the western and northern areas.
Newark Bay navigation channel south, central, and north reaches	1912	16	The wetlands in the western and northern areas were mostly intact but were bisected by multiple railways.
Newark Bay navigation channel south, central, and north reaches	1916	20-21	Port Newark terminal was built over reclaimed wetlands. The width of the shipping channel in the southern bay was increased to 400 feet.
Arthur Kill	1917	25	
Newark Bay navigation channel south and middle reaches and Port Newark reaches	1923	30	
Passaic River and Newark Bay navigation channel north reach	1923	20	
Passaic River and Newark Bay navigation channel north reach	Early 1930s	30	
Hackensack River	1954	32-34	
Newark Bay navigation channel south and middle reaches and Port Elizabeth reaches	1960s to 1970s	Not applicable	Most of the remaining wetlands in the western area were reclaimed. The width of southern Newark Bay was reduced in half with the building of the Elizabeth Channel.
Newark Bay navigation channel south, central, and north reaches	1960s to 1970s	35	
Newark Bay navigation channel south reach	1966	Not applicable	Channel near Kill Van Kull was widened to 700 feet.
Newark Bay navigation channel south reach	1973	Not applicable	Channel near Kill Van Kull was widened to 800 feet.
Newark Bay navigation channel south reach	1980	Not applicable	Channel near Kill Van Kull was widened to 1,000 feet.
Newark Bay navigation channel south, central, and north reaches	1980s	40	
Newark Bay navigation channel south, central, and north reaches	1999 to 2016	50-52	See Figure 1-3 for extent of dredging.
Kill Van Kull	1999 to 2016	50-52	See Figure 1-3 for extent of dredging.
Newark Bay navigation channel south reach	1999 to 2016	Not applicable	Channel near Kill Van Kull was widened to 1,700 feet.
Kill Van Kull navigation channel Elizabethport reach	1999 to 2016	40-43	See Figure 1-3 for extent of dredging.

Table 1-2
General Notice Letter Recipients

Recipient of General Notice Letter	Date of Letter
Honeywell International, Inc.	8/24/2006
Prentiss, Inc.	8/24/2006
Public Service Electric & Gas	8/24/2006
Troy Chemical Corporation	8/24/2006
Amcol Realty Co.	7/13/2007
BASF Catalysts LLC	7/13/2007
Bayer Corporation	7/13/2007
Chevron Texaco Corporation	7/13/2007
Colt Corporation	7/13/2007
Columbia Terminals, Inc.	7/13/2007
E.I. duPont de Nemours and Company	7/13/2007
General Cable Industries, Inc.	7/13/2007
ISP Environmental Services, Inc.	7/13/2007
OENJ Cherokee Corporation	7/13/2007
Beazer East, Inc.	9/3/2009
Cytec Industries, Inc.	9/3/2009
Exxon Mobil Corporation	9/3/2009
Koppers Inc.	9/3/2009
Reichhold, Inc.	9/3/2009
CycleChem, Inc.	1/31/2012
IBM Corporation	1/31/2012
ICI Americas Inc.	1/31/2012

Note:
The Newark Bay Study Area operable unit is part of the Diamond Alkali Superfund Site.

Table 2-1
Summary of Remedial Investigation Sampling Programs

RI Phase	Year Conducted	Sampling Program	Number of Sampling Locations	Sampling Depth (ft bss)	Sample Type	Sample Analyses	Number of Samples	Sampling Program Details
Phase I	2005	BAZ Investigation	NA	NA	NA	NA	NA	Investigation activities confirmed 0.5-ft depth bss was sufficient for BAZ sampling.
	2005	Bathymetric Survey	NA	NA	NA	NA	NA	Used to define geomorphic areas and to assist field crews with sediment core collection.
	2005	Sediment Investigation	69	0 to 11	Sediment	Chemistry, Radiochemistry	Chemistry: 301 Radiochemistry: 547	Sampling interval: 0.5- to 2-ft. Radiochemistry analyses conducted at 51 locations at non-contiguous 2-inch sampling intervals. Be-7 analyses conducted on top 1-inch of sediment at all locations.
Phase II	2007	Sediment Investigation	50	0 to 29.5	Sediment	Chemistry, Radiochemistry	Chemistry: 385 Radiochemistry: 491	Sampling interval: 0.5- to 2-ft. Radiochemistry analyses conducted at 29 locations at non-contiguous 2-inch sampling intervals. Be-7 analyses conducted on top 1-inch of sediment at all locations.
Phase III	2010	CPG Physical Water Column Monitoring	3 locations within the NBSA	Water Column	Surface Water	Physical Water Quality Parameters	Multiple depending on Parameter	Physical water quality parameters measured over a period from March through November 2010.
	2011-2013	CPG Chemical Water Column Monitoring	6 locations within the NBSA	Water Column	Surface Water	Chemistry, Water Quality	158-233	Sampling included five events under normal flow conditions, a single low-flow event, and two high-flow events. Grab samples collected from 3 feet (0.9 meter) above the bottom and 3 feet (0.9 meter) below the surface. Samples collected at four intervals (i.e., high water slack tide, low water slack tide, maximum ebb tide, and maximum flood tide) at each location and depth.
	2012/2013	Bathymetric Survey	NA	NA	NA	NA	NA	Conducted to support hydrodynamic and sediment transport modeling for the Lower Passaic River Study Area and to support the NBSA Conceptual Site Model.
	2013	Reconnaissance Survey	NA	NA	NA	NA	NA	Conducted to provide qualitative observations of shoreline features and characteristics of the NBSA as part of the Baseline Human Health and Ecological Risk Assessments.
	2014	Crab and Clam Sampling Program	18	0 to 0.5	Sediment	Chemistry	18	Co-located clam and surface sediment collected at each location.
			18	NA	Softshell Clam Tissue	Chemistry	18	
			37	NA	Blue Crab Tissue	Chemistry	111	Hepatopancreas, edible muscle, and carcass tissue samples collected at each location.
	2014, 2015, 2016	Fish Sampling Program	NA	NA	Tissue	Chemistry	190	Target species selected to represent key trophic levels and feeding guilds. Whole body, fillet, and liver fish tissue samples collected.
	2015	SQT & Porewater Sampling Program	43	0 to 0.5	Sediment	Chemistry	43	SQT analyses, benthic invertebrate community analysis, and porewater chemistry analyses conducted at 30 stations. Bioaccumulation tests conducted at a subset of eight stations. Chemistry analyses conducted on an additional 13 locations to support the Baseline Human Health Risk Assessment.
			8	NA	Tissue	Chemistry	8	
			30	0 to 0.5	Porewater	Chemistry	30	
			30	0 to 0.5	Toxicity	NA	30	
			30	0 to 0.5	Benthic Invertebrate Community	NA	90	
	2016	Sediment Investigation	220	0 to 0.5	Sediment	Chemistry	193[a]	Sampling interval: 0- to 0.5-ft.

Table 2-1
Summary of Remedial Investigation Sampling Programs

Notes:
[a] A total of 173 discrete vibracore surface sediment samples and 47 grab samples were collected in 2016, for a total of 220 individual sampling locations. The vibracore samples and 10 of the grab samples were analyzed as discrete samples, while the remaining grab samples were combined into 10 composite samples for analysis.

Acronyms and Abbreviations:
BAZ = biologically active zone
Be-7 = beryllium-7
CPG = Cooperating Parties Group
ft bss = feet below sediment surface
ft = feet
NA = not applicable
NBSA = Newark Bay Study Area
SQT = Sediment Quality Triad

Table 2-2
Remedial Investigation Goals and Objectives by Site Investigation Phase

	Remedial Investigation Goal 1: Nature and Extent of Sediment Contamination	Remedial Investigation Goal 2: Risk Assessment	Remedial Investigation Goal 3: Source Identification
Phase I	1.Confirm the presence and extent of individual geomorphic areas. 2.Estimate the approximate depth of the 1940 sediment horizon (1940 horizon) in each defined geomorphic area. 3.Better understand broad patterns of constituents in both the surface and subsurface sediments and attempt to identify preliminary "hot spots" through statistical analyses (e.g., Rosner's test [USEPA 2006]). 4.Confirm that the current analytical suite is appropriate for the various geomorphic areas. 5.Determine data needs for subsequent phases (Tierra 2005).	1.Preliminarily characterize (through sediment sampling) the nature of contamination within select ecologically sensitive intertidal mudflats. 2.Determine the depth of the biologically active zone within each geomorphic area of the Phase I Study Area (Tierra 2005).	1.Gather information to be used in identifying ongoing sources to Newark Bay, including identification of sampling locations for future phases of work. 2.Confirm (through sediment sampling) the impact to select areas of Newark Bay and the Hackensack River believed to be affected by historical and/or current discharges (Tierra 2005).
Phase II	1.Characterize sediments to the 1940 horizon depth in select areas found to be accreting sediments at a relatively high rate, including select Phase I locations and other areas of potential high net deposition, as identified by the USACE (2006). 2.Characterize sediments (both surface and at depth) in specific regions of Newark Bay to further the understanding of broad spatial patterns for constituents of potential concern (COPCs). 3.Seek to understand matrix heterogeneity in select regions of Newark Bay (Tierra 2014c).	-	1.Characterize surface and subsurface sediments in select areas found to be potentially impacted by upland sources (Tierra 2014c).
Phase III	1. Determine the approximate boundaries of subunits within Newark Bay that contain statistically distinct concentrations of COPCs, especially dioxin. 2. Determine the means and variances of COPC concentrations within these subunits. 3. Determine how surface sediment COPC concentrations within these subunits vary with time (Tierra 2016).	*Crab and Clam Sampling Program* 1. Evaluate whether exposure to site-related constituents of potential ecological concern (COPECs) in the Newark Bay Study Area (NBSA) poses unacceptable risks to benthic macroinvertebrates (represented by blue crab and softshell clams). 2. Evaluate whether the consumption of blue crabs from the NBSA poses unacceptable risks to humans. 3. Evaluate whether the consumption of blue crabs and softshell clams from the NBSA poses unacceptable risks to ecological wildlife receptors (i.e., birds and mammals). 4. Evaluate whether exposure to surface sediments in the Intertidal Areas of the NBSA poses unacceptable risks to ecological receptors (Tierra 2014a). 5. Evaluate whether exposure to surface sediments in the Intertidal Areas of the NBSA poses unacceptable risks to human receptors (Tierra 2014a)[a]. *Fish Sampling Program* 1. Evaluate whether exposure to site-related COPECs in the NBSA poses unacceptable risks to fish. 2. Evaluate whether the consumption of fish from the NBSA poses unacceptable risks to human and ecological receptors (e.g., birds, mammals) (Tierra 2014b). *Sediment Quality Triad and Porewater Sampling Program* 1. Evaluate whether exposure to site-related COPECs in the NBSA poses unacceptable risks to benthic invertebrate communities. 2. Evaluate whether the consumption of benthic invertebrates (represented by a laboratory-exposed bioaccumulation test) poses unacceptable risks to fish and wildlife (ecological) receptors. 3. Evaluate whether exposure to site-related COPCs in surface sediments in the shoreline Intertidal Areas of the NBSA poses unacceptable risks to human receptors (Tierra 2015).	*Combined Sewer Overflow (CSO) and Stormwater Outfall (SWO) Characterization* 1. Develop an inventory of CSO outfalls, SWOs, emergency relief points, publicly owned treatment works outfalls, and outfall points for permitted industrial facilities that discharge to the NBSA (GSH 2017).

Table 2-2
Remedial Investigation Goals and Objectives by Site Investigation Phase

Notes:
[a] Evaluation of risks of exposure to surface sediments in intertidal areas was not initially identified as an objective of the baseline human health and ecological risk assessment in the Crab and Clam Sampling and Analysis Quality Assurance Project

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Tierra. 2015. Sediment Quality Triad and Porewater Sampling and Analysis Quality Assurance Project Plan. Newark Bay Study Area. Revision 2. August.

Tierra. 2016. Newark Bay Study Area Phase III Sediment Investigation Quality Assurance Project Plan Amendment. Revision 2. September.

USACE. 2006. Geomorphological/Geophysical Characterization of the Nature and Dynamics of Sedimentation and Sediment Transport in Newark Bay Focusing on the Effects Related to Continued and Future Federal Navigation Channel Deepening and Maintenance. Contract W912DS-06-D-0001. U.S. Army Corps of Engineers. December 31.

USEPA. 2000. USEPA Guidance for Data Quality Assessment, Practical Methods for Data Analysis, Office of Environmental Information, Washington, D.C., USEPA QA/G-9, QA00 Update, USEPA/600/R-96/084.

Table 2-3
Newark Bay Study Area Remedial Investigation Analytical Summary

Parameter Group[a]	Phase I	Phase II	Phase III					
	Sediment	Sediment	Crab/Clam Sediment	SQT Sediment	Surface Sediment	Biota Tissue	Porewater	Surface Water
Ammonia Nitrogen	-	-	X	X	-	-	X	X
AVS/SEM	-	-	X	X	-	-	-	-
Chlorophyll-a	-	-	-	-	-	-	-	X
DOC	-	-	-	-	-	-	X	X
Grain Size	X	X	X	X	X	-	-	-
Herbicides	X	X	X	X	X	-	-	-
Hexavalent Chromium	-	-	X	X	-	-	-	X
Lipids	-	-	-	-	-	X	-	-
Metals[b]	X[c]	X[c]	X	X	X	X	X	X[d]
Organotins	X	-	X	X	-	X	-	X
ORP	-	-	X	X	-	-	-	X
PAHs	X	X	X	X	X	X	X	X
PBDEs	-	X	-	-	-	-	-	-
PCB Aroclors	X	X	X	X	X	X	-	-
PCB Congeners	X	X	X	X	X	X	X	X
PCDDs/PCDFs	X	X	X	X	X	X	X	X
PCNs	-	X	-	-	-	-	-	-
Percent Moisture	X	X	X	X	X	X	-	-
Pesticides	X[e]	X	X	X	X	X	X	X
pH	-	-	X	X	-	-	-	X
POC	-	-	-	-	-	-	-	X
Radiochemistry	X	X	-	-	-	-	-	-
Semivolatiles	X	X	X	X	X	X	-	X
Specific Gravity	-	X	-	-	-	-	-	-
TEPH[f]	X	X	-	-	-	-	-	-
TOC	X	X	X	X	X	-	-	X
Total Cyanide	X	X	X	X	X	-	-	X
Total Kjeldahl Nitrogen (TKN)	-	-	X	X	-	-	-	X
Total Phosphorus	-	-	X	X	-	-	-	X
Total Sulfide	-	-	X	X	-	-	X	X
TPH[f]	-	-	X	X	X	-	-	-
Water Quality Parameters[g]	-	-	-	-	-	-	-	X
Volatiles[h]	X	X	X	X	X	-	-	X

Notes:

[a] For specific analytical methods and target analytes in each parameter group, refer to program-specific work plans, quality assurance project plans, and data reports, as referenced in Section 2.1.

[b] Includes mercury and methylmercury.

[c] Phase I and Phase II sediment samples were not analyzed for methylmercury.

[d] Surface water samples were analyzed for both total and dissolved metals. Total metals analyses included mercury and methyl mercury. Dissolved metals analyses included hexavalent chromium, mercury and methyl mercury.

[e] Phase I sediment samples were not analyzed for 2,4'-DDD, 2,4'-DDE, or 2,4'-DDT.

[f] The Phase I/II data represent total extractable petroleum hydrocarbons (TEPH) whereas Phase III TPH data represent C9-C40 hydrocarbons.

[g] Salinity, alkalinity, hardness, suspended solids, total dissolved solids, chloride, temperature, turbidity, conductivity, and dissolved oxygen.

[h] List of target volatiles for sediment was shortened to the following after completion of the Phase I sampling program: 1,2,4-Trichlorobenzene, 1,2-Dichlorobenzene, 1,3-Dichlorobenzene and 1,4-Dichlorobenzene.

Acronyms and Abbreviations:

- = not analyzed
AVS/SEM = acid volatile sulfide/simultaneously extracted metals
DDD = dichlorodiphenyldichloroethane
DDE = dichlorodiphenyldichloroethylene
DDT = dichlorodiphenyltrichloroethane
DOC = dissolved organic carbon
ORP = oxidation reduction potential
PAHs = polycyclic aromatic hydrocarbons
PCDDs/PCDFs = polychlorinated dibenzo-*p*-dioxins/polychlorinated dibenzofurans
PBDEs = polybrominated diphenyl ethers
PCB = polychlorinated biphenyl
PCNs = polychlorinated naphthalenes
POC = particulate organic carbon
SQT = Sediment Quality Triad
TEPH = total extractable petroleum hydrocarbons
TOC = total organic carbon
TPH = total petroleum hydrocarbon

Table 3-1
Area Coverage in the Newark Bay Study Area

Geomorphic Area	Area (acres)	% of NBSA Area	Average Depth[a] (ft NAVD88)
Subtidal Flats	1715.9	42.4	7.5
Historically Disturbed Subtidal Flats	251.4	6.2	8.4
Transitional Slopes	410.7	10.1	26
Navigation Channels/Port Channels	1276.7	31.5	50[b]
Intertidal Areas	24.4	0.6	3.2
Industrial Waterfront Areas	343.6	8.5	17
Confined Disposal Facility[c]	27.4	0.7	6.1

Notes:
[a] Average depths were tide-corrected from the 2012/2013 bathymetric survey (Tierra 2013).
[b] Average depth of the Navigation Channels/Port Channels is estimated based on the Harbor Deepening Project completed in 2016.
[c] The confined disposal facility is not a designated geomorphic area but is an area of importance as described in Section 3.3.

Acronyms and Abbreviations:
% = percent
ft = feet
NAVD88 = North American Vertical Datum of 1988
NBSA = Newark Bay Study Area

References:
Tierra. 2013. Multi-beam and Single-beam Bathymetric Survey Final Report. Newark Bay Study Area Remedial Investigation. Revision 0. August.

Table 3-2
Freshwater Discharges to Newark Bay*

Source	Location	Average Flow (cfs)	Peak Flow (cfs)	Source
Passaic River	Little Falls, NJ	1,145	31,700	USGS (2020a)
	Newark Bay[1]	1,399	34,356	Suszkowski (1978)[5]
	Newark Bay[2]	1,482	36,400	HydroQual (2007)
Hackensack River	New Milford, NJ	87	11,600	USGS (2020b)
	Newark Bay[3]	152	18,302	Suszkowski (1978)[5]
Rahway River	Rahway, NJ	52	7,250	USGS (2020c)
Elizabeth River	Elizabeth, NJ	27	6,260	USGS (2020d)
Morses Creek[4]	Linden, NJ	2	12.8	USGS (2020e)
Fresh Kills Ck.	Staten Island, NY	14	NA	Thomas (1993)

Notes:
* Freshwater sources with unavailable flow data, such as Peripheral Ditch and Pierson's Creek, are not listed.
[1] Flows multiplied by 1.227 to extrapolate flow additions for area downstream from Little Falls gaging station per Suszkowski (1978).
[2] Flows multiplied by 1.3 per HydroQual, Inc. (2007).
[3] Flows multiplied by 1.743 to extrapolate flow additions for area downstream from New Milford gaging station per Suszkowski (1978). There is uncertainty inherent in use of this scaling factor as it may not be applicable to current conditions due to changes in land use within the watershed over time and because the presence of potentially significant withdrawals and discharges to the Hackensack River both upstream and downstream of the gage location in New Milford have changed.
[4] Calculated from 26 individual measurements taken 2002-2009.
[5] Historical data are referenced to further an understanding of the evolution of Newark Bay, and may not describe current conditions due to natural and anthropogenic changes which have occurred in the time period since data collection.

Acronyms and Abbreviations:
cfs = cubic feet per second
NA = not available
USGS = U.S. Geological Society

References:
HydroQual. 2007. Hydrodynamic and Sediment Transport Evaluation: Capping/Armoring Analyses of the Lower Passaic River. Appendix G: Cap Erosion and Flood Modeling, HydroQual Environmental Engineers & Scientists, Mahwah, NJ.

Suszkowski, D.J. 1978. Sedimentology of Newark Bay, New Jersey: an urban estuarine bay. Doctoral Dissertation, University of Delaware.

Thomas, S. 1993. Wind, tide and buoyancy induced residual circulation in a tidal strait, Stevens Institute of Technology, Hoboken, NJ, 180 pp.

USGS. 2020a. Surface Water Daily Data for the Nation: USGS 01389500 Passaic River at Little Falls NJ. Available online at: https://waterdata.usgs.gov/nwis/dv/?site_no=01389500&agency_cd=USGS&referred_module=sw.

USGS. 2020b. Surface Water Daily Data for the Nation: USGS 01378500 Hackensack River at New Milford NJ. Available online at: https://waterdata.usgs.gov/nwis/dv/?site_no=01378500&agency_cd=USGS&referred_module=sw.

Table 3-2
Freshwater Discharges to Newark Bay*

USGS. 2020c. Surface Water Daily Data for the Nation: USGS 01395000 Rahway River at Rahway, NJ. Available online at: https://waterdata.usgs.gov/nwis/dv/?site_no=01395000&agency_cd=USGS&referred_module=sw.

USGS. 2020d. Surface Water Daily Data for the Nation: USGS 01393450 Elizabeth River at Ursino Lake at Elizabeth, NJ. Available online at: https://waterdata.usgs.gov/nwis/dv/?site_no=01393450&agency_cd=USGS&referred_module=sw..

USGS. 2020e.Surface Water for New Jersey: Streamflow Measurements: USGS 01393690 Morses Creek at West Stimpson Avenue at Linden NJ. Available online at https://waterdata.usgs.gov/nj/nwis/measurements/?site_no=01393690.

Table 3-3
Reported Industrial and Municipal Wastewater Discharges to Newark Bay and Tributary Waterways

Source		Flow into Waterway (cfs)				
		Passaic River	Hackensack River	Kill Van Kull	Arthur Kill	Newark Bay
Suszkowski (1978)[1]		NA	NA	NA	NA	231.8
HydroQual (1991)	Industrial	1.4	6.7	NA	62.7	Total I+M = 474
	Municipal	NA	161	71	171	
Thomas (1993)	Industrial	NA	NA	NA	18	Total I+M = 188
	Municipal	NA	NA	NA	170	
Lowe et al. (2005)	Municipal	NA	113.3	NA	NA	NA

Notes:
[1] Historical data are referenced to further an understanding of the evolution of Newark Bay, and may not describe current conditions due to natural and anthropogenic changes which have occurred in the time period since data collection.

Acronyms and Abbreviations:
cfs = cubic feet per second
I = industrial
M = municipal
NA = not available

References:
HydroQual. 1991. Assessment of Pollutant Loadings to New York – New Jersey Harbor. Prepared for USEPA, Region II, New York, New York.

Lowe, S., K. Abood, and J. Ko. 2005. A sediment budget analysis of Newark Bay. Journal of Marine Science and Environment, C(3): 37-44.

Suszkowski, D.J. 1978. Sedimentology of Newark Bay, New Jersey: an urban estuarine bay. Doctoral Dissertation, University of Delaware.

Thomas, S. 1993. Wind, tide and buoyancy induced residual circulation in a tidal strait, Stevens Institute of Technology, Hoboken, NJ, 180 pp.

Table 3-4
Flows through the Tidal Straits

Strait	Tide	Estimated Flow (cfs)[1]		Estimated Average Flux (cfs)	
		Suszkowski (1978)[2,3]	Lowe et al. (2005)[4]	Pence (2004)[5]	Suszkowski (1978)[3,6]
Kill Van Kull	Flood	60,967	33,650	7,034	29,240
	Ebb	57,282	36,504		
Arthur Kill	Flood	15,976	7,034	2,119	8,158
	Ebb	16,868	6,413		

Notes:
[1] Model-calculated tidal flows by LMS (2004) are only shown in figures and not reported as an estimate or range, precluding their inclusion in the table. The model estimated flows through the Kill Van Kull and the Arthur Kill occasionally exceed 50,000 and 10,000 cfs, respectively.
[2] Measured values (flood tide of 6.0 hours and ebb tide of 6.4 hours)
[3] Historical data are referenced to further an understanding of the evolution of Newark Bay, and may not describe current conditions due to natural and anthropogenic changes which have occurred in the time period since data collection.
[4] Modeled values (flood and ebb tides of 6.2 hours)
[5] Measured average flux
[6] Modeled average flux

Acronyms and Abbreviations:
cfs = cubic feet per second

References:
LMS. 2004. A Macro Assessment of Newark Bay Sediment Budget. Lawler, Matusky & Skelly Engineers, LLP. Pearl River, New York. January.

Lowe, S., K. Abood, and J. Ko. 2005. A sediment budget analysis of Newark Bay. Journal of Marine Science and Environment, C(3): 37-44.

Pence, A.M. 2004. Dominant Forces in An Estuarine Complex with Multiple Tributaries and Free Connections to the Open Ocean with Application to Sediment. Doctoral Dissertation, Stevens Institute of Technology, Hoboken.

Suszkowski, D.J. 1978. Sedimentology of Newark Bay, New Jersey: An Urban Estuarine Bay. Doctoral Dissertation, University of Delaware, Newark

Table 3-5
Comparison of Sedimentation Rates Among Different Studies

Geomorphic Area	Method		
	Based on Bathymetry Data	Based on Dredge Volume Data	Based on Sediment Radioisotope Data[c]
Bay-wide	--	0.7[a]	--
Navigation channel	1.2 - 12[b]	2.31[a]; 5 - 13[b]	>2.5
Intertidal flats	--	--	0.2
Transitional Slopes	--	--	0.94
Subtidal flats	0.14[a]	--	0.37
Historically Disturbed Subtidal	--	--	1.68
Industrial Waterfront Areas	--	--	1.32

Note:
Sedimentation rates are provided in inches per year.

Acronyms and Abbreviations:
-- = not available
> = greater than

References:
[a] Suszkowski, D.J. 1978. Sedimentology of Newark Bay, New Jersey: an urban estuarine bay. Doctoral Dissertation, University of Delaware.

[b] USACE. 2006. Geomorphological/Geophysical Characterization of the Nature and Dynamics of Sedimentation and Sediment Transport in Newark Bay Focusing on the Effects Related to Continued and Future Federal Navigation Channel Deepening and Maintenance. Contract W912DS-06-D-0001. U.S. Army Corps of Engineers. December 31.

[c] Tierra. 2011. Final Newark Bay Study Area Remedial Investigation Phase I and Phase II Sediment Deposition Report. Revision 1. October.

Table 3-6
Estimated Sediment Loadings to NBSA

Contributing Source	Estimated Sediment Loading[1,2]			
	t/yr	MT/yr		
Passaic River	47,456	43,100	18,100	17,000
Hackensack River	3,873	3,500	(28,100)	5,000
Kill Van Kull	94,131 [3]	85,600	65,800	140,000
Arthur Kill	19,280 [3]	17,500	36,700	(20,000)
CSO/Stormwater	3,010	2,700	-	-
WWTP	3,293	3,000	6,000	-
Atmospheric	187	200	-	-
Source	LMS (2004), Lowe et al. (2005)		Suszkowski (1978)[4]	Sommerfield and Chant (2010)

Notes:

1. Estimated sediment loadings are presented in units reported by primary sources. Results from two of the studies (LMS 2004 and Lowe et al. 2005) are also shown converted from units of tons/year to metric tons per year to enable easier comparison between studies. Sediment loads were multiplied by 0.91 to convert from tons to metric tons.

2. Negative sediment loadings are shown in parentheses.

3. A combined marine load from Kill Van Kull and Arthur Kill of 113,411 t/yr is reported by LMS (2004) and Lowe et al. (2005). This load was multiplied by 0.17 for Arthur Kill and 0.83 for Kill Van Kull to calculate the load from each based on the flow split (LMS 2004; Lowe et al. 2005).

4. Suszkowski (1978) also provides estimated loadings to Newark Bay due to runoff (9,400 metric tons/yr) and phytoplankton (8,800 metric tons/yr). Historical data are referenced to further an understanding of the evolution of Newark Bay, and may not describe current conditions due to natural and anthropogenic changes which have occurred in the time period since data collection.

Abbreviations

MT/yr = metric tons per year
t/yr = U.S. tons per year

References

LMS. 2004. A Macro Assessment of Newark Bay Sediment Budget. Lawler, Matusky & Skelly Engineers, LLP. Pearl River, New York. January.

Lowe, S., K. Abood, and J. Ko. 2005. A sediment budget analysis of Newark Bay. Journal of Marine Science and Environment, C(3): 37-44.

Sommerfield, C.K. and R.J. Chant. 2010. Mechanisms of Sediment Trapping and Accumulation in Newark Bay, New Jersey: An Engineered Estuarine Basin (HRF 008/07A). Final Report to the Hudson River Foundation. July.

Suszkowski, D.J. 1978. Sedimentology of Newark Bay, New Jersey: an urban estuarine bay. Doctoral Dissertation, University of Delaware.

Table 3-7
Essential Fish Habitat Designations by Life Stage for Newark Bay

Species	Eggs	Larvae	Juveniles	Adults	Spawning Adults
Red hake (*Urophycis chuss*)	✓	✓	✓	✓	–
Winter flounder (*Pseudopluronectes americanus*)	✓	✓	✓	✓	✓
Windowpane flounder (*Scopthalmus aquosus*)	✓	✓	✓	✓	✓
American plaice (*Hippoglossoides platessoides*)	–	✓	✓	✓	–
Atlantic sea herring (*Clupea harengus*)	–	✓	✓	✓	–
Bluefish (*Pomatomus saltatrix*)	✓	✓	✓	✓	–
Atlantic butterfish (*Peprilus triacanthus*)	–	✓	✓	✓	–
Atlantic mackerel (*Scomber scombrus*)	–	–	✓	✓	–
Summer flounder (*Paralichthys dentatus*)	–	✓	✓	✓	–
Scup (*Stenotomus chrysops*)	✓	✓	✓	✓	–
Black sea bass (*Centropristus striata*)	–	–	✓	✓	–
King mackerel (*Scomberomorus cavalla*)	✓	✓	✓	✓	–
Spanish mackerel (*Scomberomorus maculates*)	✓	✓	✓	✓	–
Atlantic mackerel (*Scomber scombrus*)	–	–	✓	✓	–
Cobia (*Rachycentron canadum*)	✓	✓	✓	✓	–
Dusky shark (*Carcharhinus obscurus*)	–	✓	✓	–	–
Sand tiger shark (*Carcharias taurus*)	–	✓	✓	–	–
Sandbar shark (*Carcharhinus plumbeus*)	–	✓	✓	–	–
Clearnose skate (*Raja eglanteria*)	–	–	✓	✓	–
Little skate (*Raja erinacea*)	–	–	✓	✓	–
Winter skate (*Leucoraja ocellata*)	–	–	✓	✓	–

Notes:
✓ indicates habitat is suitable for lifestage.
– indicates habitat is not suitable for lifestage.

Acronyms and Abbreviations:
USACE = U.S. Army Corps of Engineers

Sources:
USACE. 2015. Migratory Finfish Summary Report. New York and New Jersey Harbor Deepening Project. U.S. Army Corps of Engineers, New York District. New York, New York.

Table 3-8
List of Common and Scientific Names of Fish and Shellfish Collected During Field Sampling Activities

Family	Common Name	Scientific Name
Fish Species		
Achiridae	Hogchoker	*Trinectes maculatus*
Acipenseridae	Atlantic Sturgeon	*Acipenser oxyrhynchus*
Anguillidae	American Eel	*Anguilla rostrata*
Atherinidae	Atlantic Silverside	*Menidia menidia*
Batrachoididae	Oyster Toadfish	*Opsanus tau*
Carangidae	Atlantic Moonfish	*Selene setapinnis*
	Lookdown	*Selene vomer*
Clupeidae	Alewife	*Alosa pseudoharengus*
	American Shad	*Alosa sapidissima*
	Atlantic Menhaden	*Brevoortia tyrannus*
	Blueback Herring	*Alosa aestivalis*
	Gizzard Shad	*Dorosoma cepedianum*
Cottidae	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*
Engraulidae	Bay Anchovy	*Anchoa mitchilli*
	Striped Anchovy	*Anchoa hepsetus*
Fundulidae	Mummichog	*Fundulus heteroclitus*
	Striped Killifish	*Fundulus majalis*
Gadidae	Atlantic Tomcod	*Microgadus tomcod*
Gobiidae	Naked Goby	*Gobiosoma bosc*
Labridae	Cunner	*Tautogolabrus adspersus*
	Tautog	*Tautoga onitis*
Moronidae	Striped Bass	*Morone saxatilis*
	White Perch	*Morone americana*
Mugilidae	Striped Mullet	*Mugil cephalus*
	White Mullet	*Mugil curema*
Paralichthyidae	Smallmouth Flounder	*Etropus microstomus*
	Summer Flounder	*Paralichthys dentatus*
Phycidae	Red Hake	*Urophycis chuss*
	Spotted Hake	*Urophycis regia*
Pleuronectidae	Winter Flounder	*Pseudopleuronectes americanus*
Pomatomidae	Bluefish	*Pomatomus saltatrix*
Rajidae	Little Skate	*Leucoraja erinacea*
Sciaenidae	Atlantic Croaker	*Micropogonias undulatus*
	Northern Kingfish	*Menticirrhus saxatilis*
	Silver Perch	*Bairdiella chrysoura*
	Weakfish	*Cynoscion regalis*
Scophthalmidae	Windowpane	*Scophthalmus aquosus*
Serranidae	Black Seabass	*Centropristis striata*
Sparidae	Scup	*Stenotomus chrysops*
Stromateidae	Butterfish	*Peprilus triacanthus*
Syngnathidae	Northern Pipefish	*Syngnathus fuscus*
Tetraodontidae	Northern Pufferfish	*Sphoeroides maculatus*
Triglidae	Striped Searobin	*Prionotus evolans*
Shellfish Species		
Epialtidae	Spider Crab	*Libinia emarginata*
Limulidae	Horseshoe Crab	*Limulus polyphemus*
Panopeidae	Mud Crab	*Dyspanopeus sayi*
Portunidae	Blue Crab	*Callinectes sapidus*

References:

Normandeau Associates, Inc. 2017. Final Newark Bay Study Area Environmental Sample Collection Report. June.

Table 3-9
Inventory of Bird Observations in the Newark Bay Study Area

Species	Passaic River	Hackensack River	Newark Bay	Arthur Kill	Kill Van Kull
Loons					
Loon, common	–	✓	✓	✓	–
Loon, red-throated	–	✓	–	✓	–
Grebes					
Grebe, eared	–	–	–	✓	–
Grebe, horned	–	✓	–	✓	–
Grebe, pied-billed	–	✓	–	✓	–
Pelicaniformes					
Cormorant, double-crested	✓	✓	✓	✓	✓
Cormorant, great	–	–	–	✓	–
Pelican, brown	–	–	–	✓	–
Wading Birds					
Bittern, American	–	✓	–	✓	–
Bittern, least	–	✓	–	✓	–
Egret, cattle	–	✓	✓	✓	✓
Egret, great	✓	✓	✓	✓	✓
Egret, snowy	✓	✓	✓	✓	✓
Heron, black-crowned night	✓	✓	✓		✓
Heron, great blue	✓	✓	–	✓	–
Heron, green	✓	✓	✓	✓	✓
Heron, little blue	✓	✓	✓	✓	✓
Heron, tricolored	–	✓	✓	✓	✓
Heron, yellow-crowned night	–	✓	✓	✓	
Ibis, glossy	–	✓	✓	✓	✓
Swans, Geese and Ducks					
Brant	✓	✓	✓	✓	–
Bufflehead	✓	✓	–	✓	–
Canvasback	✓	✓	✓	✓	–
Duck, American black	✓	✓		✓	✓
Duck, fulvous whistling	–	✓	–	–	–
Duck, long-tailed	–	✓	–	✓	–
Duck, ring-necked	–	✓	–	–	–
Duck, ruddy	✓	✓	–	✓	–
Duck, wood	✓	✓	–	✓	–
Gadwall	✓	✓	✓	✓	✓
Goldeneye, common	–	✓	–	✓	–
Goose, Canada	✓	✓	✓	✓	✓
Goose, cackling	✓	–	–	–	–
Goose, snow	✓	✓	–	–	–
Mallard	✓	✓	✓	✓	✓
Merganser, common	✓	–	–	✓	–
Merganser, hooded	✓	✓	–	✓	–
Merganser, red-breasted	✓	✓	–	✓	–
Northern pintail	✓	✓	–	✓	–
Northern shoveler	–	✓	–	✓	–
Redhead	–	✓	–	–	–
Scaup, greater	–	✓	✓	✓	–
Scaup, lesser	–	✓	–	✓	–
Scoter, black	✓	–	–	✓	–
Scoter, surf	–	✓	–	✓	–

Table 3-9
Inventory of Bird Observations in the Newark Bay Study Area

Species	Passaic River	Hackensack River	Newark Bay	Arthur Kill	Kill Van Kull
Scoter, white-winged	✓	✓	–	✓	–
Swan, mute	✓	✓	–	✓	–
Swan, tundra	–	✓	–	–	–
Teal, blue-winged	–	✓	–	✓	–
Teal, green-winged	–	✓	–	✓	–
Wigeon, American	–	–	–	✓	–
Diurnal Raptors					
American kestrel	✓	✓	✓	✓	–
Bald eagle	✓	✓	✓	–	–
Falcon, peregrine	✓	✓	✓	✓	–
Hawk, broad-winged	–	✓	✓	✓	–
Hawk, Cooper's	✓	✓	✓	✓	–
Hawk, red-shouldered	✓	✓	✓	✓	–
Hawk, red-tailed	✓	✓	✓	✓	–
Hawk, rough-legged	–	✓	–	✓	–
Hawk, sharp-shinned	✓	✓	✓	✓	–
Merlin	✓	✓	✓	✓	–
Northern goshawk	–	✓	–	–	–
Northern harrier	✓	✓	✓	✓	✓
Osprey	✓	✓	✓	✓	–
Vulture, turkey	✓	✓	✓	✓	–
Upland Game Birds					
Pheasant, ring-necked	–	✓	–	✓	✓
Gruiformes					
American coot	–	✓	–	✓	–
Common moorhen	–	✓	–	✓	✓
Rail, clapper	–	✓	–	✓	–
Rail, king	–	✓	–	–	–
Rail, Virginia	–	✓	–	✓	✓
Rail, yellow	–	✓	–	–	–
Sora	–	✓	–	✓	–
Shorebirds					
American avocet	–	✓	–	–	–
American oystercatcher	–	–	✓	–	–
American woodcock	–	✓	✓	✓	–
Common snipe	–	✓	–	✓	–
Dunlin	–	✓	–	✓	–
Dowitcher, long-billed	–	✓	–	✓	–
Dowitcher, short-billed	–	✓	–	–	–
Godwit, Hudsonian	–	✓	–	–	–
Godwit, marbled	–	✓	–	–	–
Killdeer	✓	✓	–	✓	–
Phalarope, red	–	✓	–	–	–
Phalarope, Wilson's	–	✓	–	–	–
Plover, American golden	–	✓	✓	–	–
Plover, black-bellied	✓	✓	–	✓	–
Plover, semipalmated	✓	✓	–	✓	–
Red knot	–	✓	–	✓	–
Ruff	–	✓	–	–	–

Table 3-9
Inventory of Bird Observations in the Newark Bay Study Area

Species	Passaic River	Hackensack River	Newark Bay	Arthur Kill	Kill Van Kull
Sanderling	✓	✓	–	✓	–
Sandpiper, Baird's	–	✓	–	–	–
Sandpiper, buff-breasted	–	✓	–	–	–
Sandpiper, curlew	–	✓	–	–	–
Sandpiper, least	✓	✓	–	✓	–
Sandpiper, pectoral	✓	✓	–	✓	–
Sandpiper, purple	–	–	–	✓	–
Sandpiper, semipalmated	✓	✓	–	✓	–
Sandpiper, solitary	✓	✓	–	✓	–
Sandpiper, spotted	✓	✓	✓	✓	✓
Sandpiper, stilt	–	✓	–	–	–
Sandpiper, upland	–	✓	✓	–	–
Sandpiper, western	✓	✓	–	–	–
Sandpiper, white-rumped	✓	✓	–	–	–
Stilt, black-necked	–	✓	–	–	–
Turnstone, ruddy	–	✓	–	✓	–
Whimbrel	–	✓	–	✓	–
Willet	–	✓	–	✓	–
Yellowlegs, greater	✓	✓	–	✓	–
Yellowlegs, lesser	✓	✓	–	–	–
Gulls, Terns and Skimmers					
Gull, great black-backed	✓	✓	✓	✓	✓
Gull, lesser black-backed	✓	–	–	–	–
Gull, Bonaparte's	–	✓	–	✓	–
Gull, common black-headed	✓	✓	–	✓	–
Gull, glaucus	✓	✓	–	✓	–
Gull, herring	✓	✓	✓	✓	✓
Gull, Iceland	✓	✓	–	–	–
Gull, laughing	✓	✓	✓	✓	–
Gull, little	–	–	–	✓	–
Gull, ring-billed	✓	✓	✓	✓	–
Skimmer, black	–	✓	–	–	–
Tern, black	–	✓	–	✓	–
Tern, Caspian	–	✓	–	✓	–
Tern, common	✓	✓	✓	✓	–
Tern, Forster's	–	✓	–	✓	–
Tern, gull-billed	–	✓	–	✓	–
Tern, least	–	✓	✓	✓	–
Tern, roseate	–	✓	–	✓	–
Tern, royal	–	✓	–	–	–
Pigeons and Doves					
Dove, mourning	✓	✓	✓	✓	–
Dove, rock	✓	✓	✓	✓	✓
Cuckoos and their Allies					
Cuckoo, black-billed	–	✓	–	✓	–
Cuckoo, yellow-billed	✓	✓	✓	✓	–
Owls					
Owl, barn	–	✓	–	✓	–
Owl, barred	–	–	–	✓	–
Owl, eastern-screech	–	✓	–	–	–

Table 3-9
Inventory of Bird Observations in the Newark Bay Study Area

Species	Passaic River	Hackensack River	Newark Bay	Arthur Kill	Kill Van Kull
Owl, great horned	–	✓	–	✓	–
Owl, long-eared	–	✓	–	–	–
Owl, short-eared	–	✓	–	✓	–
Owl, snowy	–	✓	–	–	–
Goatsuckers and Swifts					
Chimney swift	✓	✓	–	✓	–
Nighthawk, common	✓	✓	–	✓	–
Hummingbirds					
Hummingbird, ruby-throated	✓	✓	–	✓	–
Kingfishers					
Kingfisher, belted	✓	✓	✓	✓	✓
Woodpeckers					
Flicker, northern	✓	✓	–	✓	✓
Sapsucker, yellow-bellied	✓	✓	–	✓	✓
Woodpecker, hairy	✓	✓	–	–	–
Woodpecker, red-bellied	✓	–	–	✓	–
Woodpecker, downy	✓	✓	✓	✓	✓
Woodpecker, red-headed	–	✓	–	–	–
Tyrant Flycatchers					
Eastern wood-pewee	–	✓	–	✓	–
Flycatcher, great-crested	–	✓	–	✓	–
Flycatcher, least	✓	✓	–	✓	–
Flycatcher, olive-sided	–	–	–	✓	–
Flycatcher, willow	–	–	–	✓	–
Flycatcher, yellow-bellied	–	✓	–	✓	–
Kingbird, eastern	✓	✓	–	✓	–
Kingbird, western	–	✓	✓	–	–
Phoebe, eastern	✓	✓	–	✓	✓
Shrikes and Vireos					
Shrike, northern	–	✓	–	–	–
Vireo, blue-headed	✓	–	–	–	–
Vireo, red-eyed	✓	✓	–	✓	✓
Vireo, solitary	–	✓	–	✓	–
Vireo, warbling	✓	✓	✓	✓	–
Vireo, white-eyed	–	✓	–	–	–
Vireo, yellow-throated	–	✓	–	–	–
Jays, Crows and their Allies					
Crow, American	✓	✓	✓	✓	–
Crow, fish	✓	✓	✓	✓	–
Jay, blue	✓	✓	–	✓	–
Larks					
Lark, horned	✓	✓	–	–	–
Swallows					
Purple martin	–	✓	✓	–	–
Swallow, bank	–	✓	–	✓	–
Swallow, barn	✓	✓	✓	✓	–
Swallow, cliff	✓	✓	–	–	–
Swallow, northern rough-winged	✓	✓	–	✓	–
Swallow, tree	✓	✓	✓	✓	–

Table 3-9
Inventory of Bird Observations in the Newark Bay Study Area

Species	Passaic River	Hackensack River	Newark Bay	Arthur Kill	Kill Van Kull
Chickadees and their Allies					
Chickadee, black-capped	✓	✓	–	✓	–
Titmouse, tufted	✓	✓	–	✓	–
Nuthatches and Creepers					
Brown creeper	✓	✓	–	✓	–
Nuthatch, red-breasted	–	✓	–	✓	–
Nuthatch, white-breasted	✓	✓	–	✓	–
Wrens					
Wren, Carolina	✓	✓	✓	✓	–
Wren, house	✓	✓	✓	✓	✓
Wren, marsh	–	✓	–	✓	–
Wren, sedge	–	✓	–	–	–
Wren, winter	–	✓	–	✓	–
Old World Warblers, Thrushes and their Allies					
Eastern bluebird	✓	–	–	–	–
Robin, American	✓	✓	–	✓	✓
Gnatcatcher, blue-gray	–	✓	–	✓	–
Kinglet, golden-crowned	✓	✓	–	✓	✓
Kinglet, ruby-crowned	✓	✓	–	✓	✓
Thrush, gray-cheeked	✓	✓	✓	✓	–
Thrush, hermit	✓	✓	–	✓	✓
Thrush, Swainson's	✓	✓	✓	✓	✓
Thrush, wood	–	✓	–	✓	–
Veery	–	✓	–	✓	–
Mimids					
Brown thrasher	✓	✓	–	✓	✓
Catbird, gray	✓	✓	✓	✓	✓
Mockingbird, northern	✓	✓	–	✓	–
Starlings and Minas					
Starling, European	✓	✓	✓	✓	–
Wagtails and Pipits					
American pipit	✓	✓	–	–	–
Waxwings					
Waxwing, cedar	✓	✓	–	✓	✓
Wood-Warblers					
American redstart	✓	✓	✓	✓	✓
Chat, yellow-breasted	–	–	✓	–	–
Northern parula	–	✓	–	✓	–
Ovenbird	–	✓	–	✓	✓
Warbler, bay-breasted	✓	✓	–	✓	–
Warbler, black-and-white	–	✓	✓	✓	✓
Warbler, blackburnian	–	✓	–	✓	–
Warbler, blackpoll	✓	✓	–	✓	✓
Warbler, black-throated blue	–	✓	✓	✓	✓
Warbler, black-throated green	–	✓	–	✓	–
Warbler, blue-winged	–	✓	–	✓	✓
Warbler, Canada	✓	✓	–	✓	–
Warbler, Cape May	✓	✓	–	✓	–
Warbler, cerulean	–	–	✓	✓	–
Warbler, chestnut-sided	–	✓	–	✓	✓

Table 3-9
Inventory of Bird Observations in the Newark Bay Study Area

Species	Passaic River	Hackensack River	Newark Bay	Arthur Kill	Kill Van Kull
Warbler, Connecticut	–	✓	✓	✓	✓
Warbler, golden-winged	–	–	✓	–	–
Warbler, hooded	–	–	✓	✓	–
Warbler, Kentucky	–	–	–	✓	–
Warbler, magnolia	–	✓	✓	✓	✓
Warbler, mourning	–	–	✓	✓	–
Warbler, Nashville	–	✓	–	✓	✓
Warbler, orange-crowned	✓	✓	–	–	–
Warbler, palm	✓	✓	–	✓	✓
Warbler, pine	–	–	✓	–	–
Warbler, prairie	–	✓	–	✓	–
Warbler, prothonotary	–	–	–	✓	–
Warbler, Tennessee	✓	✓	–	✓	–
Warbler, Wilson's	–	✓	–	–	✓
Warbler, worm-eating	–	–	✓	✓	–
Warbler, yellow	✓	✓	✓	✓	–
Warbler, yellow-rumped	✓	✓	–	✓	✓
Warbler, yellow-throated	–	–	✓	✓	–
Waterthrush, Louisiana	–	✓	–	✓	–
Waterthrush, northern	✓	✓	✓	✓	✓
Yellowthroat, common	✓	✓	–	✓	✓
Tanagers, Cardinals and their Allies					
Bunting, indigo	✓	✓	–	✓	–
Dickcissel	–	✓	–	–	–
Grosbeak, blue	–	✓	–	–	–
Grosbeak, rose-breasted	✓	✓	–	✓	–
Northern cardinal	✓	✓	–	✓	–
Tanager, scarlet	–	✓	–	✓	–
Emberizine Sparrows and their Allies					
Bunting, snow	–	✓	–	–	–
Junco, dark-eyed	✓	✓	–	✓	✓
Longspur, lapland	–	✓	–	–	–
Sparrow, American tree	✓	✓	–	✓	–
Sparrow, chipping	✓	✓	–	✓	–
Sparrow, field	✓	✓	–	✓	✓
Sparrow, fox	✓	✓	✓	–	–
Sparrow, Lincoln's	✓	✓	✓	–	–
Sparrow, savannah	✓	✓	–	✓	–
Sparrow, seaside	–	✓	–	✓	–
Sparrow, sharp-tailed	–	✓	–	✓	–
Sparrow, song	✓	✓	✓	✓	✓
Sparrow, swamp	✓	✓	–	✓	✓
Sparrow, vesper	–	✓	–	–	–
Sparrow, white-crowned	✓	✓	–	✓	–
Sparrow, white-throated	✓	✓	–	✓	✓
Towhee, eastern	✓	✓	–	✓	✓

Table 3-9
Inventory of Bird Observations in the Newark Bay Study Area

Species	Passaic River	Hackensack River	Newark Bay	Arthur Kill	Kill Van Kull
Icterids					
Blackbird, red-winged	✓	✓	–	✓	–
Blackbird, rusty	✓	✓	–	–	–
Blackbird, yellow-headed	–	✓	–	–	–
Bobolink	–	✓	–	–	–
Cowbird, brown-headed	✓	✓	–	✓	–
Eastern meadowlark	–	✓	–	✓	–
Grackle, common	✓	✓	✓	✓	–
Grackle, boat-tailed	✓	–	–	✓	–
Oriole, Baltimore	✓	✓	✓	✓	–
Oriole, orchard	–	–	✓	–	–
Finches and Old World Sparrows					
Common redpoll	–	✓	–	–	–
Finch, house	✓	✓	–	✓	–
Finch, purple	✓	✓	–	✓	–
Goldfinch, American	✓	✓	✓	✓	✓
Siskin, pine	✓	✓	–	✓	–
Sparrow, house	✓	✓	–	✓	–
Total Number of Species	**141**	**248**	**81**	**213**	**59**

Notes:
1. ✓ indicates species was reported as observed in any one of the following: Tierra (2004), Ludwig et al. (2010), Kerlinger (2004), Bernick (2007), Bernick and Craig (2008), Mizrahi et al. (2007). Tierra (2004) provides a summary of 18 studies conducted since 1990.
2. The Passaic River Bird Survey was conducted on the lower six miles of the river in August and October 2010 and January and May of 2011. Data from non-aquatic foraging species on the Passaic River in January and May of 2011 were not available.

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Table 3-10
Threatened and Endangered Species in the NBSA

Species	Common Name	Federally Listed	State Listed
Birds			
Nycticorax nycticorax	Black-crowned night heron	--	NJ
Bubulcus ibis	Cattle egret	--	NJ, NY
Plegadis falcinellus	Glossy ibis	--	NJ, NY
Sterna antillarum	Least tern	--	NJ
Egretta caerulea	Little blue heron	--	NJ, NY
Pandion haliaetus	Osprey	--	NJ
Falco peregrinus	Peregrine falcon	--	NJ
Egretta thula	Snowy egret	--	NJ, NY
Egretta tricolor	Tricolored heron	--	NJ
Nyctanassa violacea	Yellow-crowned night heron	--	NJ, NY
Ardea alba	Great egret	--	NY
Tyto alba	Barn owl	--	NY
Insects			
Pontia protodice	Checkered white butterfly	--	NJ
Somatochlora linearis	Mocha emerald dragonfly	--	NY
Ischnura ramburii	Rambur's forktail damselfly	--	NY
Plants			
Eleocharis quadrangulata	Angled spikerush	--	NY
Fish			
Acipenser brevirostrum	Shortnose sturgeon	X	NY, NJ
Acipenser oxyrhynchus	Atlantic sturgeon	X	NJ
Habitats			
Colonial Waterbird Nesting Area		--	NY
Gull Colony		--	NY

Notes:
From Tierra Solutions, Inc. 2013. Newark Bay Study Area Problem Formulation. Baseline Human Health and Ecological Risk Assessment. June. Checked and updated 2018.

-- - not applicable

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
Dioxins/Furans	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (HpCDD)	69/69 (100%)	211/212 (100%)	50/50 (100%)	303/310 (98%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	162/233 (69.5%)
	1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF)	69/69 (100%)	204/212 (96%)	50/50 (100%)	286/310 (92%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	178/233 (76.4%)
	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin (OCDD)	69/69 (100%)	212/212 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	204/233 (87.6%)
	1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF)	69/69 (100%)	196/212 (92%)	50/50 (100%)	283/310 (91%)	254/254 (100%)	17/17 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	171/233 (73.4%)
	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (HxCDD)	68/69 (98.6%)	185/212 (87%)	50/50 (100%)	278/310 (90%)	252/254 (99.2%)	17/18 (94.4%)	37/37 (100%)	59/63 (93.7%)	19/26 (73.1%)	28/30 (93.3%)	1/233 (0.429%)
	1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF)	69/69 (100%)	197/212 (93%)	50/50 (100%)	273/310 (88%)	250/250 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	107/233 (45.9%)
	1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF)	69/69 (100%)	160/212 (75%)	50/50 (100%)	252/310 (81%)	252/254 (99.2%)	18/18 (100%)	36/37 (97.3%)	41/63 (65.1%)	14/26 (53.8%)	30/30 (100%)	5/233 (2.15%)
	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (HxCDD)	69/69 (100%)	197/212 (93%)	50/50 (100%)	283/310 (91%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	25/26 (96.2%)	30/30 (100%)	8/233 (3.43%)
	1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF)	69/69 (100%)	183/212 (86%)	50/50 (100%)	261/310 (84%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	28/233 (12%)
	1,2,3,7,8-Pentachlorodibenzo-p-dioxin (PeCDD)	69/69 (100%)	186/212 (88%)	50/50 (100%)	274/310 (88%)	250/254 (98.4%)	15/18 (83.3%)	36/37 (97.3%)	47/63 (74.6%)	22/26 (84.6%)	28/30 (93.3%)	2/233 (0.858%)
	1,2,3,7,8-Pentachlorodibenzofuran (PeCDF)	69/69 (100%)	176/212 (83%)	50/50 (100%)	258/310 (83%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	62/63 (98.4%)	24/26 (92.3%)	30/30 (100%)	3/233 (1.29%)
	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (HxCDD)	69/69 (100%)	197/212 (93%)	50/50 (100%)	285/310 (92%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	24/26 (92.3%)	30/30 (100%)	44/233 (18.9%)
	1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF)	69/69 (100%)	158/212 (75%)	16/50 (32.0%)	129/310 (42%)	154/254 (60.6%)	17/18 (94.4%)	37/37 (100%)	61/63 (96.8%)	22/26 (84.6%)	30/30 (100%)	1/233 (0.429%)
	2,3,4,6,7,8-Hexachlorodibenzofuran (HxCDF)	69/69 (100%)	179/212 (84%)	49/50 (98.0%)	259/310 (84%)	253/253 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	24/26 (92.3%)	30/30 (100%)	10/233 (4.29%)
	2,3,4,7,8-Pentachlorodibenzofuran (PeCDF)	69/69 (100%)	178/212 (84%)	49/50 (98.0%)	260/310 (84%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	24/26 (92.3%)	30/30 (100%)	13/233 (5.58%)
	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	69/69 (100%)	181/212 (85%)	50/50 (100%)	264/310 (85%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	84/233 (36.1%)
	2,3,7,8-Tetrachlorodibenzofuran (TCDF)	69/69 (100%)	183/212 (86%)	50/50 (100%)	265/310 (85%)	253/254 (99.6%)	18/18 (100%)	37/37 (100%)	50/63 (79.4%)	26/26 (100%)	30/30 (100%)	13/233 (5.58%)
	Total heptachlorodibenzo-p-dioxin (HpCDD)	69/69 (100%)	211/212 (100%)	50/50 (100%)	309/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	160/233 (68.7%)
	Total heptachlorodibenzofuran (HpCDF)	69/69 (100%)	205/212 (97%)	50/50 (100%)	286/310 (92%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	186/233 (79.8%)
	Total hexachlorodibenzo-p-dioxin (HxCDD)	69/69 (100%)	210/212 (99%)	50/50 (100%)	306/310 (99%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	70/233 (30%)
	Total hexachlorodibenzofuran (HxCDF)	69/69 (100%)	206/212 (97%)	50/50 (100%)	287/310 (93%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	131/233 (56.2%)
	Total pentachlorodibenzo-p-dioxin (PeCDD)	69/69 (100%)	208/212 (98%)	50/50 (100%)	306/310 (99%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	5/233 (2.15%)
	Total pentachlorodibenzofuran (PeCDF)	69/69 (100%)	202/212 (95%)	50/50 (100%)	288/310 (93%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	48/233 (20.6%)
	Total tetrachlorodibenzo-p-dioxin (TCDD)	69/69 (100%)	207/212 (98%)	50/50 (100%)	304/310 (98%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	62/233 (26.6%)
	Total tetrachlorodibenzofuran (TCDF)	69/69 (100%)	208/212 (98%)	50/50 (100%)	289/310 (93%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	52/233 (22.3%)
	Total WHO Dioxin TEQ(Bird)(ND=0)	69/69 (100%)	212/212 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	Total WHO Dioxin TEQ(Fish)(ND=0)	69/69 (100%)	212/212 (100%)	50/50 (100%)	307/307 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	Total WHO Dioxin TEQ(Human/Mammal)(ND=0)	69/69 (100%)	212/212 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
PCB/Dioxin Furans	Total WHO PCB/Dioxin TEQ(Bird)(ND=0)	69/69 (100%)	212/212 (100%)	50/50 (100%)	8/8 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	Total WHO PCB/Dioxin TEQ(Fish)(ND=0)	69/69 (100%)	212/212 (100%)	50/50 (100%)	8/8 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	Total WHO PCB/Dioxin TEQ(Human/Mammal)(ND=0)	69/69 (100%)	212/212 (100%)	50/50 (100%)	8/8 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
PCBs	(PCB 1) 2-Chlorobiphenyl	69/69 (100%)	163/212 (77%)	48/48 (100%)	236/300 (79%)	231/254 (90.9%)	18/18 (100%)	23/37 (62.2%)	58/60 (96.7%)	20/26 (76.9%)	30/30 (100%)	208/233 (89.3%)
	(PCB 10) 2,6-Dichlorobiphenyl	NA	NA	NA	N/A	192/254 (75.6%)	18/18 (100%)	18/37 (48.6%)	53/63 (84.1%)	26/26 (100%)	29/30 (96.7%)	232/233 (99.6%)
	(PCB 100) 2,2',4,4',6-Pentachlorobiphenyl	68/69 (98.6%)	128/211 (61%)	50/50 (100%)	198/310 (64%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 101) 2,2',4,5,5'-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 102) 2,2',4,5,6'-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 103) 2,2',4,5',6-Pentachlorobiphenyl	67/69 (97.1%)	132/212 (62%)	50/50 (100%)	206/310 (66%)	207/254 (81.5%)	18/18 (100%)	37/37 (100%)	62/63 (98.4%)	26/26 (100%)	30/30 (100%)	150/233 (64.4%)
	(PCB 104) 2,2',4,6,6'-Pentachlorobiphenyl	40/69 (58%)	72/208 (35%)	38/50 (76.0%)	95/310 (31%)	48/254 (18.9%)	18/18 (100%)	19/37 (51.4%)	47/63 (74.6%)	26/26 (100%)	25/30 (83.3%)	13/233 (5.58%)
	(PCB 105) 2,3,3',4,4'-Pentachlorobiphenyl	69/69 (100%)	196/212 (92%)	50/50 (100%)	265/310 (85%)	238/254 (93.7%)	18/18 (100%)	37/37 (100%)	55/55 (100%)	26/26 (100%)	30/30 (100%)	226/233 (97%)
	(PCB 106) 2,3,3',4,5-Pentachlorobiphenyl	NA	NA	NA	N/A	8/254 (3.15%)	0/18 (0%)	0/37 (0%)	2/63 (3.17%)	0/26 (0%)	1/30 (3.33%)	4/233 (1.72%)
	(PCB 106/118) 2,3,3',4,5-Pentachlorobiphenyl/2,3',4,4',5-Pentachlorobiphenyl	69/69 (100%)	202/212 (95%)	50/50 (100%)	282/310 (91%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 107) 2,3,3',4',5-Pentachlorobiphenyl	NA	NA	NA	N/A	240/254 (94.5%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	231/233 (99.1%)
	(PCB 107/109) 2,3,3',4',5-Pentachlorobiphenyl/2,3,3',4,6-Pentachlorobiphenyl	69/69 (100%)	160/212 (75%)	50/50 (100%)	230/310 (74%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 108) 2,3,3',4,5'-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	202/233 (86.7%)
	(PCB 108/112) 2,3,3',4,5'-Pentachlorobiphenyl/2,3,3',5,6-Pentachlorobiphenyl	68/69 (98.6%)	156/212 (74%)	50/50 (100%)	229/310 (74%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 108/124) 2,3,3',4,5'-Pentachlorobiphenyl/2,3',4',5,5'-Pentachlorobiphenyl	NA	NA	NA	N/A	205/254 (80.7%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 109) 2,3,3',4,6-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 11) 3,3'-Dichlorobiphenyl	69/69 (100%)	173/211 (82%)	50/50 (100%)	232/310 (75%)	246/254 (96.9%)	18/18 (100%)	34/37 (91.9%)	55/63 (87.3%)	20/26 (76.9%)	30/30 (100%)	76/233 (32.6%)
	(PCB 110) 2,3,3',4',6-Pentachlorobiphenyl	69/69 (100%)	198/212 (93%)	50/50 (100%)	275/310 (89%)	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 110/115) 2,3,3',4',6-Pentachlorobiphenyl/2,3,4,4',6-Pentachlorobiphenyl	NA	NA	NA	N/A	239/254 (94.1%)	18/18 (100%)	36/36 (100%)	52/52 (100%)	26/26 (100%)	27/28 (96.4%)	NA

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
PCBs (cont.)	(PCB 111) 2,3,3',5,5'-Pentachlorobiphenyl	NA	NA	NA	N/A	7/254 (2.76%)	16/18 (88.9%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	24/30 (80%)	0/233 (0%)
	(PCB 111/115) 2,3,3',5,5'-Pentachlorobiphenyl/2,3,4,4',6-Pentachlorobiphenyl	68/69 (98.6%)	144/212 (68%)	50/50 (100%)	220/310 (71%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 112) 2,3,3',5,6-Pentachlorobiphenyl	NA	NA	NA	N/A	59/253 (23.3%)	4/18 (22.2%)	19/37 (51.4%)	33/57 (57.9%)	20/26 (76.9%)	27/30 (90%)	0/233 (0%)
	(PCB 113) 2,3,3',5',6-Pentachlorobiphenyl	44/69 (63.8%)	88/209 (42%)	45/50 (90.0%)	183/310 (59%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 114) 2,3,4,4',5-Pentachlorobiphenyl	68/69 (98.6%)	148/212 (70%)	50/50 (100%)	223/310 (72%)	204/254 (80.3%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	187/233 (80.3%)
	(PCB 115) 2,3,4,4',6-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 116) 2,3,4,5,6-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 117) 2,3,4',5,6-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 118) 2,3',4,4',5-Pentachlorobiphenyl	NA	NA	NA	N/A	250/254 (98.4%)	17/18 (94.4%)	36/36 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 119) 2,3',4,4',6-Pentachlorobiphenyl	68/69 (98.6%)	147/212 (69%)	50/50 (100%)	222/310 (72%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 12) 3,4-Dichlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	182/233 (78.1%)
	(PCB 12/13) 3,4-Dichlorobiphenyl/3,4'-Dichlorobiphenyl	68/69 (98.6%)	131/211 (62%)	50/50 (100%)	198/310 (64%)	247/254 (97.2%)	18/18 (100%)	33/37 (89.2%)	55/63 (87.3%)	20/26 (76.9%)	30/30 (100%)	NA
	(PCB 120) 2,3',4,5,5'-Pentachlorobiphenyl	50/69 (72.5%)	109/208 (52%)	48/50 (96.0%)	193/310 (62%)	142/254 (55.9%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	15/233 (6.44%)
	(PCB 121) 2,3',4,5',6-Pentachlorobiphenyl	2/69 (2.90%)	0/206 (0%)	0/50 (0%)	0/310 (0%)	1/254 (0.394%)	15/18 (83.3%)	36/37 (97.3%)	61/63 (96.8%)	20/22 (90.9%)	23/30 (76.7%)	0/233 (0%)
	(PCB 122) 2,3,3',4',5'-Pentachlorobiphenyl	68/69 (98.6%)	138/212 (65%)	50/50 (100%)	208/310 (67%)	186/253 (73.5%)	18/18 (100%)	27/37 (73%)	60/63 (95.2%)	23/26 (88.5%)	30/30 (100%)	146/233 (62.7%)
	(PCB 123) 2',3,4,4',5-Pentachlorobiphenyl	68/69 (98.6%)	156/212 (74%)	50/50 (100%)	221/310 (71%)	200/254 (78.7%)	17/18 (94.4%)	37/37 (100%)	62/63 (98.4%)	26/26 (100%)	30/30 (100%)	203/233 (87.1%)
	(PCB 124) 2,3',4',5,5'-Pentachlorobiphenyl	68/69 (98.6%)	147/212 (69%)	50/50 (100%)	210/310 (68%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 125) 2',3,4,5,6'-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 126) 3,3',4,4',5-Pentachlorobiphenyl	68/69 (98.6%)	135/211 (64%)	49/50 (98.0%)	205/310 (66%)	109/254 (42.9%)	17/18 (94.4%)	36/36 (100%)	32/41 (78.0%)	24/26 (92.3%)	19/22 (86.4%)	40/233 (17.2%)
	(PCB 127) 3,3',4,5,5'-Pentachlorobiphenyl	1/69 (1.45%)	1/206 (0.5%)	1/50 (2.00%)	0/310 (0%)	83/254 (32.7%)	3/10 (30.0%)	37/37 (100%)	57/57 (100%)	25/26 (96.2%)	19/28 (67.9%)	2/233 (0.858%)
	(PCB 128) 2,2',3,3',4,4'-Hexachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	224/233 (96.1%)
	(PCB 128/162) 2,2',3,3',4,4'-Hexachlorobiphenyl/2,3,3',4',5,5'-Hexachlorobiphenyl	69/69 (100%)	172/212 (81%)	50/50 (100%)	238/310 (77%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 128/166) 2,2',3,3',4,4'-Hexachlorobiphenyl/2,3,4,4',5,6-Hexachlorobiphenyl	NA	NA	NA	N/A	233/254 (91.7%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 129) 2,2',3,3',4,5-Hexachlorobiphenyl	68/69 (98.6%)	147/212 (69%)	50/50 (100%)	227/310 (73%)	NA	NA	NA	NA	NA	NA	231/233 (99.1%)
	(PCB 129/138/163) Hexachlorobiphenyl	NA	NA	NA	N/A	241/254 (94.9%)	17/18 (94.4%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 13) 3,4'-Dichlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 130) 2,2',3,3',4,5'-Hexachlorobiphenyl	69/69 (100%)	156/212 (74%)	50/50 (100%)	229/310 (74%)	240/254 (94.5%)	18/18 (100%)	35/35 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	229/233 (98.3%)
	(PCB 131) 2,2',3,3',4,6-Hexachlorobiphenyl	7/69 (10.1%)	25/207 (12%)	3/50 (6.00%)	19/310 (6%)	168/254 (66.1%)	17/18 (94.4%)	28/28 (100%)	57/57 (100%)	24/24 (100%)	30/30 (100%)	49/233 (21%)
	(PCB 132) 2,2',3,3',4,6'-Hexachlorobiphenyl	NA	NA	NA	N/A	236/254 (92.9%)	18/18 (100%)	30/32 (93.8%)	56/56 (100%)	24/24 (100%)	28/28 (100%)	228/233 (97.9%)
	(PCB 132/161) 2,2',3,3',4,6'-Hexachlorobiphenyl/2,3,3',4,5',6-Hexachlorobiphenyl	69/69 (100%)	178/212 (84%)	50/50 (100%)	243/310 (78%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 133) 2,2',3,3',5,5'-Hexachlorobiphenyl	NA	NA	NA	N/A	210/254 (82.7%)	18/18 (100%)	37/37 (100%)	62/62 (100%)	26/26 (100%)	30/30 (100%)	132/233 (56.7%)
	(PCB 133/142) 2,2',3,3',5,5'-Hexachlorobiphenyl/2,2',3,4,5,6-Hexachlorobiphenyl	68/69 (98.6%)	146/212 (69%)	50/50 (100%)	222/310 (72%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 134) 2,2',3,3',5,6-Hexachlorobiphenyl	NA	NA	NA	N/A	215/254 (84.6%)	18/18 (100%)	32/32 (100%)	56/56 (100%)	24/24 (100%)	30/30 (100%)	229/233 (98.3%)
	(PCB 134/143) 2,2',3,3',5,6-Hexachlorobiphenyl/2,2',3,4,5,6'-Hexachlorobiphenyl	68/69 (98.6%)	150/212 (71%)	50/50 (100%)	229/310 (74%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 135) 2,2',3,3',5,6'-Hexachlorobiphenyl	69/69 (100%)	166/212 (78%)	50/50 (100%)	234/310 (75%)	NA	NA	NA	NA	NA	NA	232/233 (99.6%)
	(PCB 135/151) 2,2',3,3',5,6'-Hexachlorobiphenyl/2,2',3,5,5', 6-Hexachlorobiphenyl	NA	NA	NA	N/A	241/254 (94.9%)	18/18 (100%)	37/37 (100%)	62/62 (100%)	25/25 (100%)	30/30 (100%)	NA
	(PCB 136) 2,2',3,3',6,6'-Hexachlorobiphenyl	69/69 (100%)	167/212 (79%)	50/50 (100%)	236/310 (76%)	239/254 (94.1%)	18/18 (100%)	37/37 (100%)	62/62 (100%)	25/25 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 137) 2,2',3,4,4',5-Hexachlorobiphenyl	68/69 (98.6%)	152/212 (72%)	50/50 (100%)	227/310 (73%)	222/254 (87.4%)	18/18 (100%)	35/35 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	222/233 (95.3%)
	(PCB 138) 2,2',3,4,4',5'-Hexachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 138/163/164) Hexachlorobiphenyl	69/69 (100%)	194/212 (92%)	50/50 (100%)	266/310 (86%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 139) 2,2',3,4,4',6-Hexachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	120/233 (51.5%)
	(PCB 139/140) 2,2',3,4,4',6-Hexachlorobiphenyl/2,2',3,4,4', 6'-Hexachlorobiphenyl	NA	NA	NA	N/A	167/254 (65.7%)	18/18 (100%)	37/37 (100%)	57/57 (100%)	24/24 (100%)	30/30 (100%)	NA
	(PCB 139/149) 2,2',3,4,4',6-Hexachlorobiphenyl/2,2',3,4',5',6-Hexachlorobiphenyl	69/69 (100%)	193/212 (91%)	50/50 (100%)	260/310 (84%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 14) 3,5-Dichlorobiphenyl	1/69 (1.45%)	2/205 (1%)	2/50 (4.00%)	20/310 (6%)	8/254 (3.15%)	0/18 (0%)	2/37 (5.41%)	1/63 (1.59%)	5/26 (19.2%)	7/30 (23.3%)	14/233 (6.01%)
	(PCB 140) 2,2',3,4,4',6'-Hexachlorobiphenyl	63/69 (91.3%)	124/210 (59%)	50/50 (100%)	199/310 (64%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 141) 2,2',3,4,5,5'-Hexachlorobiphenyl	69/69 (100%)	171/212 (81%)	50/50 (100%)	239/310 (77%)	246/254 (96.9%)	16/18 (88.9%)	35/35 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	225/233 (96.6%)

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
PCBs (cont.)	(PCB 142) 2,2',3,4,5,6-Hexachlorobiphenyl	NA	NA	NA	N/A	1/254 (0.394%)	1/18 (5.56%)	0/33 (0%)	16/56 (28.6%)	6/25 (24.0%)	0/30 (0%)	0/233 (0%)
	(PCB 143) 2,2',3,4,5,6'-Hexachlorobiphenyl	NA	NA	NA	N/A	13/254 (5.12%)	2/18 (11.1%)	5/32 (15.6%)	24/56 (42.9%)	18/24 (75.0%)	21/30 (70%)	0/233 (0%)
	(PCB 144) 2,2',3,4,5',6-Hexachlorobiphenyl	68/69 (98.6%)	149/212 (70%)	50/50 (100%)	226/310 (73%)	226/254 (89%)	18/18 (100%)	34/34 (100%)	56/56 (100%)	24/24 (100%)	30/30 (100%)	173/233 (74.2%)
	(PCB 145) 2,2',3,4,6,6'-Hexachlorobiphenyl	16/69 (23.2%)	59/209 (28%)	16/50 (32.0%)	141/310 (45%)	2/254 (0.787%)	6/18 (33.3%)	0/37 (0%)	33/62 (53.2%)	23/26 (88.5%)	7/30 (23.3%)	0/233 (0%)
	(PCB 146) 2,2',3,4',5,5'-Hexachlorobiphenyl	NA	NA	NA	N/A	246/254 (96.9%)	17/17 (100%)	18/18 (100%)	41/41 (100%)	21/21 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 146/165) 2,2',3,4',5,5'-Hexachlorobiphenyl/2,3,3',5,5',6-Hexachlorobiphenyl	69/69 (100%)	170/212 (80%)	50/50 (100%)	238/310 (77%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 147) 2,2',3,4',5,6-Hexachlorobiphenyl	68/69 (98.6%)	146/212 (69%)	50/50 (100%)	218/310 (70%)	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 147/149) 2,2',3,4',5, 6-Hexachlorobiphenyl/2,2',3,4',5',6-Hexachlorobiphenyl	NA	NA	NA	N/A	242/254 (95.3%)	18/18 (100%)	37/37 (100%)	57/57 (100%)	24/24 (100%)	30/30 (100%)	NA
	(PCB 148) 2,2',3,4',5,6'-Hexachlorobiphenyl	56/69 (81.2%)	119/210 (57%)	45/50 (90.0%)	189/310 (61%)	84/254 (33.1%)	17/18 (94.4%)	37/37 (100%)	51/51 (100%)	24/24 (100%)	28/30 (93.3%)	0/233 (0%)
	(PCB 149) 2,2',3,4',5',6-Hexachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 15) 4,4'-Dichlorobiphenyl	69/69 (100%)	183/212 (86%)	50/50 (100%)	240/310 (77%)	252/254 (99.2%)	18/18 (100%)	37/37 (100%)	46/62 (74.2%)	23/26 (88.5%)	30/30 (100%)	233/233 (100%)
	(PCB 150) 2,2',3,4',6,6'-Hexachlorobiphenyl	62/69 (89.9%)	118/211 (56%)	48/50 (96.0%)	189/310 (61%)	113/254 (44.5%)	18/18 (100%)	29/37 (78.4%)	49/62 (79.0%)	26/26 (100%)	30/30 (100%)	4/233 (1.72%)
	(PCB 151) 2,2',3,5,5',6-Hexachlorobiphenyl	68/69 (98.6%)	175/212 (83%)	50/50 (100%)	238/310 (77%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 152) 2,2',3,5,6,6'-Hexachlorobiphenyl	48/69 (69.6%)	106/210 (50%)	43/50 (86.0%)	177/310 (57%)	42/254 (16.5%)	16/18 (88.9%)	9/37 (24.3%)	46/62 (74.2%)	26/26 (100%)	29/30 (96.7%)	1/233 (0.429%)
	(PCB 153) 2,2',4,4',5,5'-Hexachlorobiphenyl	69/69 (100%)	193/212 (91%)	50/50 (100%)	268/310 (86%)	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 153/168) 2,2',4,4',5,5'-Hexachlorobiphenyl/2,3',4,4',5', 6-Hexachlorobiphenyl	NA	NA	NA	N/A	244/254 (96.1%)	16/18 (88.9%)	37/37 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 154) 2,2',4,4',5,6'-Hexachlorobiphenyl	68/69 (98.6%)	139/212 (66%)	50/50 (100%)	222/310 (72%)	146/254 (57.5%)	18/18 (100%)	34/34 (100%)	56/56 (100%)	25/25 (100%)	30/30 (100%)	200/233 (85.8%)
	(PCB 155) 2,2',4,4',6,6'-Hexachlorobiphenyl	63/69 (91.3%)	113/210 (54%)	48/50 (96.0%)	160/310 (52%)	138/254 (54.3%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/30 (96.7%)	21/233 (9.01%)
	(PCB 156) 2,3,3',4,4',5-Hexachlorobiphenyl	68/69 (98.6%)	171/212 (81%)	50/50 (100%)	237/310 (76%)	NA	NA	NA	NA	NA	NA	209/233 (89.7%)
	(PCB 156/157) 2,3,3',4,4', 5-Hexachlorobiphenyl/2,3,3',4,4',5'-Hexachlorobiphenyl	NA	NA	NA	N/A	241/254 (94.9%)	17/18 (94.4%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 157) 2,3,3',4,4',5'-Hexachlorobiphenyl	68/69 (98.6%)	154/212 (73%)	50/50 (100%)	224/310 (72%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 158) 2,3,3',4,4',6-Hexachlorobiphenyl	NA	NA	NA	N/A	231/254 (90.9%)	17/18 (94.4%)	37/37 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	231/233 (99.1%)
	(PCB 158/160) 2,3,3',4,4',6-Hexachlorobiphenyl/2,3,3',4,5,6-Hexachlorobiphenyl	69/69 (100%)	165/212 (78%)	50/50 (100%)	235/310 (76%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 159) 2,3,3',4,5,5'-Hexachlorobiphenyl	67/69 (97.1%)	137/212 (65%)	11/50 (22.0%)	62/310 (20%)	10/254 (3.94%)	0/18 (0%)	36/37 (97.3%)	13/63 (20.6%)	17/26 (65.4%)	0/30 (0%)	45/233 (19.3%)
	(PCB 16) 2,2',3-Trichlorobiphenyl	NA	NA	NA	N/A	248/254 (97.6%)	18/18 (100%)	21/37 (56.8%)	52/52 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 16/32) 2,2',3-Trichlorobiphenyl/2,4',6-Trichlorobiphenyl	69/69 (100%)	184/212 (87%)	50/50 (100%)	251/310 (81%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 160) 2,3,3',4,5,6-Hexachlorobiphenyl	NA	NA	NA	N/A	0/254 (0%)	0/18 (0%)	1/37 (2.70%)	4/57 (7.02%)	16/26 (61.5%)	0/30 (0%)	0/233 (0%)
	(PCB 161) 2,3,3',4,5',6-Hexachlorobiphenyl	NA	NA	NA	N/A	0/254 (0%)	0/17 (0%)	11/28 (39.3%)	8/51 (15.7%)	15/25 (60.0%)	1/30 (3.33%)	0/233 (0%)
	(PCB 162) 2,3,3',4',5,5'-Hexachlorobiphenyl	NA	NA	NA	N/A	26/254 (10.2%)	10/18 (55.6%)	33/34 (97.1%)	60/62 (96.8%)	9/12 (75.0%)	21/30 (70%)	34/233 (14.6%)
	(PCB 163) 2,3,3',4',5,6-Hexachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 164) 2,3,3',4',5',6-Hexachlorobiphenyl	NA	NA	NA	N/A	236/254 (92.9%)	18/18 (100%)	37/37 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 165) 2,3,3',5,5',6-Hexachlorobiphenyl	NA	NA	NA	N/A	2/254 (0.787%)	14/17 (82.4%)	12/12 (100%)	49/49 (100%)	21/21 (100%)	17/23 (73.9%)	0/233 (0%)
	(PCB 166) 2,3,4,4',5,6-Hexachlorobiphenyl	61/69 (88.4%)	125/211 (59%)	48/50 (96.0%)	197/310 (64%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 167) 2,3',4,4',5,5'-Hexachlorobiphenyl	69/69 (100%)	162/212 (76%)	50/50 (100%)	232/310 (75%)	233/254 (91.7%)	18/18 (100%)	37/37 (100%)	54/54 (100%)	26/26 (100%)	30/30 (100%)	219/233 (94%)
	(PCB 168) 2,3',4,4',5',6-Hexachlorobiphenyl	50/69 (72.5%)	109/210 (52%)	42/50 (84.0%)	174/310 (56%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 169) 3,3',4,4',5,5'-Hexachlorobiphenyl	9/69 (13.0%)	31/206 (15%)	6/50 (12.0%)	20/310 (6%)	1/254 (0.394%)	0/17 (0%)	18/37 (48.6%)	13/63 (20.6%)	0/26 (0%)	1/30 (3.33%)	4/233 (1.72%)
	(PCB 17) 2,2',4-Trichlorobiphenyl	69/69 (100%)	178/212 (84%)	50/50 (100%)	235/310 (76%)	248/254 (97.6%)	18/18 (100%)	35/37 (94.6%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 170) 2,2',3,3',4,4',5-Heptachlorobiphenyl	69/69 (100%)	175/212 (83%)	50/50 (100%)	240/310 (77%)	248/254 (97.6%)	15/18 (83.3%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	219/233 (94%)
	(PCB 171) 2,2',3,3',4,4',6-Heptachlorobiphenyl	69/69 (100%)	153/211 (73%)	50/50 (100%)	231/310 (75%)	NA	NA	NA	NA	NA	NA	227/233 (97.4%)
	(PCB 171/173) 2,2',3,3',4,4',6-Heptachlorobiphenyl/2,2', 3,3',4,5,6-Heptachlorobiphenyl	NA	NA	NA	N/A	227/254 (89.4%)	13/13 (100%)	6/6 (100%)	34/34 (100%)	16/16 (100%)	18/19 (94.7%)	NA
	(PCB 172) 2,2',3,3',4,5,5'-Heptachlorobiphenyl	68/69 (98.6%)	147/211 (70%)	50/50 (100%)	227/310 (73%)	233/254 (91.7%)	15/18 (83.3%)	37/37 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	196/233 (84.1%)
	(PCB 173) 2,2',3,3',4,5,6-Heptachlorobiphenyl	62/69 (89.9%)	125/211 (59%)	49/50 (98.0%)	205/310 (66%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 174) 2,2',3,3',4,5,6'-Heptachlorobiphenyl	69/69 (100%)	176/211 (83%)	50/50 (100%)	244/310 (79%)	247/254 (97.2%)	16/17 (94.1%)	9/9 (100%)	37/37 (100%)	20/20 (100%)	27/27 (100%)	223/233 (95.7%)
	(PCB 175) 2,2',3,3',4,5',6-Heptachlorobiphenyl	68/69 (98.6%)	135/212 (64%)	50/50 (100%)	223/310 (72%)	181/254 (71.3%)	17/17 (100%)	21/21 (100%)	35/35 (100%)	21/21 (100%)	25/25 (100%)	48/233 (20.6%)
	(PCB 176) 2,2',3,3',4,6,6'-Heptachlorobiphenyl	68/69 (98.6%)	148/211 (70%)	50/50 (100%)	230/310 (74%)	225/254 (88.6%)	18/18 (100%)	37/37 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	216/233 (92.7%)
	(PCB 177) 2,2',3,3',4',5,6-Heptachlorobiphenyl	69/69 (100%)	170/211 (81%)	50/50 (100%)	240/310 (77%)	247/254 (97.2%)	16/16 (100%)	8/8 (100%)	35/35 (100%)	3/3 (100%)	25/25 (100%)	223/233 (95.7%)
	(PCB 178) 2,2',3,3',5,5',6-Heptachlorobiphenyl	68/69 (98.6%)	156/212 (74%)	50/50 (100%)	231/310 (75%)	238/254 (93.7%)	17/17 (100%)	24/24 (100%)	38/38 (100%)	23/23 (100%)	30/30 (100%)	227/233 (97.4%)
	(PCB 179) 2,2',3,3',5,6,6'-Heptachlorobiphenyl	69/69 (100%)	172/212 (81%)	50/50 (100%)	238/310 (77%)	246/254 (96.9%)	18/18 (100%)	36/36 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 18) 2,2',5-Trichlorobiphenyl	69/69 (100%)	192/212 (91%)	50/50 (100%)	263/310 (85%)	NA	NA	NA	NA	NA	NA	233/233 (100%)

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
PCBs (cont.)	(PCB 18/30) 2,2',5-Trichlorobiphenyl/2,4,6-Trichlorobiphenyl	NA	NA	NA	N/A	248/254 (97.6%)	18/18 (100%)	35/37 (94.6%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 180) 2,2',3,4,4',5,5'-Heptachlorobiphenyl	69/69 (100%)	189/211 (90%)	50/50 (100%)	260/310 (84%)	NA	NA	NA	NA	NA	NA	219/233 (94%)
	(PCB 180/193) 2,2',3,4,4',5, 5'-Heptachlorobiphenyl/2,3,3',4',5,5',6-Heptachlorobiphenyl	NA	NA	NA	N/A	244/254 (96.1%)	16/18 (88.9%)	37/37 (100%)	63/63 (100%)	23/23 (100%)	30/30 (100%)	NA
	(PCB 181) 2,2',3,4,4',5,6-Heptachlorobiphenyl	57/69 (82.6%)	118/209 (56%)	45/50 (90.0%)	197/310 (64%)	71/254 (28%)	16/16 (100%)	5/5 (100%)	32/32 (100%)	8/8 (100%)	24/25 (96%)	0/233 (0%)
	(PCB 182) 2,2',3,4,4',5,6'-Heptachlorobiphenyl	NA	NA	NA	N/A	50/254 (19.7%)	17/17 (100%)	8/8 (100%)	32/32 (100%)	21/21 (100%)	23/27 (85.2%)	3/233 (1.29%)
	(PCB 182/187) 2,2',3,4,4',5,6'-Heptachlorobiphenyl/2,2',3,4',5,5',6-Heptachlorobiphenyl	68/69 (98.6%)	185/212 (87%)	50/50 (100%)	254/310 (82%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 183) 2,2',3,4,4',5',6-Heptachlorobiphenyl	69/69 (100%)	173/212 (82%)	50/50 (100%)	239/310 (77%)	NA	NA	NA	NA	NA	NA	232/233 (99.6%)
	(PCB 183/185) 2,2',3,4,4',5',6-Heptachlorobiphenyl/2,2',3,4,5,5', 6-Heptachlorobiphenyl	NA	NA	NA	N/A	244/254 (96.1%)	16/17 (94.1%)	14/14 (100%)	34/35 (97.1%)	22/22 (100%)	17/17 (100%)	NA
	(PCB 184) 2,2',3,4,4',6,6'-Heptachlorobiphenyl	48/69 (69.6%)	111/208 (53%)	43/50 (86.0%)	180/310 (58%)	13/254 (5.12%)	16/18 (88.9%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	24/30 (80%)	3/233 (1.29%)
	(PCB 185) 2,2',3,4,5,5',6-Heptachlorobiphenyl	68/69 (98.6%)	147/211 (70%)	50/50 (100%)	225/310 (73%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 186) 2,2',3,4,5,6,6'-Heptachlorobiphenyl	2/69 (2.90%)	1/206 (0.5%)	0/50 (0%)	3/310 (1%)	0/254 (0%)	0/18 (0%)	0/34 (0%)	12/57 (21.1%)	9/26 (34.6%)	0/30 (0%)	0/233 (0%)
	(PCB 187) 2,2',3,4',5,5',6-Heptachlorobiphenyl	NA	NA	NA	N/A	249/254 (98.0%)	16/16 (100%)	11/11 (100%)	36/36 (100%)	24/24 (100%)	25/25 (100%)	232/233 (99.6%)
	(PCB 188) 2,2',3,4',5,6,6'-Heptachlorobiphenyl	51/69 (73.9%)	117/209 (56%)	45/50 (90.0%)	200/310 (65%)	66/254 (26%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	1/233 (0.429%)
	(PCB 189) 2,3,3',4,4',5,5'-Heptachlorobiphenyl	67/69 (97.1%)	143/211 (68%)	50/50 (100%)	224/310 (72%)	186/254 (73.2%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	57/233 (24.5%)
	(PCB 19) 2,2',6-Trichlorobiphenyl	68/69 (98.6%)	145/212 (68%)	50/50 (100%)	209/310 (67%)	247/254 (97.2%)	18/18 (100%)	34/37 (91.9%)	63/63 (100%)	23/23 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 190) 2,3,3',4,4',5,6-Heptachlorobiphenyl	68/69 (98.6%)	149/212 (70%)	50/50 (100%)	229/310 (74%)	233/254 (91.7%)	15/18 (83.3%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	211/233 (90.6%)
	(PCB 191) 2,3,3',4,4',5',6-Heptachlorobiphenyl	67/69 (97.1%)	135/211 (64%)	50/50 (100%)	218/310 (70%)	177/254 (69.7%)	18/18 (100%)	37/37 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	62/233 (26.6%)
	(PCB 192) 2,3,3',4,5,5',6-Heptachlorobiphenyl	2/69 (2.90%)	2/206 (1%)	1/50 (2.00%)	0/310 (0%)	1/254 (0.394%)	0/18 (0%)	25/37 (67.6%)	26/56 (46.4%)	15/26 (57.7%)	0/30 (0%)	0/233 (0%)
	(PCB 193) 2,3,3',4',5,5',6-Heptachlorobiphenyl	68/69 (98.6%)	146/211 (69%)	50/50 (100%)	227/310 (73%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 194) 2,2',3,3',4,4',5,5'-Octachlorobiphenyl	69/69 (100%)	175/212 (83%)	50/50 (100%)	243/310 (78%)	247/254 (97.2%)	15/18 (83.3%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	216/233 (92.7%)
	(PCB 195) 2,2',3,3',4,4',5,6-Octachlorobiphenyl	68/69 (98.6%)	152/212 (72%)	50/50 (100%)	228/310 (74%)	225/254 (88.6%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	211/233 (90.6%)
	(PCB 196) 2,2',3,3',4,4',5,6'-Octachlorobiphenyl	NA	NA	NA	N/A	236/254 (92.9%)	18/18 (100%)	37/37 (100%)	61/61 (100%)	26/26 (100%)	30/30 (100%)	223/233 (95.7%)
	(PCB 196/203) 2,2',3,3',4,4',5,6'- Octachlorobiphenyl/2,2',3,4,4',5,5',6-Octachlorobiphenyl	69/69 (100%)	179/212 (84%)	50/50 (100%)	251/310 (81%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 197) 2,2',3,3',4,4',6,6'-Octachlorobiphenyl	64/69 (92.8%)	136/212 (64%)	49/50 (98.0%)	220/310 (71%)	NA	NA	NA	NA	NA	NA	32/233 (13.7%)
	(PCB 197/200) 2,2',3,3',4,4',6,6'- Octachlorobiphenyl/2,2',3,3',4,5,6,6'-Octachlorobiphenyl	NA	NA	NA	N/A	162/253 (64.0%)	15/15 (100%)	26/26 (100%)	61/61 (100%)	23/23 (100%)	30/30 (100%)	NA
	(PCB 198) 2,2',3,3',4,5,5',6-Octachlorobiphenyl	67/69 (97.1%)	139/212 (66%)	49/50 (98.0%)	226/310 (73%)	NA	NA	NA	NA	NA	NA	221/233 (94.8%)
	(PCB 198/199) 2,2',3,3',4,5,5',6- Octachlorobiphenyl/2,2',3,3',4,5,5',6'-Octachlorobiphenyl	NA	NA	NA	N/A	243/254 (95.7%)	17/18 (94.4%)	37/37 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 199) 2,2',3,3',4,5,5',6-Octachlorobiphenyl	69/69 (100%)	180/212 (85%)	50/50 (100%)	250/310 (81%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 2) 3-Chlorobiphenyl	69/69 (100%)	190/212 (90%)	48/48 (100%)	267/300 (89%)	245/254 (96.5%)	13/18 (72.2%)	15/37 (40.5%)	45/63 (71.4%)	16/26 (61.5%)	29/30 (96.7%)	59/233 (25.3%)
	(PCB 20) 2,3,3'-Trichlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 20/21/33) 2,3,3'-TrCB/2,3,4-TrCB/2',3,4-TrCB	69/69 (100%)	185/212 (87%)	50/50 (100%)	247/310 (80%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 20/28) 2,3,3'-Trichlorobiphenyl/2,4,4'-Trichlorobiphenyl	NA	NA	NA	N/A	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 200) 2,2',3,3',4,5,6,6'-Octachlorobiphenyl	68/69 (98.6%)	143/212 (67%)	50/50 (100%)	230/310 (74%)	NA	NA	NA	NA	NA	NA	127/233 (54.5%)
	(PCB 201) 2,2',3,3',4,5',6,6'-Octachlorobiphenyl	68/69 (98.6%)	148/211 (70%)	50/50 (100%)	231/310 (75%)	200/254 (78.7%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	181/233 (77.7%)
	(PCB 202) 2,2',3,3',5,5',6,6'-Octachlorobiphenyl	69/69 (100%)	165/212 (78%)	50/50 (100%)	241/310 (78%)	231/254 (90.9%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	231/233 (99.1%)
	(PCB 203) 2,2',3,4,4',5,5',6-Octachlorobiphenyl	NA	NA	NA	N/A	242/254 (95.3%)	18/18 (100%)	37/37 (100%)	59/59 (100%)	26/26 (100%)	30/30 (100%)	231/233 (99.1%)
	(PCB 204) 2,2',3,4,4',5,6,6'-Octachlorobiphenyl	6/68 (8.82%)	22/208 (11%)	7/50 (14.0%)	34/310 (11%)	0/254 (0%)	0/18 (0%)	35/37 (94.6%)	49/63 (77.8%)	15/26 (57.7%)	0/30 (0%)	0/233 (0%)
	(PCB 205) 2,3,3',4,4',5,5',6-Octachlorobiphenyl	67/69 (97.1%)	136/212 (64%)	50/50 (100%)	221/310 (71%)	165/254 (65%)	16/18 (88.9%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/30 (96.7%)	45/233 (19.3%)
	(PCB 206) 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	69/69 (100%)	180/212 (85%)	50/50 (100%)	255/310 (82%)	244/254 (96.1%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	217/233 (93.1%)
	(PCB 207) 2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl	68/69 (98.6%)	145/212 (68%)	50/50 (100%)	233/310 (75%)	194/254 (76.4%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/30 (96.7%)	110/233 (47.2%)
	(PCB 208) 2,2',3,3',4,5,5',6,6'-Nonachlorobiphenyl	69/69 (100%)	167/212 (79%)	50/50 (100%)	248/310 (80%)	240/254 (94.5%)	18/18 (100%)	37/37 (100%)	60/60 (100%)	26/26 (100%)	30/30 (100%)	229/233 (98.3%)
	(PCB 209) Decachlorobiphenyl	69/69 (100%)	179/212 (84%)	50/50 (100%)	259/310 (84%)	227/254 (89.4%)	3/18 (16.7%)	34/34 (100%)	54/54 (100%)	26/26 (100%)	30/30 (100%)	231/233 (99.1%)
	(PCB 21) 2,3,4-Trichlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	228/233 (97.9%)
	(PCB 21/33) 2,3,4-Trichlorobiphenyl/2',3,4-Trichlorobiphenyl	NA	NA	NA	N/A	253/254 (99.6%)	17/18 (94.4%)	37/37 (100%)	59/63 (93.7%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 22) 2,3,4'-Trichlorobiphenyl	69/69 (100%)	181/212 (85%)	49/50 (98.0%)	238/310 (77%)	253/254 (99.6%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 23) 2,3,5-Trichlorobiphenyl	28/69 (40.6%)	89/208 (43%)	35/50 (70.0%)	160/310 (52%)	56/254 (22.0%)	11/18 (61.1%)	0/37 (0%)	42/63 (66.7%)	25/26 (96.2%)	17/30 (56.7%)	1/233 (0.429%)
	(PCB 24) 2,3,6-Trichlorobiphenyl	NA	NA	NA	N/A	161/254 (63.4%)	4/18 (22.2%)	0/37 (0%)	36/63 (57.1%)	20/26 (76.9%)	20/30 (66.7%)	199/233 (85.4%)
	(PCB 24/27) 2,3,6-Trichlorobiphenyl/2,3',6-Trichlorobiphenyl	68/69 (98.6%)	151/212 (71%)	50/50 (100%)	212/310 (68%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 25) 2,3',4-Trichlorobiphenyl	69/69 (100%)	161/212 (76%)	50/50 (100%)	217/310 (70%)	253/254 (99.6%)	18/18 (100%)	36/37 (97.3%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
PCBs (cont.)	(PCB 26) 2,3',5-Trichlorobiphenyl	69/69 (100%)	174/212 (82%)	50/50 (100%)	229/310 (74%)	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 26/29) 2,3',5-Trichlorobipheny/2,4,5-Trichlorobiphenyl	NA	NA	NA	N/A	241/254 (94.9%)	18/18 (100%)	36/37 (97.3%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 27) 2,3',6-Trichlorobiphenyl	NA	NA	NA	N/A	247/254 (97.2%)	18/18 (100%)	37/37 (100%)	59/59 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 28) 2,4,4'-Trichlorobiphenyl	69/69 (100%)	201/212 (95%)	50/50 (100%)	268/310 (86%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 29) 2,4,5-Trichlorobiphenyl	56/69 (81.2%)	113/211 (54%)	48/50 (96.0%)	172/310 (55%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 3) 4-Monochlorobiphenyl	69/69 (100%)	171/212 (81%)	50/50 (100%)	257/310 (83%)	253/254 (99.6%)	13/13 (100%)	9/21 (42.9%)	20/58 (34.5%)	6/26 (23.1%)	28/30 (93.3%)	67/233 (28.8%)
	(PCB 30) 2,4,6-Trichlorobiphenyl	7/69 (10.1%)	34/206 (17%)	13/50 (26.0%)	118/310 (38%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 31) 2,4',5-Trichlorobiphenyl	69/69 (100%)	200/212 (94%)	50/50 (100%)	266/310 (86%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 32) 2,4',6-Trichlorobiphenyl	NA	NA	NA	N/A	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 33) 2,3',4'-Trichlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 34) 2,3',5'-Trichlorobiphenyl	63/69 (91.3%)	118/211 (56%)	49/50 (98.0%)	171/310 (55%)	187/254 (73.6%)	18/18 (100%)	37/37 (100%)	62/63 (98.4%)	26/26 (100%)	30/30 (100%)	176/233 (75.5%)
	(PCB 35) 3,3',4-Trichlorobiphenyl	67/69 (97.1%)	137/211 (65%)	50/50 (100%)	207/310 (67%)	240/254 (94.5%)	17/18 (94.4%)	33/37 (89.2%)	11/63 (17.5%)	7/26 (26.9%)	30/30 (100%)	213/233 (91.4%)
	(PCB 36) 3,3',5-Trichlorobiphenyl	46/69 (66.7%)	98/209 (47%)	40/50 (80.0%)	125/310 (40%)	78/254 (30.7%)	16/18 (88.9%)	33/37 (89.2%)	1/63 (1.59%)	3/26 (11.5%)	18/30 (60%)	93/233 (39.9%)
	(PCB 37) 3,4,4'-Trichlorobiphenyl	69/69 (100%)	182/212 (86%)	50/50 (100%)	236/310 (76%)	254/254 (100%)	17/18 (94.4%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 38) 3,4,5-Trichlorobiphenyl	62/69 (89.9%)	118/210 (56%)	49/50 (98.0%)	167/310 (54%)	51/254 (20.1%)	18/18 (100%)	19/37 (51.4%)	61/63 (96.8%)	26/26 (100%)	19/30 (63.3%)	14/233 (6.01%)
	(PCB 39) 3,4',5-Trichlorobiphenyl	57/69 (82.6%)	111/210 (53%)	46/50 (92.0%)	159/310 (51%)	192/254 (75.6%)	18/18 (100%)	37/37 (100%)	49/63 (77.8%)	26/26 (100%)	30/30 (100%)	170/233 (73%)
	(PCB 4) 2,2'-Dichlorobiphenyl	NA	NA	NA	N/A	248/254 (97.6%)	18/18 (100%)	32/37 (86.5%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 4/10) 2,2'-Dichlorobiphenyl/2,6-Dichlorobiphenyl	67/69 (97.1%)	131/211 (62%)	50/50 (100%)	196/310 (63%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 40) 2,2',3,3'-Tetrachlorobiphenyl	69/69 (100%)	166/210 (79%)	43/43 (100%)	216/296 (73%)	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 40/71) 2,2',3,3'-Tetrachlorobiphenyl/2,3',4', 6-Tetrachlorobiphenyl	NA	NA	NA	N/A	248/254 (97.6%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 41) 2,2',3,4-Tetrachlorobiphenyl	NA	NA	NA	N/A	184/254 (72.4%)	18/18 (100%)	16/37 (43.2%)	40/57 (70.2%)	25/26 (96.2%)	29/30 (96.7%)	0/233 (0%)
	(PCB 41/64/71/72) 2,2',3,4-TeCB/2,3,4',6-TeCB/2,3',5,5'-TeCB/2,3',4',6-TeCB/2,3',5,5'-TeCB	62/63 (98.4%)	174/189 (92%)	39/39 (100%)	234/271 (86%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 42) 2,2',3,4'-Tetrachlorobiphenyl	NA	NA	NA	N/A	250/254 (98.4%)	18/18 (100%)	37/37 (100%)	59/59 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 42/59) 2,2',3,4'-Tetrachlorobiphenyl/2,3,3',6-Tetrachlorobiphenyl	69/69 (100%)	180/212 (85%)	50/50 (100%)	242/310 (78%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 43) 2,2',3,5-Tetrachlorobiphenyl	NA	NA	NA	N/A	194/253 (76.7%)	18/18 (100%)	37/37 (100%)	55/63 (87.3%)	26/26 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 43/49) 2,2',3,5-Tetrachlorobiphenyl/2,2',4,5'-Tetrachlorobiphenyl	69/69 (100%)	193/212 (91%)	50/50 (100%)	262/310 (85%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 44) 2,2',3,5'-Tetrachlorobiphenyl	69/69 (100%)	200/212 (94%)	50/50 (100%)	272/310 (88%)	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 44/47/65) 2,2',3,5'-TeCB/2,2',4,4'-TeCB/2,3,5,6-TeCB	NA	NA	NA	N/A	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 45) 2,2',3,6-Tetrachlorobiphenyl	68/69 (98.6%)	167/212 (79%)	50/50 (100%)	232/310 (75%)	238/254 (93.7%)	18/18 (100%)	30/37 (81.1%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 46) 2,2',3,6'-Tetrachlorobiphenyl	68/69 (98.6%)	154/212 (73%)	50/50 (100%)	221/310 (71%)	235/254 (92.5%)	18/18 (100%)	35/37 (94.6%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 47) 2,2',4,4'-Tetrachlorobiphenyl	69/69 (100%)	185/212 (87%)	50/50 (100%)	240/310 (77%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 48) 2,2',4,5-Tetrachlorobiphenyl	NA	NA	NA	N/A	246/254 (96.9%)	18/18 (100%)	36/37 (97.3%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 48/75) 2,2',4,5-Tetrachlorobiphenyl/2,4,4',6-Tetrachlorobiphenyl	69/69 (100%)	175/212 (83%)	50/50 (100%)	233/310 (75%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 49) 2,2',4,5'-Tetrachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 49/69) 2,2',4,5'-Tetrachlorobiphenyl/2,3',4, 6-Tetrachlorobiphenyl	NA	NA	NA	N/A	252/254 (99.2%)	18/18 (100%)	36/37 (97.3%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 5) 2,3-Dichlorobiphenyl	NA	NA	NA	N/A	117/254 (46.1%)	11/18 (61.1%)	0/37 (0%)	40/63 (63.5%)	19/26 (73.1%)	22/30 (73.3%)	46/233 (19.7%)
	(PCB 5/8) 2,3-Dichlorobiphenyl/2,4'-Dichlorobiphenyl	68/69 (98.6%)	157/212 (74%)	50/50 (100%)	220/310 (71%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 50) 2,2',4,6-Tetrachlorobiphenyl	58/69 (84.1%)	119/210 (57%)	49/50 (98.0%)	174/310 (56%)	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 50/53) 2,2',4,6-Tetrachlorobipheny/2,2',5, 6'-Tetrachlorobiphenyl	NA	NA	NA	N/A	225/254 (88.6%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 51) 2,2',4,6'-Tetrachlorobiphenyl	68/69 (98.6%)	155/212 (73%)	50/50 (100%)	220/310 (71%)	229/254 (90.2%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/30 (96.7%)	0/233 (0%)
	(PCB 52) 2,2',5,5'-Tetrachlorobiphenyl	NA	NA	NA	N/A	245/254 (96.5%)	18/18 (100%)	36/37 (97.3%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 52/69) 2,2',5,5'-Tetrachlorobiphenyl/ 2,3',4,6-Tetrachlorobiphenyl	69/69 (100%)	205/212 (97%)	50/50 (100%)	287/310 (93%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 53) 2,2',5,6'-Tetrachlorobiphenyl	69/69 (100%)	170/212 (80%)	50/50 (100%)	234/310 (75%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 54) 2,2',6,6'-Tetrachlorobiphenyl	61/69 (88.4%)	116/211 (55%)	50/50 (100%)	169/310 (55%)	138/254 (54.3%)	18/18 (100%)	2/37 (5.41%)	56/63 (88.9%)	26/26 (100%)	28/30 (93.3%)	139/233 (59.7%)
	(PCB 55) 2,3,3',4-Tetrachlorobiphenyl	68/69 (98.6%)	135/212 (64%)	50/50 (100%)	209/310 (67%)	173/254 (68.1%)	18/18 (100%)	33/37 (89.2%)	40/57 (70.2%)	21/26 (80.8%)	27/30 (90%)	200/233 (85.8%)
	(PCB 56) 2,3,3',4'-Tetrachlorobiphenyl	NA	NA	NA	N/A	237/254 (93.3%)	18/18 (100%)	37/37 (100%)	57/57 (100%)	24/24 (100%)	30/30 (100%)	233/233 (100%)

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
PCBs (cont.)	(PCB 56/60) 2,3,3',4'-Tetrachlorobiphenyl/2,3,4,4'-Tetrachlorobiphenyl	69/69 (100%)	192/212 (91%)	50/50 (100%)	263/310 (85%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 57) 2,3,3',5-Tetrachlorobiphenyl	65/69 (94.2%)	121/211 (57%)	50/50 (100%)	188/310 (61%)	160/254 (63%)	17/18 (94.4%)	37/37 (100%)	51/57 (89.5%)	25/26 (96.2%)	29/30 (96.7%)	112/233 (48.1%)
	(PCB 58) 2,3,3',5'-Tetrachlorobiphenyl	62/69 (89.9%)	119/210 (57%)	49/50 (98.0%)	183/310 (59%)	136/254 (53.5%)	18/18 (100%)	36/37 (97.3%)	57/57 (100%)	26/26 (100%)	27/30 (90%)	146/233 (62.7%)
	(PCB 59) 2,3,3',6-Tetrachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 59/62/75) 2,3,3',6-TeCB/2,3,4,6-TeCB/ 2,4,4',6-TeCB	NA	NA	NA	N/A	227/254 (89.4%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 6) 2,3'-Dichlorobiphenyl	67/69 (97.1%)	128/211 (61%)	50/50 (100%)	195/310 (63%)	243/254 (95.7%)	18/18 (100%)	28/37 (75.7%)	60/61 (98.4%)	20/26 (76.9%)	29/30 (96.7%)	198/233 (85%)
	(PCB 60) 2,3,4,4'-Tetrachlorobiphenyl	NA	NA	NA	N/A	251/254 (98.8%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 61) 2,3,4,5-Tetrachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	232/233 (99.6%)
	(PCB 61/70) 2,3,4,5-Tetrachlorobiphenyl/2,3',4',5-Tetrachlorobiphenyl	69/69 (100%)	196/212 (92%)	50/50 (100%)	277/310 (89%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 61/70/74/76) 2,3,4,5-TeCB/2,3',4',5-TeCB/2,4,4', 5-TeCB/2,3',4',5'-TeCB	NA	NA	NA	N/A	246/254 (96.9%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 62) 2,3,4,6-Tetrachlorobiphenyl	0/69 (0%)	4/206 (2%)	0/50 (0%)	7/310 (2%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 63) 2,3,4',5-Tetrachlorobiphenyl	68/69 (98.6%)	150/212 (71%)	50/50 (100%)	220/310 (71%)	235/254 (92.5%)	18/18 (100%)	37/37 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 64) 2,3,4',6-Tetrachlorobiphenyl	NA	NA	NA	N/A	248/254 (97.6%)	18/18 (100%)	37/37 (100%)	61/61 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 65) 2,3,5,6-Tetrachlorobiphenyl	6/69 (8.70%)	31/207 (15%)	5/50 (10.0%)	48/310 (15%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 66) 2,3',4,4'-Tetrachlorobiphenyl	NA	NA	NA	N/A	248/254 (97.6%)	18/18 (100%)	37/37 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 66/76) 2,3',4,4'-Tetrachlorobiphenyl/2,3',4',5'-Tetrachlorobiphenyl	69/69 (100%)	195/212 (92%)	50/50 (100%)	273/310 (88%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 67) 2,3',4,5-Tetrachlorobiphenyl	68/69 (98.6%)	145/211 (69%)	50/50 (100%)	217/310 (70%)	226/254 (89%)	18/18 (100%)	37/37 (100%)	60/61 (98.4%)	25/25 (100%)	30/30 (100%)	230/233 (98.7%)
	(PCB 68) 2,3',4,5'-Tetrachlorobiphenyl	68/69 (98.6%)	122/210 (58%)	35/35 (100%)	141/253 (56%)	194/254 (76.4%)	18/18 (100%)	37/37 (100%)	56/57 (98.2%)	26/26 (100%)	30/30 (100%)	158/233 (67.8%)
	(PCB 69) 2,3',4,6-Tetrachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 7) 2,4-Dichlorobiphenyl	NA	NA	NA	N/A	144/254 (56.7%)	13/18 (72.2%)	16/37 (43.2%)	44/61 (72.1%)	20/26 (76.9%)	26/30 (86.7%)	95/233 (40.8%)
	(PCB 7/9) 2,4-Dichlorobiphenyl/2,5-Dichlorobiphenyl	62/69 (89.9%)	122/211 (58%)	49/50 (98.0%)	193/310 (62%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 70) 2,3',4',5-Tetrachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 71) 2,3',4',6-Tetrachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 72) 2,3',5,5'-Tetrachlorobiphenyl	NA	NA	NA	N/A	204/254 (80.3%)	18/18 (100%)	37/37 (100%)	55/59 (93.2%)	26/26 (100%)	30/30 (100%)	210/233 (90.1%)
	(PCB 73) 2,3',5',6-Tetrachlorobiphenyl	2/69 (2.90%)	3/206 (1%)	8/50 (16.0%)	21/310 (7%)	18/254 (7.09%)	14/18 (77.8%)	36/37 (97.3%)	50/63 (79.4%)	21/26 (80.8%)	25/30 (83.3%)	0/233 (0%)
	(PCB 74) 2,4,4',5-Tetrachlorobiphenyl	69/69 (100%)	186/212 (88%)	50/50 (100%)	257/310 (83%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 75) 2,4,4',6-Tetrachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 76) 2',3,4,5-Tetrachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 77) 3,3',4,4'-Tetrachlorobiphenyl	69/69 (100%)	185/212 (87%)	50/50 (100%)	268/310 (86%)	250/254 (98.4%)	5/5 (100%)	11/11 (100%)	63/63 (100%)	15/15 (100%)	30/30 (100%)	232/233 (99.6%)
	(PCB 78) 3,3',4,5-Tetrachlorobiphenyl	21/69 (30.4%)	41/206 (20%)	2/50 (4.00%)	7/310 (2%)	2/254 (0.787%)	2/18 (11.1%)	0/37 (0%)	2/63 (3.17%)	0/26 (0%)	0/30 (0%)	0/233 (0%)
	(PCB 79) 3,3',4,5'-Tetrachlorobiphenyl	58/69 (84.1%)	128/211 (61%)	40/50 (80.0%)	162/310 (52%)	175/254 (68.9%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	25/26 (96.2%)	29/30 (96.7%)	145/233 (62.2%)
	(PCB 8) 2,4'-Dichlorobiphenyl	NA	NA	NA	N/A	254/254 (100%)	18/18 (100%)	26/37 (70.3%)	51/54 (94.4%)	24/26 (92.3%)	30/30 (100%)	217/233 (93.1%)
	(PCB 80) 3,3',5,5'-Tetrachlorobiphenyl	0/69 (0%)	0/206 (0%)	0/50 (0%)	0/310 (0%)	0/254 (0%)	1/18 (5.56%)	37/37 (100%)	14/61 (23%)	3/26 (11.5%)	0/30 (0%)	0/233 (0%)
	(PCB 81) 3,4,4',5-Tetrachlorobiphenyl	66/69 (95.7%)	141/212 (67%)	49/50 (98.0%)	215/310 (69%)	105/254 (41.3%)	17/18 (94.4%)	37/37 (100%)	45/60 (75.0%)	26/26 (100%)	27/30 (90%)	50/233 (21.5%)
	(PCB 82) 2,2',3,3',4-Pentachlorobiphenyl	69/69 (100%)	165/212 (78%)	50/50 (100%)	234/310 (75%)	243/254 (95.7%)	18/18 (100%)	33/37 (89.2%)	59/59 (100%)	26/26 (100%)	30/30 (100%)	231/233 (99.1%)
	(PCB 83) 2,2',3,3',5-Pentachlorobiphenyl	32/69 (46.4%)	82/208 (39%)	23/50 (46.0%)	125/310 (40%)	207/254 (81.5%)	18/18 (100%)	26/37 (70.3%)	54/57 (94.7%)	26/26 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 84) 2,2',3,3',6-Pentachlorobiphenyl	NA	NA	NA	N/A	238/254 (93.7%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/30 (96.7%)	233/233 (100%)
	(PCB 84/92) 2,2',3,3',6-Pentachlorobiphenyl/2,2',3,5,5'-Pentachlorobiphenyl	69/69 (100%)	189/212 (89%)	50/50 (100%)	257/310 (83%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 85) 2,2',3,4,4'-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	231/233 (99.1%)
	(PCB 85/116) 2,2',3,4,4'-Pentachlorobiphenyl/2,3,4,5,6-Pentachlorobiphenyl	69/69 (100%)	178/212 (84%)	50/50 (100%)	237/310 (76%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 85/116/117) 2,2',3,4,4'-PeCB/2,3,4,5,6-PeCB/2,3,4',5,6-PeCB	NA	NA	NA	N/A	240/254 (94.5%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 86) 2,2',3,4,5-Pentachlorobiphenyl	65/69 (94.2%)	129/212 (61%)	48/50 (96.0%)	190/310 (61%)	NA	NA	NA	NA	NA	NA	232/233 (99.6%)
	(PCB 86/87/97/109/119/125) 2,2',3,4,5-PeCB/ 2,2',3,4,5'-PeCB/2,2',3',4,5-PeCB/2,3,3',4,6-PeCB/2,3',4,4', 6-PeCB/2',3,4,5,6'-PeCB	NA	NA	NA	N/A	233/254 (91.7%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	23/23 (100%)	30/30 (100%)	NA
	(PCB 87) 2,2',3,4,5'-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 87/117/125) 2,2',3,4,5'-PeCB/2,3,4',5,6-PeCB/2',3,4,5,6'-PeCB	69/69 (100%)	186/212 (88%)	50/50 (100%)	249/310 (80%)	NA	NA	NA	NA	NA	NA	NA

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
PCBs (cont.)	(PCB 88) 2,2',3,4,6-Pentachlorobiphenyl	NA	NA	NA	N/A	6/254 (2.36%)	0/18 (0%)	4/37 (10.8%)	6/63 (9.52%)	19/26 (73.1%)	11/30 (36.7%)	232/233 (99.6%)
	(PCB 88/91) 2,2',3,4,6-Pentachlorobiphenyl/2,2',3,4',6-Pentachlorobiphenyl	69/69 (100%)	174/212 (82%)	50/50 (100%)	236/310 (76%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 89) 2,2',3,4,6'-Pentachlorobiphenyl	67/69 (97.1%)	136/211 (64%)	50/50 (100%)	205/310 (66%)	188/254 (74.0%)	18/18 (100%)	25/37 (67.6%)	53/63 (84.1%)	26/26 (100%)	28/30 (93.3%)	58/233 (24.9%)
	(PCB 9) 2,5-Dichlorobiphenyl	NA	NA	NA	N/A	210/254 (82.7%)	15/18 (83.3%)	20/37 (54.1%)	49/61 (80.3%)	20/26 (76.9%)	29/30 (96.7%)	116/233 (49.8%)
	(PCB 90) 2,2',3,4',5-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	233/233 (100%)
	(PCB 90/101) Pentachlorobiphenyl	69/69 (100%)	202/212 (95%)	50/50 (100%)	280/310 (90%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 90/101/113) 2,2',3,4',5-PeCB/2,2',4,5,5'-PeCB/2,3,3',5',6-PeCB	NA	NA	NA	N/A	239/254 (94.1%)	18/18 (100%)	37/37 (100%)	59/59 (100%)	25/25 (100%)	30/30 (100%)	NA
	(PCB 91) 2,2',3,4',6-Pentachlorobiphenyl	NA	NA	NA	N/A	244/254 (96.1%)	18/18 (100%)	37/37 (100%)	62/62 (100%)	26/26 (100%)	30/30 (100%)	0/233 (0%)
	(PCB 92) 2,2',3,5,5'-Pentachlorobiphenyl	NA	NA	NA	N/A	223/254 (87.8%)	18/18 (100%)	37/37 (100%)	57/57 (100%)	22/22 (100%)	29/30 (96.7%)	233/233 (100%)
	(PCB 93) 2,2',3,5,6-Pentachlorobiphenyl	3/69 (4.35%)	3/206 (1%)	0/50 (0%)	0/310 (0%)	NA	NA	NA	NA	NA	NA	222/233 (95.3%)
	(PCB 93/100) 2,2',3,5,6-Pentachlorobiphenyl/2,2',4,4',6-Pentachlorobiphenyl	NA	NA	NA	N/A	138/254 (54.3%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/30 (96.7%)	NA
	(PCB 94) 2,2',3,5,6'-Pentachlorobiphenyl	67/69 (97.1%)	126/212 (59%)	50/50 (100%)	199/310 (64%)	163/254 (64.2%)	18/18 (100%)	37/37 (100%)	61/63 (96.8%)	25/26 (96.2%)	30/30 (100%)	71/233 (30.5%)
	(PCB 95) 2,2',3,5',6-Pentachlorobiphenyl	NA	NA	NA	N/A	242/254 (95.3%)	18/18 (100%)	27/27 (100%)	63/63 (100%)	11/11 (100%)	30/30 (100%)	233/233 (100%)
	(PCB 95/98/102) Pentachlorobiphenyl	69/69 (100%)	197/212 (93%)	50/50 (100%)	271/310 (87%)	NA	NA	NA	NA	NA	NA	NA
	(PCB 96) 2,2',3,6,6'-Pentachlorobiphenyl	67/69 (97.1%)	130/212 (61%)	49/50 (98.0%)	203/310 (65%)	162/254 (63.8%)	18/18 (100%)	7/37 (18.9%)	59/63 (93.7%)	26/26 (100%)	30/30 (100%)	110/233 (47.2%)
	(PCB 97) 2,2',3',4,5-Pentachlorobiphenyl	69/69 (100%)	181/212 (85%)	50/50 (100%)	242/310 (78%)	NA	NA	NA	NA	NA	NA	0/233 (0%)
	(PCB 98) 2,2',3',4,6-Pentachlorobiphenyl	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	226/233 (97%)
	(PCB 98/102) 2,2',3,4',6'-Pentachlorobiphenyl/2,2',4,5,6'-Pentachlorobiphenyl	NA	NA	NA	N/A	177/254 (69.7%)	18/18 (100%)	37/37 (100%)	56/63 (88.9%)	26/26 (100%)	30/30 (100%)	NA
	(PCB 99) 2,2',4,4',5-Pentachlorobiphenyl	68/69 (98.6%)	189/212 (89%)	50/50 (100%)	256/310 (83%)	249/254 (98.0%)	17/18 (94.4%)	37/37 (100%)	57/57 (100%)	26/26 (100%)	30/30 (100%)	0/233 (0%)
	Aroclor-1016 (PCB-1016)	0/69 (0%)	0/212 (0%)	0/50 (0%)	0/310 (0%)	0/254 (0%)	0/18 (0%)	0/37 (0%)	0/59 (0%)	0/26 (0%)	NA	NA
	Aroclor-1221 (PCB-1221)	0/69 (0%)	0/212 (0%)	0/50 (0%)	0/310 (0%)	0/254 (0%)	0/18 (0%)	0/37 (0%)	0/59 (0%)	0/26 (0%)	NA	NA
	Aroclor-1232 (PCB-1232)	0/69 (0%)	0/212 (0%)	0/50 (0%)	0/310 (0%)	0/254 (0%)	0/18 (0%)	0/37 (0%)	0/59 (0%)	0/26 (0%)	NA	NA
	Aroclor-1242 (PCB-1242)	1/69 (1.45%)	13/212 (6%)	49/50 (98.0%)	177/310 (57%)	1/254 (0.394%)	0/18 (0%)	0/37 (0%)	0/59 (0%)	0/26 (0%)	NA	NA
	Aroclor-1248 (PCB-1248)	66/69 (95.7%)	110/212 (52%)	0/50 (0%)	0/310 (0%)	231/254 (90.9%)	18/18 (100%)	1/37 (2.70%)	34/59 (57.6%)	11/26 (42.3%)	NA	NA
	Aroclor-1254 (PCB-1254)	64/69 (92.8%)	128/212 (60%)	49/50 (98.0%)	197/307 (64%)	231/254 (90.9%)	12/18 (66.7%)	0/37 (0%)	49/59 (83.1%)	25/26 (96.2%)	NA	NA
	Aroclor-1260 (PCB-1260)	60/69 (87%)	118/212 (56%)	50/50 (100%)	201/310 (65%)	160/254 (63%)	0/18 (0%)	3/37 (8.11%)	55/59 (93.2%)	1/26 (3.85%)	NA	NA
	Aroclor-1262 (PCB-1262)	0/69 (0%)	0/212 (0%)	0/50 (0%)	0/310 (0%)	9/254 (3.54%)	0/18 (0%)	28/37 (75.7%)	0/59 (0%)	15/26 (57.7%)	NA	NA
	Aroclor-1268 (PCB-1268)	0/69 (0%)	12/212 (6%)	3/50 (6.00%)	39/310 (13%)	1/254 (0.394%)	0/18 (0%)	0/37 (0%)	0/59 (0%)	0/26 (0%)	NA	NA
	Total decachlorobiphenyl	69/69 (100%)	179/212 (84%)	50/50 (100%)	259/310 (84%)	227/254 (89.4%)	3/18 (16.7%)	36/37 (97.3%)	54/63 (85.7%)	26/26 (100%)	NA	NA
	Total dichlorobiphenyl	69/69 (100%)	188/212 (89%)	50/50 (100%)	257/310 (83%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	NA
	Total heptachlorobiphenyl	69/69 (100%)	192/212 (91%)	50/50 (100%)	262/310 (85%)	251/254 (98.8%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	NA
	Total hexachlorobiphenyl	69/69 (100%)	201/212 (95%)	50/50 (100%)	274/310 (88%)	249/254 (98.0%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	NA
	Total monochlorobiphenyl	69/69 (100%)	193/212 (91%)	50/50 (100%)	278/310 (90%)	253/254 (99.6%)	18/18 (100%)	31/37 (83.8%)	59/63 (93.7%)	20/26 (76.9%)	NA	NA
	Total nonachlorobiphenyl	69/69 (100%)	181/212 (85%)	50/50 (100%)	256/310 (83%)	245/254 (96.5%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	NA
	Total octachlorobiphenyl	69/69 (100%)	181/212 (85%)	50/50 (100%)	252/310 (81%)	247/254 (97.2%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	NA
	Total PCB congeners (NOAA 1989)	69/69 (100%)	209/212 (99%)	50/50 (100%)	302/310 (97%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	Total PCBs (7)	67/69 (97.1%)	131/212 (62%)	50/50 (100%)	211/310 (68%)	239/254 (94.1%)	18/18 (100%)	4/37 (10.8%)	59/59 (100%)	25/26 (96.2%)	NA	NA
	Total PCBs (9)	67/69 (97.1%)	140/212 (66%)	50/50 (100%)	220/310 (71%)	239/254 (94.1%)	18/18 (100%)	29/37 (78.4%)	59/59 (100%)	25/26 (96.2%)	NA	NA
	Total PCBs congener (209 specified)	69/69 (100%)	209/212 (99%)	50/50 (100%)	307/310 (99%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	351/351 (100%)
	Total pentachlorobiphenyl	69/69 (100%)	205/212 (97%)	50/50 (100%)	288/310 (93%)	253/254 (99.6%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	NA
	Total tetrachlorobiphenyl	69/69 (100%)	208/212 (98%)	50/50 (100%)	298/310 (96%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	NA
	Total trichlorobiphenyl	69/69 (100%)	202/212 (95%)	50/50 (100%)	273/310 (88%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	NA	NA
	Total WHO PCB TEQ(Bird)(ND=0)	69/69 (100%)	212/212 (100%)	50/50 (100%)	310/310 (100%)	253/254 (99.6%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	Total WHO PCB TEQ(Fish)(ND=0)	69/69 (100%)	212/212 (100%)	50/50 (100%)	310/310 (100%)	253/254 (99.6%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	Total WHO PCB TEQ(Human/Mammal)(ND=0)	69/69 (100%)	212/212 (100%)	50/50 (100%)	310/310 (100%)	253/254 (99.6%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
Pesticides	2,4'-DDD	NA	NA	16/47 (34.0%)	129/303 (43%)	251/253 (99.2%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	125/158 (79.1%)
	2,4'-DDE	NA	NA	17/46 (37%)	170/301 (56%)	253/253 (100%)	18/18 (100%)	35/35 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	66/158 (41.8%)
	2,4'-DDT	NA	NA	14/50 (28.0%)	50/307 (16%)	131/248 (52.8%)	14/18 (77.8%)	33/36 (91.7%)	63/63 (100%)	24/26 (92.3%)	3/30 (10%)	9/158 (5.7%)
	4,4'-DDD	14/68 (20.6%)	29/212 (14%)	50/50 (100%)	190/309 (61%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	135/158 (85.4%)
	4,4'-DDE	50/69 (72.5%)	124/212 (58%)	50/50 (100%)	218/310 (70%)	253/253 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	120/158 (75.9%)
	4,4'-DDT	10/65 (15.4%)	34/201 (17%)	25/50 (50.0%)	177/306 (58%)	203/236 (86.0%)	18/18 (100%)	36/36 (100%)	63/63 (100%)	26/26 (100%)	4/30 (13.3%)	75/158 (47.5%)

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
Pesticides (cont.)	Aldrin	0/69 (0%)	0/212 (0%)	11/49 (22.4%)	44/301 (15%)	4/145 (2.76%)	12/18 (66.7%)	3/32 (9.38%)	57/63 (90.5%)	12/26 (46.2%)	20/30 (66.7%)	25/158 (15.8%)
	alpha-BHC	4/69 (5.80%)	20/212 (9%)	6/50 (12.0%)	100/305 (33%)	172/252 (68.3%)	12/18 (66.7%)	35/35 (100%)	58/61 (95.1%)	18/26 (69.2%)	5/30 (16.7%)	139/158 (88%)
	alpha-Chlordane	0/69 (0%)	0/212 (0%)	44/50 (88.0%)	124/310 (40%)	238/253 (94.1%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	156/158 (98.7%)
	beta-BHC	8/69 (11.6%)	20/212 (9%)	8/45 (17.8%)	84/278 (30%)	148/253 (58.5%)	2/18 (11.1%)	37/37 (100%)	57/63 (90.5%)	23/26 (88.5%)	0/30 (0%)	108/158 (68.4%)
	cis-Nonachlor	NA	NA	NA	N/A	202/248 (81.5%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/30 (96.7%)	84/158 (53.2%)
	delta-BHC	10/69 (14.5%)	10/212 (5%)	11/49 (22.4%)	22/306 (7%)	38/253 (15.0%)	0/18 (0%)	4/32 (12.5%)	4/57 (7.02%)	6/23 (26.1%)	0/30 (0%)	26/158 (16.5%)
	Dieldrin	0/69 (0%)	0/212 (0%)	26/49 (53.1%)	146/305 (48%)	240/253 (94.9%)	18/18 (100%)	36/36 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	153/158 (96.8%)
	Endosulfan I	0/69 (0%)	1/212 (0.5%)	2/50 (4.00%)	16/308 (5%)	4/249 (1.61%)	0/18 (0%)	1/23 (4.35%)	0/60 (0%)	0/26 (0%)	6/30 (20%)	15/158 (9.49%)
	Endosulfan II	0/69 (0%)	0/212 (0%)	1/50 (2.00%)	30/310 (10%)	3/248 (1.21%)	0/18 (0%)	1/34 (2.94%)	0/61 (0%)	0/26 (0%)	0/30 (0%)	10/158 (6.33%)
	Endosulfan sulfate	0/69 (0%)	5/212 (2%)	15/49 (30.6%)	73/307 (24%)	0/237 (0%)	0/17 (0%)	2/29 (6.90%)	8/62 (12.9%)	9/26 (34.6%)	0/30 (0%)	86/158 (54.4%)
	Endrin	1/69 (1.45%)	4/212 (2%)	4/50 (8.00%)	31/309 (10%)	1/250 (0.400%)	1/18 (5.56%)	0/37 (0%)	25/63 (39.7%)	7/26 (26.9%)	0/30 (0%)	31/158 (19.6%)
	Endrin aldehyde	0/69 (0%)	2/212 (1%)	14/50 (28.0%)	94/308 (31%)	0/158 (0%)	0/15 (0%)	1/11 (9.09%)	0/62 (0%)	0/24 (0%)	1/30 (3.33%)	10/158 (6.33%)
	Endrin ketone	0/69 (0%)	0/212 (0%)	7/50 (14.0%)	30/310 (10%)	2/213 (0.939%)	0/17 (0%)	0/15 (0%)	3/60 (5.00%)	2/25 (8.00%)	1/27 (3.7%)	40/158 (25.3%)
	gamma-BHC (lindane)	1/69 (1.45%)	6/212 (3%)	7/49 (14.3%)	29/303 (10%)	61/253 (24.1%)	9/18 (50.0%)	32/37 (86.5%)	61/63 (96.8%)	23/26 (88.5%)	0/30 (0%)	119/158 (75.3%)
	gamma-Chlordane	0/69 (0%)	2/212 (1%)	27/46 (58.7%)	85/272 (31%)	242/250 (96.8%)	18/18 (100%)	28/30 (93.3%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	143/158 (90.5%)
	Heptachlor	0/69 (0%)	1/212 (0.5%)	13/48 (27.1%)	91/298 (31%)	18/249 (7.23%)	0/18 (0%)	2/37 (5.41%)	30/63 (47.6%)	12/26 (46.2%)	26/30 (86.7%)	53/158 (33.5%)
	Heptachlor endo-epoxide	NA	NA	NA	N/A	52/253 (20.6%)	2/18 (11.1%)	37/37 (100%)	17/63 (27%)	26/26 (100%)	1/30 (3.33%)	NA
	Heptachlor epoxide	3/69 (4.35%)	13/212 (6%)	25/45 (55.6%)	99/249 (40%)	81/249 (32.5%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	13/30 (43.3%)	143/158 (90.5%)
	Hexachlorobenzene	0/69 (0%)	0/212 (0%)	12/50 (24.0%)	80/310 (26%)	252/253 (99.6%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	8/158 (5.06%)
	Methoxychlor	1/69 (1.45%)	5/211 (2%)	2/50 (4.00%)	24/310 (8%)	8/151 (5.30%)	0/17 (0%)	0/22 (0%)	1/59 (1.69%)	0/25 (0%)	0/29 (0%)	38/158 (24.1%)
	Mirex	NA	NA	NA	N/A	37/181 (20.4%)	14/17 (82.4%)	33/33 (100%)	61/61 (100%)	24/25 (96.0%)	16/28 (57.1%)	NA
	Oxychlordane	NA	NA	NA	N/A	7/250 (2.80%)	15/18 (83.3%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	2/30 (6.67%)	13/158 (8.23%)
	Total alpha + gamma chlordane	0/69 (0%)	2/212 (1%)	46/50 (92.0%)	168/310 (54%)	244/254 (96.1%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	158/158 (100%)
	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	NA	NA	50/50 (100%)	237/310 (76%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	144/158 (91.1%)
	Total DDx (2,4') Total Fraction (ND=0)	NA	NA	27/50 (54.0%)	192/310 (62%)	253/254 (99.6%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	NA
	Total DDx (4,4') Total Fraction (ND=0)	52/69 (75.4%)	139/212 (66%)	50/50 (100%)	235/310 (76%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	143/158 (90.5%)
	Toxaphene	0/69 (0%)	0/212 (0%)	0/50 (0%)	0/310 (0%)	NA	NA	NA	NA	NA	NA	NA
	trans-Nonachlor	NA	NA	NA	N/A	227/249 (91.2%)	18/18 (100%)	36/36 (100%)	63/63 (100%)	26/26 (100%)	30/30 (100%)	142/158 (89.9%)
SVOCs	1-Chloropropane	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	NA	NA	NA	NA	NA	NA	NA
	1-Methylnaphthalene	NA	NA	NA	N/A	224/254 (88.2%)	6/18 (33.3%)	11/37 (29.7%)	5/63 (7.94%)	1/26 (3.85%)	0/30 (0%)	67/157 (42.7%)
	1-Methylphenanthrene	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	144/157 (91.7%)
	1,2-Diphenylhydrazine	NA	NA	NA	N/A	0/247 (0%)	0/18 (0%)	1/36 (2.78%)	0/63 (0%)	0/26 (0%)	NA	NA
	1,2,4-Trichlorobenzene	4/69 (5.80%)	12/212 (6%)	1/49 (2.04%)	6/309 (2%)	NA	NA	NA	NA	NA	NA	1/158 (0.633%)
	1,2,4,5-Tetrachlorobenzene	NA	NA	0/49 (0%)	7/310 (2%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	1,4-Dioxane (p-Dioxane)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	1/157 (0.637%)
	1,6,7-Trimethylnapthalene	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	97/157 (61.8%)
	2-Chloronaphthalene	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	2/157 (1.27%)
	2-Chlorophenol	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	2-Methylnaphthalene	19/69 (27.5%)	81/212 (38%)	48/50 (96.0%)	263/310 (85%)	217/254 (85.4%)	10/18 (55.6%)	26/37 (70.3%)	7/63 (11.1%)	6/26 (23.1%)	2/30 (6.67%)	57/157 (36.3%)
	2-Methylphenol	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	4/18 (22.2%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	2-Nitroaniline	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	1/247 (0.405%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	2-Nitrophenol	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	2,2'-Oxybis(1-chloropropane) (bis(2-Chloroisopropyl) ether)	NA	NA	NA	N/A	1/247 (0.405%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	2/157 (1.27%)
	2,3,4,6-Tetrachlorophenol	NA	NA	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	2,4-Dichlorophenol	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	3/157 (1.91%)
	2,4-Dimethylphenol	1/69 (1.45%)	3/212 (1%)	0/49 (0%)	0/310 (0%)	2/247 (0.810%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	2,4-Dinitrophenol	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	2,4-Dinitrotoluene	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	3/157 (1.91%)
	2,4,5-Trichlorophenol	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	2,4,6-Trichlorophenol	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/308 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	2,6-Dimethylnapthalene	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	110/157 (70.1%)
	2,6-Dinitrotoluene	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	1/247 (0.405%)	0/18 (0%)	0/36 (0%)	1/63 (1.59%)	0/26 (0%)	NA	0/157 (0%)
	3-Nitroaniline	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	3,3'-Dichlorobenzidine	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	1/36 (2.78%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	4-Bromophenyl phenyl ether	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
SVOCs (cont.)	4-Chloro-3-methylphenol	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	1/247 (0.405%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	4-Chloroaniline	9/69 (13.0%)	44/212 (21%)	12/49 (24.5%)	103/310 (33%)	1/247 (0.405%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	1/157 (0.637%)
	4-Chlorophenyl phenyl ether	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	1/157 (0.637%)
	4-Methylphenol	0/69 (0%)	1/212 (0.5%)	3/49 (6.12%)	41/310 (13%)	161/249 (64.7%)	1/18 (5.56%)	2/36 (5.56%)	1/63 (1.59%)	0/26 (0%)	NA	2/157 (1.27%)
	4-Nitroaniline	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	4-Nitrophenol	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	4,6-Dinitro-2-methylphenol	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	Acenaphthene	21/69 (30.4%)	83/212 (39%)	49/50 (98.0%)	267/310 (86%)	208/254 (81.9%)	10/18 (55.6%)	34/37 (91.9%)	27/63 (42.9%)	16/26 (61.5%)	3/30 (10%)	156/157 (99.4%)
	Acenaphthylene	61/69 (88.4%)	134/212 (63%)	50/50 (100%)	251/310 (81%)	235/254 (92.5%)	11/18 (61.1%)	15/37 (40.5%)	1/63 (1.59%)	1/26 (3.85%)	8/30 (26.7%)	111/157 (70.7%)
	Acetophenone	NA	NA	7/49 (14.3%)	25/310 (8%)	80/253 (31.6%)	10/18 (55.6%)	3/36 (8.33%)	0/63 (0%)	0/26 (0%)	NA	1/157 (0.637%)
	Anthracene	63/69 (91.3%)	146/212 (69%)	49/49 (100%)	278/310 (90%)	242/254 (95.3%)	18/18 (100%)	27/37 (73%)	1/63 (1.59%)	6/26 (23.1%)	14/30 (46.7%)	98/157 (62.4%)
	Atrazine	NA	NA	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	1/63 (1.59%)	0/26 (0%)	NA	1/157 (0.637%)
	Benzaldehyde	NA	NA	17/49 (34.7%)	58/310 (19%)	3/247 (1.21%)	17/18 (94.4%)	27/36 (75.0%)	1/63 (1.59%)	4/26 (15.4%)	NA	9/157 (5.73%)
	Benzidine	NA	NA	NA	N/A	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	NA
	Benzo(a)anthracene	69/69 (100%)	162/212 (76%)	49/49 (100%)	280/310 (90%)	242/254 (95.3%)	18/18 (100%)	27/37 (73%)	0/63 (0%)	6/26 (23.1%)	30/30 (100%)	119/157 (75.8%)
	Benzo(a)pyrene	69/69 (100%)	163/212 (77%)	49/49 (100%)	253/310 (82%)	249/254 (98.0%)	18/18 (100%)	21/37 (56.8%)	0/63 (0%)	5/26 (19.2%)	30/30 (100%)	92/157 (58.6%)
	Benzo(b)fluoranthene	69/69 (100%)	162/212 (76%)	49/49 (100%)	280/310 (90%)	247/254 (97.2%)	18/18 (100%)	20/37 (54.1%)	0/63 (0%)	5/26 (19.2%)	30/30 (100%)	97/157 (61.8%)
	Benzo(e)pyrene	NA	NA	NA	N/A	252/254 (99.2%)	18/18 (100%)	20/37 (54.1%)	0/63 (0%)	4/26 (15.4%)	30/30 (100%)	121/157 (77.1%)
	Benzo(g,h,i)perylene	69/69 (100%)	157/212 (74%)	49/49 (100%)	275/310 (89%)	245/254 (96.5%)	18/18 (100%)	19/37 (51.4%)	1/63 (1.59%)	4/26 (15.4%)	30/30 (100%)	100/157 (63.7%)
	Benzo(j)fluoranthene/Benzo(k)fluoranthene	66/69 (95.7%)	156/212 (74%)	49/49 (100%)	278/310 (90%)	244/254 (96.1%)	18/18 (100%)	19/37 (51.4%)	0/63 (0%)	6/26 (23.1%)	30/30 (100%)	106/157 (67.5%)
	Benzoic acid	NA	NA	NA	N/A	17/247 (6.88%)	15/18 (83.3%)	23/36 (63.9%)	0/63 (0%)	0/26 (0%)	NA	NA
	Biphenyl (1,1-Biphenyl)	NA	NA	9/49 (18.4%)	80/310 (26%)	41/247 (16.6%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	bis(2-Chloroethoxy)methane	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	bis(2-Chloroethyl)ether	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	bis(2-Ethylhexyl)phthalate (DEHP)	68/69 (98.6%)	143/212 (67%)	48/49 (98%)	194/310 (63%)	198/253 (78.3%)	1/18 (5.56%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	5/157 (3.18%)
	Butyl benzylphthalate (BBP)	4/69 (5.80%)	7/212 (3%)	37/49 (75.5%)	81/310 (26%)	2/247 (0.810%)	0/18 (0%)	0/36 (0%)	1/63 (1.59%)	0/26 (0%)	NA	46/157 (29.3%)
	C1-Chrysenes	NA	NA	NA	N/A	240/254 (94.5%)	18/18 (100%)	9/37 (24.3%)	0/63 (0%)	0/26 (0%)	30/30 (100%)	58/157 (36.9%)
	C1-Dibenzothiophenes	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	4/157 (2.55%)
	C1-Fluoranthenes/Pyrenes	NA	NA	NA	N/A	240/254 (94.5%)	18/18 (100%)	6/37 (16.2%)	1/63 (1.59%)	1/26 (3.85%)	30/30 (100%)	124/157 (79%)
	C1-Fluorenes	NA	NA	NA	N/A	98/254 (38.6%)	0/18 (0%)	2/37 (5.41%)	1/63 (1.59%)	0/26 (0%)	2/30 (6.67%)	8/157 (5.1%)
	C1-Naphthalenes	NA	NA	NA	N/A	47/254 (18.5%)	17/18 (94.4%)	32/37 (86.5%)	13/63 (20.6%)	9/26 (34.6%)	0/30 (0%)	NA
	C1-Phenanthrenes/Anthracenes	NA	NA	NA	N/A	231/254 (90.9%)	4/18 (22.2%)	5/37 (13.5%)	0/63 (0%)	1/26 (3.85%)	7/30 (23.3%)	67/157 (42.7%)
	C2-Chrysenes	NA	NA	NA	N/A	235/254 (92.5%)	7/18 (38.9%)	1/37 (2.70%)	0/63 (0%)	0/26 (0%)	30/30 (100%)	14/157 (8.92%)
	C2-Dibenzothiophenes	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	12/157 (7.64%)
	C2-Fluoranthenes/Pyrenes	NA	NA	NA	N/A	240/254 (94.5%)	18/18 (100%)	0/37 (0%)	0/63 (0%)	0/26 (0%)	30/30 (100%)	NA
	C2-Fluorenes	NA	NA	NA	N/A	172/254 (67.7%)	0/18 (0%)	3/37 (8.11%)	1/63 (1.59%)	0/26 (0%)	4/30 (13.3%)	24/157 (15.3%)
	C2-Naphthalenes	NA	NA	NA	N/A	221/254 (87.0%)	13/18 (72.2%)	17/37 (45.9%)	21/63 (33.3%)	7/26 (26.9%)	2/30 (6.67%)	57/157 (36.3%)
	C2-Phenanthrenes/Anthracenes	NA	NA	NA	N/A	235/254 (92.5%)	7/18 (38.9%)	3/37 (8.11%)	0/63 (0%)	0/26 (0%)	20/30 (66.7%)	88/157 (56.1%)
	C3-Chrysenes	NA	NA	NA	N/A	226/254 (89%)	8/18 (44.4%)	0/37 (0%)	0/63 (0%)	0/26 (0%)	30/30 (100%)	6/157 (3.82%)
	C3-Dibenzothiophenes	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	12/157 (7.64%)
	C3-Fluoranthenes/Pyrenes	NA	NA	NA	N/A	232/254 (91.3%)	17/18 (94.4%)	0/37 (0%)	0/63 (0%)	0/26 (0%)	30/30 (100%)	NA
	C3-Fluorenes	NA	NA	NA	N/A	199/254 (78.3%)	0/18 (0%)	3/37 (8.11%)	0/63 (0%)	0/26 (0%)	3/30 (10%)	17/157 (10.8%)
	C3-Naphthalenes	NA	NA	NA	N/A	236/254 (92.9%)	4/18 (22.2%)	7/37 (18.9%)	20/63 (31.7%)	1/26 (3.85%)	1/30 (3.33%)	51/157 (32.5%)
	C3-Phenanthrenes/Anthracenes	NA	NA	NA	N/A	230/254 (90.6%)	4/18 (22.2%)	1/37 (2.70%)	0/63 (0%)	0/26 (0%)	26/30 (86.7%)	36/157 (22.9%)
	C4-Chrysenes	NA	NA	NA	N/A	168/254 (66.1%)	0/18 (0%)	0/37 (0%)	0/63 (0%)	0/26 (0%)	30/30 (100%)	1/157 (0.637%)
	C4-Dibenzothiophenes	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	5/157 (3.18%)
	C4-Naphthalenes	NA	NA	NA	N/A	215/254 (84.6%)	4/18 (22.2%)	2/37 (5.41%)	1/63 (1.59%)	0/26 (0%)	6/30 (20%)	74/157 (47.1%)
	C4-Phenanthrenes/Anthracenes	NA	NA	NA	N/A	224/254 (88.2%)	3/18 (16.7%)	1/37 (2.70%)	0/63 (0%)	0/26 (0%)	15/30 (50%)	12/157 (7.64%)
	Caprolactam	NA	NA	1/49 (2.04%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	4/157 (2.55%)
	Carbazole	18/69 (26.1%)	33/212 (16%)	35/49 (71.4%)	179/310 (58%)	62/248 (25.0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	3/157 (1.91%)
	Chrysene	69/69 (100%)	161/212 (76%)	49/49 (100%)	284/310 (92%)	252/254 (99.2%)	18/18 (100%)	27/37 (73%)	0/63 (0%)	7/26 (26.9%)	30/30 (100%)	144/157 (91.7%)
	Di-n-butylphthalate (DBP)	10/69 (14.5%)	24/212 (11%)	11/49 (22.4%)	31/310 (10%)	1/247 (0.405%)	0/18 (0%)	0/36 (0%)	1/63 (1.59%)	0/26 (0%)	NA	6/157 (3.82%)
	Di-n-octyl phthalate (DnOP)	7/69 (10.1%)	46/212 (22%)	13/39 (33.3%)	91/259 (35%)	1/247 (0.405%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	1/157 (0.637%)
	Dibenz(a,h)anthracene	57/69 (82.6%)	121/212 (57%)	38/49 (77.6%)	210/310 (68%)	240/254 (94.5%)	17/18 (94.4%)	8/37 (21.6%)	0/63 (0%)	0/26 (0%)	26/30 (86.7%)	99/157 (63.1%)
	Dibenzofuran	12/69 (17.4%)	44/212 (21%)	26/49 (53.1%)	177/310 (57%)	95/248 (38.3%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	1/157 (0.637%)

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
SVOCs (cont.)	Dibenzothiophene	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	113/157 (72%)
	Diethyl phthalate	0/69 (0%)	0/212 (0%)	0/49 (0%)	1/310 (0.3%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	21/157 (13.4%)
	Dimethyl phthalate	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	Fluoranthene	69/69 (100%)	162/212 (76%)	49/49 (100%)	296/310 (95%)	244/254 (96.1%)	18/18 (100%)	33/37 (89.2%)	13/63 (20.6%)	13/26 (50.0%)	30/30 (100%)	147/157 (93.6%)
	Fluorene	32/69 (46.4%)	103/212 (49%)	49/50 (98.0%)	269/310 (87%)	178/254 (70.1%)	4/18 (22.2%)	7/37 (18.9%)	10/63 (15.9%)	7/26 (26.9%)	2/30 (6.67%)	71/157 (45.2%)
	Hexachlorobutadiene	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	2/157 (1.27%)
	Hexachlorocyclopentadiene	0/69 (0%)	0/206 (0%)	0/10 (0%)	0/62 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	Hexachloroethane	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	Indeno(1,2,3-cd)pyrene	66/69 (95.7%)	155/212 (73%)	49/49 (100%)	275/310 (89%)	251/254 (98.8%)	17/18 (94.4%)	17/37 (45.9%)	1/63 (1.59%)	2/26 (7.69%)	30/30 (100%)	114/157 (72.6%)
	Isophorone	0/69 (0%)	0/212 (0%)	0/49 (0%)	1/310 (0.3%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	1/157 (0.637%)
	N-Nitrosodi-n-propylamine	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	N-Nitrosodiphenylamine	2/69 (2.90%)	11/212 (5%)	4/49 (8.16%)	78/310 (25%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	Naphthalene	39/69 (56.5%)	113/212 (53%)	50/50 (100%)	248/310 (80%)	224/254 (88.2%)	16/18 (88.9%)	16/37 (43.2%)	16/63 (25.4%)	5/26 (19.2%)	1/30 (3.33%)	68/157 (43.3%)
	Nitrobenzene	0/69 (0%)	0/212 (0%)	0/49 (0%)	0/310 (0%)	1/247 (0.405%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	Pentachlorophenol	0/69 (0%)	0/212 (0%)	0/50 (0%)	4/309 (1%)	0/247 (0%)	0/18 (0%)	0/36 (0%)	0/63 (0%)	0/26 (0%)	NA	0/157 (0%)
	Perylene	NA	NA	NA	N/A	250/254 (98.4%)	18/18 (100%)	19/37 (51.4%)	0/63 (0%)	3/26 (11.5%)	17/30 (56.7%)	109/157 (69.4%)
	Phenanthrene	65/69 (94.2%)	151/212 (71%)	49/49 (100%)	288/310 (93%)	236/254 (92.9%)	18/18 (100%)	27/37 (73%)	22/63 (34.9%)	10/26 (38.5%)	2/30 (6.67%)	76/157 (48.4%)
	Phenol	3/69 (4.35%)	17/212 (8%)	3/49 (6.12%)	10/310 (3%)	42/247 (17.0%)	3/18 (16.7%)	7/36 (19.4%)	6/63 (9.52%)	1/26 (3.85%)	NA	4/157 (2.55%)
	Pyrene	69/69 (100%)	165/212 (78%)	49/49 (100%)	268/309 (87%)	250/254 (98.4%)	18/18 (100%)	34/37 (91.9%)	3/63 (4.76%)	10/26 (38.5%)	30/30 (100%)	157/157 (100%)
	Pyridine	NA	NA	NA	N/A	0/247 (0%)	0/18 (0%)	8/36 (22.2%)	0/63 (0%)	0/26 (0%)	NA	NA
	Total Alkylated PAHs	NA	NA	NA	N/A	245/254 (96.5%)	NA	NA	NA	NA	NA	NA
	Total HMW PAHs	69/69 (100%)	166/212 (78%)	49/49 (100%)	297/310 (96%)	252/254 (99.2%)	18/18 (100%)	34/37 (91.9%)	14/63 (22.2%)	16/26 (61.5%)	30/30 (100%)	157/157 (100%)
	Total LMW PAHs	65/69 (94.2%)	157/212 (74%)	50/50 (100%)	292/310 (94%)	245/254 (96.5%)	18/18 (100%)	35/37 (94.6%)	38/63 (60.3%)	17/26 (65.4%)	15/30 (50%)	157/157 (100%)
	Total PAH	69/69 (100%)	169/212 (80%)	50/50 (100%)	297/310 (96%)	252/254 (99.2%)	18/18 (100%)	35/37 (94.6%)	38/63 (60.3%)	20/26 (76.9%)	30/30 (100%)	157/157 (100%)
Petroleum Products	Eicosane	NA	NA	NA	N/A	84/254 (33.1%)	NA	NA	NA	NA	NA	NA
	Heneicosane	NA	NA	NA	N/A	128/254 (50.4%)	NA	NA	NA	NA	NA	NA
	Heptacosane	NA	NA	NA	N/A	78/254 (30.7%)	NA	NA	NA	NA	NA	NA
	Heptadecane	NA	NA	NA	N/A	181/253 (71.5%)	NA	NA	NA	NA	NA	NA
	Hexatriacontane	NA	NA	NA	N/A	91/254 (35.8%)	NA	NA	NA	NA	NA	NA
	N-Decane	NA	NA	NA	N/A	45/254 (17.7%)	NA	NA	NA	NA	NA	NA
	N-Docosane	NA	NA	NA	N/A	214/254 (84.3%)	NA	NA	NA	NA	NA	NA
	N-Dodecane	NA	NA	NA	N/A	112/254 (44.1%)	NA	NA	NA	NA	NA	NA
	N-Dotriacontane	NA	NA	NA	N/A	204/254 (80.3%)	NA	NA	NA	NA	NA	NA
	N-Hentriacontane	NA	NA	NA	N/A	138/254 (54.3%)	NA	NA	NA	NA	NA	NA
	N-Heptatriacontane	NA	NA	NA	N/A	133/254 (52.4%)	NA	NA	NA	NA	NA	NA
	N-Hexacosane	NA	NA	NA	N/A	97/254 (38.2%)	NA	NA	NA	NA	NA	NA
	N-Hexadecane	NA	NA	NA	N/A	59/254 (23.2%)	NA	NA	NA	NA	NA	NA
	N-Nonacosane	NA	NA	NA	N/A	230/254 (90.6%)	NA	NA	NA	NA	NA	NA
	N-Nonadecane	NA	NA	NA	N/A	70/254 (27.6%)	NA	NA	NA	NA	NA	NA
	N-Octatriacontane	NA	NA	NA	N/A	47/254 (18.5%)	NA	NA	NA	NA	NA	NA
	N-Tetracontane	NA	NA	NA	N/A	155/254 (61.0%)	NA	NA	NA	NA	NA	NA
	N-Tetracosane	NA	NA	NA	N/A	177/254 (69.7%)	NA	NA	NA	NA	NA	NA
	N-Tetradecane	NA	NA	NA	N/A	126/254 (49.6%)	NA	NA	NA	NA	NA	NA
	N-Tetratriacontane	NA	NA	NA	N/A	59/254 (23.2%)	NA	NA	NA	NA	NA	NA
	N-Triacontane	NA	NA	NA	N/A	85/254 (33.5%)	NA	NA	NA	NA	NA	NA
	N-Tridecane	NA	NA	NA	N/A	61/254 (24.0%)	NA	NA	NA	NA	NA	NA
	N-Tritriacontane	NA	NA	NA	N/A	89/254 (35.0%)	NA	NA	NA	NA	NA	NA
	N-Undecane	NA	NA	NA	N/A	15/254 (5.91%)	NA	NA	NA	NA	NA	NA
	Nonane	NA	NA	NA	N/A	30/254 (11.8%)	NA	NA	NA	NA	NA	NA
	Nonatriacontane (C39)	NA	NA	NA	N/A	23/254 (9.06%)	NA	NA	NA	NA	NA	NA
	Octacosane	NA	NA	NA	N/A	247/254 (97.2%)	NA	NA	NA	NA	NA	NA
	Octadecane	NA	NA	NA	N/A	156/254 (61.4%)	NA	NA	NA	NA	NA	NA
	Pentacosane	NA	NA	NA	N/A	211/254 (83.1%)	NA	NA	NA	NA	NA	NA
	Pentadecane	NA	NA	NA	N/A	131/254 (51.6%)	NA	NA	NA	NA	NA	NA
	Pentatriacontane	NA	NA	NA	N/A	205/254 (80.7%)	NA	NA	NA	NA	NA	NA

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
Petroleum Products (cont.)	PHC as Gasoline	NA	NA	NA	N/A	75/254 (29.5%)	NA	NA	NA	NA	NA	NA
	Phytane	NA	NA	NA	N/A	165/254 (65%)	NA	NA	NA	NA	NA	NA
	Pristane	NA	NA	NA	N/A	114/254 (44.9%)	NA	NA	NA	NA	NA	NA
	Total Petroleum Hydrocarbons	69/69 (100%)	202/210 (96%)	50/50 (100%)	270/310 (87%)	246/254 (96.9%)	NA	NA	NA	NA	NA	NA
	Tricosane	NA	NA	NA	N/A	228/254 (89.8%)	NA	NA	NA	NA	NA	NA
Herbicides	2,4-DB	0/69 (0%)	11/210 (5%)	20/26 (76.9%)	83/146 (57%)	5/253 (1.98%)	NA	NA	NA	NA	NA	NA
	2,4-Dichlorophenoxyacetic acid (2,4-D)	0/69 (0%)	0/210 (0%)	25/48 (52.1%)	175/301 (58%)	10/252 (3.97%)	NA	NA	NA	NA	NA	NA
	2,4,5-T	4/69 (5.80%)	8/210 (4%)	26/47 (55.3%)	112/284 (39%)	23/249 (9.24%)	NA	NA	NA	NA	NA	NA
	2,4,5-TP (Silvex)	1/69 (1.45%)	7/210 (3%)	29/30 (96.7%)	144/206 (70%)	5/251 (1.99%)	NA	NA	NA	NA	NA	NA
Butyltins	Dibutyltin	55/69 (79.7%)	111/210 (53%)	NA	N/A	13/61 (21.3%)	4/18 (22.2%)	5/36 (13.9%)	0/54 (0%)	0/26 (0%)	NA	2/158 (1.27%)
	Monobutyltin	0/67 (0%)	3/194 (2%)	NA	N/A	0/61 (0%)	0/18 (0%)	0/36 (0%)	0/54 (0%)	0/26 (0%)	NA	2/158 (1.27%)
	Tetrabutyltin	3/69 (4.35%)	27/210 (13%)	NA	N/A	1/61 (1.64%)	0/18 (0%)	0/36 (0%)	0/54 (0%)	0/26 (0%)	NA	0/158 (0%)
	Tributyltin	54/69 (78.3%)	105/210 (50%)	NA	N/A	12/61 (19.7%)	18/18 (100%)	0/36 (0%)	33/54 (61.1%)	5/26 (19.2%)	NA	0/77 (0%)
	Tributyltin cation	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/81 (0%)
PBDE	(BDE 1) 2-BDE	NA	NA	12/16 (75.0%)	34/70 (49%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 10) 2,6-DiBDE	NA	NA	3/16 (18.8%)	0/70 (0%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 100) 2,2',4,4',6-PeBDE	NA	NA	11/16 (68.8%)	21/70 (30%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 105) 2,3,3',4,4'-PeBDE	NA	NA	0/16 (0%)	0/70 (0%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 116) 2,3,4,5,6-PeBDE	NA	NA	0/16 (0%)	2/70 (3%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 118) 2,3',4,4',5-PeBDE	NA	NA	1/16 (6.25%)	1/70 (1%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 119) 2,3',4,4',6-PeBDE	NA	NA	2/16 (12.5%)	3/70 (4%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 12/13) 3,4-DiBDE/3,4'-DiBDE	NA	NA	9/16 (56.2%)	20/70 (29%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 126) 3,3',4,4',5-PeBDE	NA	NA	0/16 (0%)	0/70 (0%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 138) 2,2',3,4,4',5'-HxBDE	NA	NA	2/16 (12.5%)	6/70 (9%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 139) 2,2',3,4,4',6-HxBDE	NA	NA	3/16 (18.8%)	3/70 (4%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 140) 2,2',3,4,4',6'-HxBDE	NA	NA	1/16 (6.25%)	2/70 (3%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 15) 4,4'-DiBDE	NA	NA	16/16 (100%)	48/70 (69%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 153) 2,2',4,4',5,5'-HxBDE	NA	NA	10/16 (62.5%)	22/70 (31%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 154) 2,2',4,4',5',6-HxBDE	NA	NA	10/16 (62.5%)	25/70 (36%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 155) 2,2',4,4',6,6'-HxBDE	NA	NA	7/16 (43.8%)	7/70 (10%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 156/169) 2,3,3',4,4',5-HxBDE/3,3',4,4',5,5'-HxBDE	NA	NA	0/16 (0%)	0/70 (0%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 166) 2,3,4,4',5,6-HxBDE	NA	NA	0/16 (0%)	0/70 (0%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 17) 2,2',4-TriBDE	NA	NA	15/16 (93.8%)	20/70 (29%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 176/183) 2,2',3,3',4,6,6'-HpBDE/2,2',3,4,4',5',6-HpBDE	NA	NA	13/16 (81.2%)	33/70 (47%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 179) 2,2'3,3',5,6,6'-HpBDE	NA	NA	3/16 (18.8%)	19/70 (27%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 181) 2,2',3,4,4',5,6-HpBDE	NA	NA	0/16 (0%)	1/70 (1%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 188) 2,2',3,4',5,6,6'-HpBDE	NA	NA	1/16 (6.25%)	3/70 (4%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 190) 2,3,3',4,4',5,6-HpBDE	NA	NA	1/16 (6.25%)	7/70 (10%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 191) 2,3,3',4,4',5',6-HpBDE	NA	NA	2/16 (12.5%)	13/70 (19%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 196) 2,2',3,3',4,4',5,6'-OcBDE	NA	NA	11/16 (68.8%)	25/70 (36%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 197) 2,2',3,3',4,4',6,6'-OcBDE	NA	NA	11/16 (68.8%)	25/70 (36%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 2) 3-BDE	NA	NA	11/16 (68.8%)	26/70 (37%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 202) 2,2'3,3',5,5'6,6'-OcBDE	NA	NA	1/16 (6.25%)	13/70 (19%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 203) 2,2',3,4,4',5,5',6-OcBDE	NA	NA	6/16 (37.5%)	24/70 (34%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 205) 2,3,3',4,4',5,5',6-OcBDE	NA	NA	0/16 (0%)	0/70 (0%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 207) 2,2',3,3',4,4',5,6,6'-NoBDE	NA	NA	9/15 (60.0%)	25/63 (40%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 208) 2,2',3,3',4,5,5',6,6'-NoBDE3	NA	NA	7/15 (46.7%)	17/63 (27%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 209) DeBDE	NA	NA	14/15 (93.3%)	29/57 (51%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 25) 2,3',4-TriBDE	NA	NA	3/16 (18.8%)	13/70 (19%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 28/33) 2,4,4'-TrBDE/2',3,4-TrBDE	NA	NA	15/16 (93.8%)	43/70 (61%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 3) 4-BDE	NA	NA	16/16 (100%)	53/70 (76%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 30) 2,4,6-TrBDE	NA	NA	0/16 (0%)	1/70 (1%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 32) 2,4',6-TrBDE	NA	NA	7/16 (43.8%)	21/70 (30%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 35) 3,3',4-TrBDE	NA	NA	1/16 (6.25%)	1/70 (1%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 37) 3,4,4'-TrBDE	NA	NA	0/16 (0%)	0/70 (0%)	NA	NA	NA	NA	NA	NA	NA

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
PBDE	(BDE 47) 2,2',4,4'-TeBDE	NA	NA	11/16 (68.8%)	13/70 (19%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 49) 2,2',4,5'-TeBDE	NA	NA	15/16 (93.8%)	27/70 (39%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 66) 2,3',4,4'-TeBDE	NA	NA	8/16 (50.0%)	8/70 (11%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 7) 2,4-DiBDE	NA	NA	15/16 (93.8%)	27/70 (39%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 71) 2,3',4',6-TeBDE	NA	NA	8/16 (50.0%)	9/70 (13%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 75) 2,4,4',6-TeBDE	NA	NA	3/16 (18.8%)	4/70 (6%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 77) 3,3',4,4'-TeBDE	NA	NA	1/16 (6.25%)	0/70 (0%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 8/11)2,4'-DiBDE/3,3'-DiBDE	NA	NA	15/16 (93.8%)	50/70 (71%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 85) 2,2',3,4,4'-PeBDE	NA	NA	6/16 (37.5%)	4/70 (6%)	NA	NA	NA	NA	NA	NA	NA
	(BDE 99) 2,2',4,4',5-PeBDE	NA	NA	11/16 (68.8%)	15/70 (21%)	NA	NA	NA	NA	NA	NA	NA
PCNs	(PCN 12)	NA	NA	14/14 (100%)	69/77 (90%)	NA	NA	NA	NA	NA	NA	NA
	(PCN 66/67) 1,2,3,4,6,7-Hexapolychlorinated naphthalene/1,2,3,5,6,7-Hexapolychlorinated naphthalene	NA	NA	14/14 (100%)	64/77 (83%)	NA	NA	NA	NA	NA	NA	NA
	(PCN 71/72) 1,2,4,5,6,8-Hexapolychlorinated naphthalene/1,2,4,5,7,8-Hexapolychlorinated naphthalene	NA	NA	14/14 (100%)	63/77 (82%)	NA	NA	NA	NA	NA	NA	NA
	(PCN 74) 1,2,3,4,5,6,8-Heptapolychlorinated naphthalene	NA	NA	14/14 (100%)	65/77 (84%)	NA	NA	NA	NA	NA	NA	NA
	1-MoCN	NA	NA	14/14 (100%)	75/77 (97%)	NA	NA	NA	NA	NA	NA	NA
	1,2-DiCN	NA	NA	13/14 (92.9%)	63/77 (82%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3-TriCN	NA	NA	6/13 (46.2%)	47/77 (61%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,4-TeCN	NA	NA	13/14 (92.9%)	62/77 (81%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,4,5-PeCN	NA	NA	11/14 (78.6%)	53/77 (69%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,4,5,6,7-Heptachloronaphthalene	NA	NA	13/14 (92.9%)	64/77 (83%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,4,5,6,7,8-OcCN	NA	NA	10/14 (71.4%)	62/77 (81%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,4,6-PeCN	NA	NA	14/14 (100%)	62/77 (81%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,5-Tetrachloronaphthalene/1,2,5,6-Tetrachloronaphthalene	NA	NA	13/14 (92.9%)	61/77 (79%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,5,6,8-HxCN	NA	NA	14/14 (100%)	62/77 (81%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,5,7-PeCN	NA	NA	14/14 (100%)	63/77 (82%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,5,7,8-Hexachloronaphthalene	NA	NA	14/14 (100%)	64/77 (83%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,5,8-PeCN	NA	NA	13/14 (92.9%)	55/77 (71%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,6,7-PeCN	NA	NA	8/13 (61.5%)	43/77 (56%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,6,7,8-HxCN	NA	NA	3/13 (23.1%)	29/76 (38%)	NA	NA	NA	NA	NA	NA	NA
	1,2,3,8-TeCN	NA	NA	14/14 (100%)	65/77 (84%)	NA	NA	NA	NA	NA	NA	NA
	1,3,5,7-TeCN	NA	NA	14/14 (100%)	64/77 (83%)	NA	NA	NA	NA	NA	NA	NA
	1,4-DiCN	NA	NA	13/14 (92.9%)	70/77 (91%)	NA	NA	NA	NA	NA	NA	NA
	1,4,5,8-TeCN	NA	NA	4/13 (30.8%)	27/76 (36%)	NA	NA	NA	NA	NA	NA	NA
	1,5-DiCN	NA	NA	14/14 (100%)	69/77 (90%)	NA	NA	NA	NA	NA	NA	NA
	1,8-DiCN	NA	NA	10/14 (71.4%)	43/77 (56%)	NA	NA	NA	NA	NA	NA	NA
	2-MoCN	NA	NA	14/14 (100%)	72/77 (94%)	NA	NA	NA	NA	NA	NA	NA
	2,3-DiCN	NA	NA	9/14 (64.3%)	44/77 (57%)	NA	NA	NA	NA	NA	NA	NA
	2,3,6,7-TeCN	NA	NA	3/14 (21.4%)	28/76 (37%)	NA	NA	NA	NA	NA	NA	NA
VOCs	1,1-Dichloroethane	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	1,1-Dichloroethene	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	1,1,1-Trichloroethane	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	13/158 (8.23%)
	1,1,2-Trichloroethane	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	1,1,2,2-Tetrachloroethane	0/68 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	1,2-Dibromo-3-chloropropane	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	1,2-Dibromoethane	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	1,2-Dichloroethane	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	1,2-Dichloroethene (total)	0/69 (0%)	1/212 (0.5%)	NA	N/A	NA	NA	NA	NA	NA	NA	NA
	1,2-Dichloropropane	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	1,2,3-Trichlorobenzene	NA	NA	1/49 (2.04%)	0/309 (0%)	NA	NA	NA	NA	NA	NA	0/158 (0%)
	1,2,4-Trichlorobenzene	4/69 (6%)	12/212 (6%)	1/49 (2%)	6/309 (2%)	2/254 (0.8%)	NA	NA	NA	NA	NA	NA
	1,2-Dichlorobenzene	0/69 (0%)	3/212 (1%)	0/49 (0%)	38/309 (12%)	0/254 (0%)	NA	NA	NA	NA	NA	0/158 (0%)
	1,3-Dichlorobenzene	1/69 (1%)	4/212 (2%)	0/49 (0%)	40/309 (13%)	0/254 (0%)	NA	NA	NA	NA	NA	0/158 (0%)
	1,4-Dichlorobenzene	14/69 (20%)	60/212 (28%)	2/49 (4%)	72/310 (23%)	3/254 (1%)	NA	NA	NA	NA	NA	1/158 (0.6%)

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
VOCs (cont.)	2-Butanone (Methyl ethyl ketone) (MEK)	16/34 (47.1%)	60/112 (54%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	2-Hexanone	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	4-Methyl-2-pentanone (Methyl isobutyl ketone) (MIBK)	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Acetone	68/68 (100%)	204/205 (100%)	NA	N/A	NA	NA	NA	NA	NA	NA	1/158 (0.633%)
	Benzene	6/69 (8.70%)	69/212 (33%)	NA	N/A	NA	NA	NA	NA	NA	NA	2/158 (1.27%)
	Bromochloromethane	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Bromodichloromethane	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Bromoform	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	1/158 (0.633%)
	Bromomethane (Methyl bromide)	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	1/158 (0.633%)
	Carbon disulfide	45/69 (65.2%)	138/212 (65%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Carbon tetrachloride	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Chlorobenzene	24/69 (34.8%)	34/212 (16%)	0/49 (0%)	46/310 (15%)	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Chloroethane	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Chloroform (Trichloromethane)	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	56/158 (35.4%)
	Chloromethane (Methyl chloride)	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	40/158 (25.3%)
	cis-1,2-Dichloroethylene	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	cis-1,3-Dichloropropene	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Cyclohexane	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Dibromochloromethane	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Dichlorodifluoromethane (Freon 12)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Ethylbenzene	2/69 (2.90%)	15/212 (7%)	NA	N/A	NA	NA	NA	NA	NA	NA	6/158 (3.8%)
	Isopropylbenzene (Cumene)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	m,p-Xylenes	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	18/158 (11.4%)
	Methyl acetate	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Methylcyclohexane	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Methylene chloride	0/69 (0%)	1/212 (0.5%)	NA	N/A	NA	NA	NA	NA	NA	NA	4/158 (2.53%)
	o-Xylene (1,2-Dimethylbenzene)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	3/158 (1.9%)
	Styrene	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	tert-Butyl methyl ether (MTBE)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	1/158 (0.633%)
	Tetrachloroethene	1/69 (1.45%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	97/158 (61.4%)
	Toluene	5/69 (7.25%)	41/212 (19%)	NA	N/A	NA	NA	NA	NA	NA	NA	8/158 (5.06%)
	trans-1,2-Dichloroethene	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	trans-1,3-Dichloropropene	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Trichloroethene	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	73/158 (46.2%)
	Trichlorofluoromethane (Freon 11)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Trichlorotrifluoroethane	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Vinyl chloride	0/69 (0%)	0/212 (0%)	NA	N/A	NA	NA	NA	NA	NA	NA	0/158 (0%)
	Xylenes (total)	3/69 (4.35%)	58/212 (27%)	NA	N/A	NA	NA	NA	NA	NA	NA	NA
Metals	Aluminum	69/69 (100%)	211/211 (100%)	49/50 (98.0%)	310/310 (100%)	254/254 (100%)	17/18 (94.4%)	36/37 (97.3%)	27/63 (42.9%)	24/26 (92.3%)	4/29 (13.8%)	158/158 (100%)
	Antimony	17/66 (25.8%)	52/201 (26%)	1/49 (2.04%)	5/294 (2%)	230/254 (90.6%)	16/18 (88.9%)	1/37 (2.70%)	0/63 (0%)	0/26 (0%)	1/29 (3.45%)	32/158 (20.3%)
	Arsenic	69/69 (100%)	206/211 (98%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	9/29 (31%)	158/158 (100%)
	Barium	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	49/63 (77.8%)	26/26 (100%)	29/29 (100%)	158/158 (100%)
	Beryllium	69/69 (100%)	211/211 (100%)	45/50 (90.0%)	285/310 (92%)	254/254 (100%)	17/18 (94.4%)	1/37 (2.70%)	0/63 (0%)	0/26 (0%)	0/29 (0%)	43/158 (27.2%)
	Cadmium	64/69 (92.8%)	169/211 (80%)	48/50 (96.0%)	302/310 (97%)	252/254 (99.2%)	17/18 (94.4%)	37/37 (100%)	1/63 (1.59%)	0/26 (0%)	0/29 (0%)	274/274 (100%)
	Calcium	64/64 (100%)	197/197 (100%)	50/50 (100%)	310/310 (100%)	252/252 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/29 (100%)	158/158 (100%)
	Chromium	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	17/18 (94.4%)	37/37 (100%)	38/63 (60.3%)	21/26 (80.8%)	26/29 (89.7%)	158/158 (100%)
	Chromium VI (hexavalent)	NA	NA	NA	N/A	5/55 (9.09%)	NA	NA	NA	NA	NA	NA
	Cobalt	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	17/18 (94.4%)	37/37 (100%)	30/63 (47.6%)	22/26 (84.6%)	0/29 (0%)	158/158 (100%)
	Copper	67/67 (100%)	208/208 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	62/63 (98.4%)	25/26 (96.2%)	5/29 (17.2%)	274/274 (100%)
	Iron	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	28/29 (96.6%)	158/158 (100%)
	Lead	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	17/18 (94.4%)	37/37 (100%)	58/63 (92.1%)	25/26 (96.2%)	6/29 (20.7%)	274/274 (100%)
	Magnesium	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/29 (100%)	158/158 (100%)
	Manganese	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/29 (100%)	158/158 (100%)
	Mercury	69/69 (100%)	205/211 (97%)	50/50 (100%)	266/310 (86%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/30 (96.7%)	274/274 (100%)
	Methyl mercury	NA	NA	NA	N/A	253/254 (99.6%)	18/18 (100%)	34/34 (100%)	62/62 (100%)	26/26 (100%)	30/30 (100%)	142/158 (89.9%)

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
Metals (cont.)	Nickel	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	17/18 (94.4%)	36/37 (97.3%)	19/63 (30.2%)	7/26 (26.9%)	0/29 (0%)	158/158 (100%)
	Potassium	60/60 (100%)	183/183 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/29 (100%)	158/158 (100%)
	Selenium	32/66 (48.5%)	91/197 (46%)	45/50 (90.0%)	264/310 (85%)	250/253 (98.8%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	10/29 (34.5%)	25/158 (15.8%)
	Silver	67/69 (97.1%)	171/211 (81%)	39/39 (100%)	255/274 (93%)	253/254 (99.6%)	18/18 (100%)	37/37 (100%)	44/63 (69.8%)	18/26 (69.2%)	0/29 (0%)	139/158 (88%)
	Sodium	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	29/29 (100%)	158/158 (100%)
	Thallium	18/65 (27.7%)	54/190 (28%)	40/50 (80.0%)	249/310 (80%)	250/254 (98.4%)	0/18 (0%)	0/37 (0%)	0/63 (0%)	0/26 (0%)	0/29 (0%)	77/158 (48.7%)
	Titanium	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	31/37 (83.8%)	28/63 (44.4%)	20/26 (76.9%)	20/28 (71.4%)	124/158 (78.5%)
	Vanadium	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	20/63 (31.7%)	26/26 (100%)	24/29 (82.8%)	137/158 (86.7%)
	Zinc	69/69 (100%)	211/211 (100%)	50/50 (100%)	310/310 (100%)	254/254 (100%)	18/18 (100%)	37/37 (100%)	63/63 (100%)	26/26 (100%)	3/29 (10.3%)	158/158 (100%)
	Aluminum (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	97/158 (61.4%)
	Antimony (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	13/158 (8.23%)
	Arsenic (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Barium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Beryllium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	36/158 (22.8%)
	Cadmium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	273/274 (99.6%)
	Calcium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Chromium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	156/158 (98.7%)
	Chromium VI (hexavalent) (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	54/157 (34.4%)
	Cobalt (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Copper (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	274/274 (100%)
	Iron (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	142/158 (89.9%)
	Lead (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	274/274 (100%)
	Magnesium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Manganese (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Mercury (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	248/274 (90.5%)
	Methyl mercury (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	49/158 (31%)
	Nickel (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Potassium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Selenium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	12/158 (7.59%)
	Silver (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	93/158 (58.9%)
	Sodium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Thallium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	62/158 (39.2%)
	Titanium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	45/158 (28.5%)
	Vanadium (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	131/158 (82.9%)
	Zinc (dissolved)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
AVS/SEM	Acid volatile sulfide	NA	NA	NA	NA	57/59 (97%)	NA	NA	NA	NA	NA	NA
	Cadmium	NA	NA	NA	NA	61/61 (100%)	NA	NA	NA	NA	NA	NA
	Copper	NA	NA	NA	NA	60/61 (98%)	NA	NA	NA	NA	NA	NA
	Lead	NA	NA	NA	NA	61/61 (100%)	NA	NA	NA	NA	NA	NA
	Mercury	NA	NA	NA	NA	5/58 (9%)	NA	NA	NA	NA	NA	NA
	Nickel	NA	NA	NA	NA	61/61 (100%)	NA	NA	NA	NA	NA	NA
	Zinc	NA	NA	NA	NA	61/61 (100%)	NA	NA	NA	NA	NA	NA
Radiochemistry	Beryllium-7	60/69 (87%)	NA	48/49 (98%)	N/A	NA	NA	NA	NA	NA	NA	NA
	Cesium-137	30/45 (66.7%)	165/344 (48%)	27/29 (93.1%)	202/371 (54%)	NA	NA	NA	NA	NA	NA	NA
	Lead-210	50/50 (100%)	365/365 (100%)	29/29 (100%)	371/371 (100%)	NA	NA	NA	NA	NA	NA	NA
Miscellaneous	Ammonia	NA	NA	NA	N/A	16/58 (28%)	NA	NA	NA	NA	29/29 (100%)	201/201 (100%)
	Sulfide	NA	NA	NA	N/A	NA	NA	NA	NA	NA	30/30 (100%)	4/274 (1.46%)
	Total organic carbon (TOC)	69/69 (100%)	209/210 (100%)	50/50 (100%)	307/310 (99%)	252/254 (99%)	NA	NA	NA	NA	NA	274/274 (100%)
	Alkalinity, Total (As Caco3)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	273/274 (99.6%)
	Chloride (As Cl)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	274/274 (100%)
	Chlorophyll-A	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	274/274 (100%)
	Cyanide	3/66 (5%)	37/204 (18%)	30/50 (60%)	224/310 (72%)	14/253 (6%)	NA	NA	NA	NA	NA	4/158 (2.53%)
	Dissolved Organic Carbon	NA	NA	NA	N/A	NA	NA	NA	NA	NA	29/29 (100%)	274/274 (100%)
	Hardness (As CaCO3)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Nitrogen	NA	NA	NA	N/A	53/60 (88%)	NA	NA	NA	NA	NA	NA

Table 4-1
Analytical Sample Summary for Phase I, Phase II, Phase III, Surface Water, and Porewater

Analyte Group	Analyte	Frequency of Detection										
		Phase I		Phase II		Phase III[a]						
		Surface Sediment	Subsurface Sediment	Surface Sediment	Subsurface Sediment	Surface Sediment	Softshell Clam	Blue Crab[b]	Sport Fish[c]	Forage Fish	Porewater	Surface Water[d]
Miscellaneous	Particulate Organic Carbon	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	173/238 (72.7%)
	Phosphorus	NA	NA	NA	N/A	61/61 (100%)	NA	NA	NA	NA	NA	NA
	Phosphorus, Dissolved (as P)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	158/158 (100%)
	Salinity	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	273/273 (100%)
	Sulfate (As So4)	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	274/274 (100%)
	Sulfide	NA	NA	NA	N/A	60/60 (100%)	NA	NA	NA	NA	NA	NA
	Total Dissolved Solids	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	274/274 (100%)
	Total Kjeldahl Nitrogen	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	201/201 (100%)
	Total Suspended Solids	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	274/274 (100%)

Notes:
[a]Phase III surface sediment data includes sediment collected during the crab/clam (n=18), SQT (n=43) and Phase III (n=193) sediment sampling programs. The detection frequencies reported for biota include only whole body samples.
[b]Whole body crab concentrations were estimated using a weighted average of the concentrations of the individual tissue types (i.e., muscle, hepatopancreas, and carcass) in each sample as described in the BERA. (GSH 2020)
[c]Whole body sportfish include the following species: American eel, summer flounder, winter flounder and white perch.
[d]The surface water sampling program was conducted by the Cooperating Parties Group (AECOM 2010, 2011). Surface water data were retrieved from http://ourpassaic.org.
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Acronyms and Abbreviations:
% = percent
AVS/SEM = acid volatile sulfide/simultaneously extracted metals
BDE = brominated diphenyl ether
BHC = hexachlorocyclohexane
DBE = decabromodiphenyl ether
DDD = dichlorodiphenyldichloroethane
DDE = dichlorodiphenyldichloroethylene
DDT = dichlorodiphenyltrichloroethane
HMW = high molecular weight
LMW = low molecular weight
NA = not analyzed
ND = Non Detect
(ND=0) = Only detected compounds were included in the summation
PAH = polycyclic aromatic hydrocarbon
PBDE = polybrominated diphenyl ether
PCB = polychlorinated biphenyl
PCN = polychlorinated naphthalene
SQT = sediment quality triad
SVOC = semi-volatile organic compound
TEQ = toxic equivalency
Total DDx = sum of DDE, DDD, and DDT
VOC = volatile organic compound
WHO = World Health Organization

References:
AECOM. 2011. Quality Assurance Project Plan/Field Sampling Plan Addendum. Remedial Investigation Water Column Monitoring/Small Volume Chemical Data Collection. Lower Passaic River Restoration Project. Revision 2. August, 2011.
AECOM. 2010. Remedial Investigation Water Column Monitoring/Physical Data Collection for the Lower Passaic River, Newark Bay and Wet weather monitoring: Lower Passaic River Restoration Project. Quality Assurance Project Plan. Revision 5.
GSH. 2020. Final Baseline Ecological Risk Assessment. Newark Bay Study Area. August.

Table 4-3
Summary of Sediment Contaminants Retained for Focused Nature and Extent

Phase	Analyte Group	Analyte	Units	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	641	564	88%	261	771	30.4	36.2	0.0561	8,840	0.0478	4.68
Phase III	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	254	254	100%	87.1	182	11.4	42.8	0.12	1,710	--	--
Phase I/II	PCBs	Total PCBs (9 Aroclors)	µg/kg	641	477	74%	1,330	2,330	92.2	450	8.2	18,000	35	1100
Phase III	PCBs	Total PCBs (9 Aroclors)	µg/kg	254	239	94%	239	317	19.9	140	6.4	2,500	21	46
Phase I/II	PCBs	Total PCBs congener (209 specified)	ng/kg	641	635	99%	1,560,000	2,740,000	108,000	538,000	1	32,100,000	2.45	16.1
Phase III	PCBs	Total PCBs congener (209 specified)	ng/kg	254	254	100%	480,000	691,000	43,400	278,000	2,480	5,030,000	--	--
Phase I/II	Pesticides	alpha-BHC	pg/g	636	130	20%	6,480	11,500	457	<4200	250	28,000	1,800	230,000
Phase III	Pesticides	alpha-BHC	pg/g	252	172	68%	118	174	11	63	6	1,260	38	939
Phase I/II	Pesticides	beta-BHC	pg/g	604	120	20%	8,410	15,600	635	<5650	370	180,000	1,800	230,000
Phase III	Pesticides	beta-BHC	pg/g	253	148	58%	117	174	10.9	74.8	6.24	1,430	32	1,090
Phase III	Pesticides	cis-Nonachlor	pg/g	248	202	81%	879	877	55.7	781	22.3	4,830	39	394
Phase I/II	Pesticides	Dieldrin	pg/g	635	172	27%	16,300	24,700	981	<13000	670	120,000	2,600	460,000
Phase III	Pesticides	Dieldrin	pg/g	253	240	95%	1,740	3,510	221	947	39.4	37,400	39.7	1,560
Phase I/II	Pesticides	Heptachlor epoxide	pg/g	575	140	24%	10,700	18,000	752	<8600	330	240,000	1,800	230,000
Phase III	Pesticides	Heptachlor epoxide	pg/g	249	81	33%	113	239	15.1	<79.4	14.6	2,400	33.8	939
Phase I/II	Pesticides	Hexachlorobenzene	pg/g	641	92	14%	385,000	780,000	30,800	<82,000	930	7,800,000	3,500	9,800,000
Phase III	Pesticides	Hexachlorobenzene	pg/g	253	252	100%	2,870	6,250	393	1040	13.2	46,200	221	221
Phase I/II	Pesticides	Total alpha + gamma chlordane	pg/g	641	217	34%	10,000	16,000	632	<7900	--	140,000	1800	230,000
Phase III	Pesticides	Total alpha + gamma chlordane	pg/g	253	244	96%	5,070	4,800	302	4,300	39	32,000	39.7	335
Phase III	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	254	254	100%	131,000	301,000	18,900	34,500	120	2,600,000	--	--
Phase III	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (1/2 DL Substituti	pg/g	254	254	100%	131,000	301,000	18,900	34,500	130	2,600,000	--	--
Phase III	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (FULL DL Substit	pg/g	254	254	100%	131,000	301,000	18,900	34,500	130	2,600,000	--	--
Phase I/II	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	641	476	74%	163,000	455,000	18,000	35,000	550	5,300,000	3,500	240,000
Phase I/II	Pesticides	Total DDx (4,4') Total Fraction (1/2 DL Substitution)	pg/g	641	476	74%	175,000	459,000	18,100	45,000	2,700	5,300,000	3,500	240,000
Phase I/II	Pesticides	Total DDx (4,4') Total Fraction (FULL DL Substitution)	pg/g	641	476	74%	187,000	465,000	18,400	56,000	2,700	5,300,000	3,500	240,000
Phase III	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	254	254	100%	93,100	205,000	12,900	26,000	93	1,800,000	--	--
Phase III	Pesticides	Total DDx (4,4') Total Fraction (1/2 DL Substitution)	pg/g	254	254	100%	93,100	205,000	12,900	26,000	93	1,800,000	--	--
Phase III	Pesticides	Total DDx (4,4') Total Fraction (FULL DL Substitution)	pg/g	254	254	100%	93,100	205,000	12,900	26,000	93	1,800,000	--	--
Phase III	PAHs	Total Alkylated PAHs	µg/kg	254	245	96%	12,900	21,200	1,330	5,990	38.5	168,000	35	1,400
Phase I/II	PAHs	Total HMW PAHs	µg/kg	640	581	91%	19,700	30,600	1,210	12,000	0.82	470,000	3.5	3,300
Phase III	PAHs	Total HMW PAHs	µg/kg	254	252	99%	10,900	12,400	780	6,980	37	100,000	41	45
Phase I/II	PAHs	Total LMW PAHs	µg/kg	641	564	88%	9,390	37,700	1,490	1,800	1.1	510,000	3.5	4,100
Phase III	PAHs	Total LMW PAHs	µg/kg	254	245	96%	1,350	2,130	133	785	5.2	17,000	35	1,400
Phase I/II	PAHs	Total PAH	µg/kg	641	585	91%	29,100	57,800	2,280	14,000	0.82	580,000	3.5	3,300
Phase III	PAHs	Total PAH	µg/kg	254	252	99%	12,200	14,200	893	7,700	37	110,000	41	45
Phase I/II	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	640	453	71%	16,700	39,800	1,570	3,050	31	540,000	180	12,000
Phase III	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	253	198	78%	1,120	3,360	211	400	96	38,000	210	460
Phase I/II	TPH	Total Petroleum Hydrocarbons	mg/kg	639	591	92%	4,140	11,400	449	1,500	4.8	150,000	4.3	52
Phase III	TPH	Total Petroleum Hydrocarbons	mg/kg	254	246	97%	342	435	27.3	190	6.45	2,910	14.6	135
Phase I/II	Metals	Aluminum	mg/kg	640	639	100%	14,700	5,000	198	15,100	2230	51,200	1.1	1.1
Phase III	Metals	Aluminum	mg/kg	254	254	100%	13,700	5,960	374	14,000	1,650	35,000	--	--
Phase I/II	Metals	Arsenic	mg/kg	640	635	99%	28.6	34.2	1.35	16.6	0.23	530	0.46	2.9
Phase III	Metals	Arsenic	mg/kg	254	254	100%	18.3	16.8	1.05	13.3	1.18	115	--	--
Phase I/II	Metals	Cadmium	mg/kg	640	583	91%	5.12	7.39	0.292	2.2	0.033	90.1	0.027	2.8
Phase III	Metals	Cadmium	mg/kg	254	252	99%	2.06	3.28	0.206	0.905	0.0592	24.6	0.0867	0.103
Phase I/II	Metals	Chromium	mg/kg	640	640	100%	244	298	11.8	132	5.9	2,000	--	--
Phase III	Metals	Chromium	mg/kg	254	254	100%	123	117	7.33	95.8	3.95	777	--	--
Phase I/II	Metals	Copper	mg/kg	635	635	100%	246	238	9.43	183	0.85	1,670	--	--
Phase III	Metals	Copper	mg/kg	254	254	100%	149	152	9.52	100	1.5	924	--	--

Table 4-3
Summary of Sediment Contaminants Retained for Focused Nature and Extent

Phase	Analyte Group	Analyte	Units	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Metals	Lead	mg/kg	640	640	100%	269	415	16.4	181	1.4	7,920	--	--
Phase III	Metals	Lead	mg/kg	254	254	100%	166	220	13.8	111	2.18	2,190	--	--
Phase I/II	Metals	Mercury	ng/g	640	590	92%	9,600	40,000	1,580	2,900	3.4	758,000	2.4	62
Phase III	Metals	Mercury	ng/g	254	254	100%	2,350	2,850	179	1,480	5.11	22,100	--	--
Phase III	Metals	Methyl mercury	ng/g	254	253	100%	1.1	1.15	0.0719	0.833	0.027	11.9	0.058	0.058
Phase I/II	Metals	Nickel	mg/kg	640	640	100%	41.8	21.9	0.867	40.2	3.5	159	--	--
Phase III	Metals	Nickel	mg/kg	254	254	100%	40.9	28.9	1.81	37.9	3.83	282	--	--
Phase I/II	Metals	Selenium	mg/kg	623	432	69%	1.5	1.47	0.0589	1.1	0.018	11.3	0.017	7.1
Phase III	Metals	Selenium	mg/kg	253	250	99%	1.02	1.11	0.0697	0.704	0.0939	7.58	0.347	0.484
Phase I/II	Metals	Silver	mg/kg	593	532	90%	3.76	4.36	0.179	2.7	0.0031	61.6	0.003	7.8
Phase III	Metals	Silver	mg/kg	254	253	100%	1.81	1.64	0.103	1.46	0.0448	12	0.103	0.103
Phase I/II	Metals	Zinc	mg/kg	640	640	100%	420	445	17.6	298	8.9	3,450	--	--
Phase III	Metals	Zinc	mg/kg	254	254	100%	300	486	30.5	220	8.18	6,810	--	--
Phase I/II	Grain Size	Fines	%	310	310	100%	71.7	18.3	1.04	76.6	2.81	98.2	--	--
Phase III	Grain Size	Fines	%	254	254	100%	56	27	1.69	61.1	2.6	96.8	--	--
Phase I/II	TOC	Total organic carbon (TOC)	mg/kg	639	635	99%	33,800	23,700	936	30,000	140	190,000	110	521
Phase III	TOC	Total organic carbon (TOC)	mg/kg	254	252	99%	23,600	16,100	1,010	22,200	1,030	151,000	668	689

Notes:
Non-detects included at the 1/2 quantitation limit for mean, standard deviation, and standard error estimates.
Non-detects evaluated at full quantitation limit for median estimate. If the median is a non-detect, it is indicated by the "less than" symbol (<).
When all data are reported as non-detect, the calculated mean and standard deviation are calculated using the full quantitation limit; a “less than” symbol (<) was assigned to the mean to indicate all values are below the quantitation limit.

Total Petroleum Hydrocarbons (TPH) is the sum of gasoline range organics (GRO) and diesel range organics (DRO).
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.
Total 2,4' and 4,4' DDx is not evaluated for Phase I/II because 2,4' isomers were not analyzed in Phase I.

Acronyms and Abbreviations:
< = indicates the median is a non-detect or that the mean was calculated using all non-detects reported at the quantitation limit
% = percent
BHC = hexachlorocyclohexane
DL = detection limit
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligram per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/g = nanogram per gram
ng/kg = nanogram per kilogram
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
pg/g = picogram per gram
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
µg/kg = microgram per kilogram

Table 4-4
Surface Sediment Summary Statistics – By Sampling Program

Phase	Sampling Program	Depth Group	Analyte Group	Analyte	Units	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Phase I	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	69	69	100%	62	79.9	9.62	45.1	0.947	592	--	--
Phase I/II	Phase I	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	69	67	97%	1,050	1,930	232	510	37	14,000	220	260
Phase I/II	Phase I	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	69	69	100%	728,000	1,120,000	135,000	439,000	4,530	7,700,000	--	--
Phase I/II	Phase I	Surface	Pesticides	Dieldrin	pg/g	69	0	0%	<39200	30800	3710	<20000	--	--	5300	460000
Phase I/II	Phase I	Surface	Pesticides	Heptachlor epoxide	pg/g	69	3	4%	9,840	15,600	1,880	<9900	1,200	9,100	2,800	230,000
Phase I/II	Phase I	Surface	Pesticides	Hexachlorobenzene	pg/g	69	0	0%	<1,670,000	917,000	110,000	<1,000,000	--	--	220,000	8,900,000
Phase I/II	Phase I	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	69	52	75%	88,900	202,000	24,400	33,000	2,700	1,100,000	5,300	170,000
Phase I/II	Phase I	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	69	0	0%	<20200	15,500	1,870	<11000	--	--	2,800	230,000
Phase I/II	Phase I	Surface	Pesticides	alpha-BHC	pg/g	69	4	6%	9,780	15,600	1,880	<10000	1,400	2,700	2,800	230,000
Phase I/II	Phase I	Surface	Pesticides	beta-BHC	pg/g	69	8	12%	9,770	15,600	1,880	<9900	1,500	6,100	2,800	230,000
Phase I/II	Phase I	Surface	PAHs	Total HMW PAHs	µg/kg	69	69	100%	20,100	57,600	6,930	8,700	1,770	470,000	--	--
Phase I/II	Phase I	Surface	PAHs	Total LMW PAHs	µg/kg	69	65	94%	2,500	5,570	671	1,200	150	44,000	940	4100
Phase I/II	Phase I	Surface	PAHs	Total PAH	µg/kg	69	69	100%	22,700	63,900	7,700	10,000	1,770	520,000	--	--
Phase I/II	Phase I	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	69	68	99%	7,140	12,000	1,450	2,900	170	68,500	2700	2700
Phase I/II	Phase I	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	69	69	100%	1,310	1,600	192	920	67	9,700	--	--
Phase I/II	Phase I	Surface	Metals	Aluminum	mg/kg	69	69	100%	14,700	4,800	578	14,700	3,290	31,500	--	--
Phase I/II	Phase I	Surface	Metals	Arsenic	mg/kg	69	69	100%	14.4	9.51	1.14	11.6	3.7	51.8	--	--
Phase I/II	Phase I	Surface	Metals	Cadmium	mg/kg	69	64	93%	2.2	3.36	0.404	1.2	0.08	21.5	0.04	0.39
Phase I/II	Phase I	Surface	Metals	Chromium	mg/kg	69	69	100%	119	92.7	11.2	103	21	649	--	--
Phase I/II	Phase I	Surface	Metals	Copper	mg/kg	67	67	100%	147	131	16	108	11	781	--	--
Phase I/II	Phase I	Surface	Metals	Lead	mg/kg	69	69	100%	151	155	18.7	107	12.4	882	--	--
Phase I/II	Phase I	Surface	Metals	Mercury	ng/g	69	69	100%	3,350	9,330	1,120	1,600	140	77,000	--	--
Phase I/II	Phase I	Surface	Metals	Nickel	mg/kg	69	69	100%	35.9	15.4	1.85	34.6	9.3	89.6	--	--
Phase I/II	Phase I	Surface	Metals	Selenium	mg/kg	66	32	48%	1.13	1.04	0.129	<1	0.77	4.6	0.51	3.6
Phase I/II	Phase I	Surface	Metals	Silver	mg/kg	69	67	97%	2.44	2.32	0.279	2	0.29	15.9	0.21	0.46
Phase I/II	Phase I	Surface	Metals	Zinc	mg/kg	69	69	100%	255	216	26	196	48.1	1460	--	--
Phase I/II	Phase I	Surface	Grain Size	Fines	%	69	69	100%	68	18.8	2.26	73.9	26.3	94.6	--	--
Phase I/II	Phase I	Surface	TOC	Total organic carbon (TOC)	mg/kg	69	69	100%	24,800	20,700	2,490	19,500	1,800	135,000	--	--
Phase I/II	Phase II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	50	50	100%	70.6	67.7	9.57	50.8	1.68	423	--	--
Phase I/II	Phase II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	50	50	100%	509	434	61.4	380	67	2,000	--	--
Phase I/II	Phase II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	50	50	100%	773,000	736,000	104,000	549,000	88,600	3,670,000	--	--
Phase I/II	Phase II	Surface	Pesticides	Dieldrin	pg/g	49	26	53%	5,730	9,710	1,390	5,900	670	70,000	2,600	20,000
Phase I/II	Phase II	Surface	Pesticides	Heptachlor epoxide	pg/g	45	25	56%	4,980	5,020	748	4,100	1,400	22,000	2,200	10,000
Phase I/II	Phase II	Surface	Pesticides	Hexachlorobenzene	pg/g	50	12	24%	13,800	36,300	5,130	<9,900	1,600	15,000	5,200	490,000
Phase I/II	Phase II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	50	50	100%	233,000	627,000	88,700	33,000	8,500	3,700,000	--	--
Phase I/II	Phase II	Surface	Pesticides	Total DDx (4,4) Total Fraction (ND=0)	pg/g	50	50	100%	202,000	557,000	78,700	32,500	8,500	3,200,000	--	--
Phase I/II	Phase II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	50	47	94%	9,100	12,200	1,730	5,050		61,000	2,300	9,500
Phase I/II	Phase II	Surface	Pesticides	alpha-BHC	pg/g	50	6	12%	1,940	945	134	<3700	480	5,400	2,200	10,000
Phase I/II	Phase II	Surface	Pesticides	beta-BHC	pg/g	45	8	18%	3,770	11,100	1,650	<3600	1,200	76,000	2,200	10,000
Phase I/II	Phase II	Surface	PAHs	Total HMW PAHs	µg/kg	49	49	100%	15,000	19,800	2,830	9,700	3,100	140,000	--	--
Phase I/II	Phase II	Surface	PAHs	Total LMW PAHs	µg/kg	50	50	100%	2,290	5,240	741	1,450	390	38,000	--	--
Phase I/II	Phase II	Surface	PAHs	Total PAH	µg/kg	50	50	100%	16,800	23,800	3,370	11,000	400	170,000	--	--
Phase I/II	Phase II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	49	48	98%	6,020	11,100	1,580	3,100	640	71,000	270	270
Phase I/II	Phase II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	50	50	100%	1,480	1,300	183	1,000	230	5,800	--	--
Phase I/II	Phase II	Surface	Metals	Aluminum	mg/kg	50	49	98%	12,900	4,330	612	13,900	3,200	19,600	1.1	1.1
Phase I/II	Phase II	Surface	Metals	Arsenic	mg/kg	50	50	100%	15.9	10.7	1.52	12	1.5	54.1	--	--
Phase I/II	Phase II	Surface	Metals	Cadmium	mg/kg	50	48	96%	2.21	2.02	0.286	1.65	0.41	12.3	1.5	2.8
Phase I/II	Phase II	Surface	Metals	Chromium	mg/kg	50	50	100%	121	69.4	9.82	103	28.5	402	--	--

Table 4-4
Surface Sediment Summary Statistics – By Sampling Program

Phase	Sampling Program	Depth Group	Analyte Group	Analyte	Units	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Phase II	Surface	Metals	Copper	mg/kg	50	50	100%	177	123	17.4	136	24.8	598	--	--
Phase I/II	Phase II	Surface	Metals	Lead	mg/kg	50	50	100%	191	163	23	124	39.3	1,000	--	--
Phase I/II	Phase II	Surface	Metals	Mercury	ng/g	50	50	100%	4,080	6,000	848	2,350	770	38,800	--	--
Phase I/II	Phase II	Surface	Metals	Nickel	mg/kg	50	50	100%	37.9	18.9	2.68	35.5	8.9	147	--	--
Phase I/II	Phase II	Surface	Metals	Selenium	mg/kg	50	45	90%	1.07	0.893	0.126	0.78	0.085	3.3	4	7.1
Phase I/II	Phase II	Surface	Metals	Silver	mg/kg	39	39	100%	2.78	1.86	0.299	2.2	0.36	10.6	--	--
Phase I/II	Phase II	Surface	Metals	Zinc	mg/kg	50	50	100%	301	164	23.3	243	63.4	857	--	--
Phase I/II	Phase II	Surface	Grain Size	Fines	%	50	50	100%	73.3	13.6	1.92	74	8.51	97	--	--
Phase I/II	Phase II	Surface	TOC	Total organic carbon (TOC)	mg/kg	50	50	100%	33,400	20,100	2,850	28,500	3,640	128,000	--	--
Phase III	Crab/Clam	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	18	18	100%	38.8	65.9	15.5	12.6	2.18	271	--	--
Phase III	Crab/Clam	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	18	17	94%	231	315	74.3	59.5	20	1200	21	21
Phase III	Crab/Clam	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	18	18	100%	558,000	1,030,000	243,000	120,000	23,400	4,000,000	--	--
Phase III	Crab/Clam	Surface	Pesticides	Dieldrin	pg/g	18	16	89%	2,740	5,740	1350	905	119	20,900	1020	1560
Phase III	Crab/Clam	Surface	Pesticides	Heptachlor epoxide	pg/g	18	12	67%	180	293	69.1	69.7	14.6	1,170	34.6	54.7
Phase III	Crab/Clam	Surface	Pesticides	Hexachlorobenzene	pg/g	18	18	100%	2,710	5,770	1,360	630	42.1	24,800	--	--
Phase III	Crab/Clam	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	18	18	100%	108,000	162,000	38,200	28,000	1,600	540,000	--	--
Phase III	Crab/Clam	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	18	18	100%	77,900	117,000	27,500	20,000	1,300	400,000	--	--
Phase III	Crab/Clam	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	18	18	100%	5,510	5,750	1,360	3,050	430	22,000	--	--
Phase III	Crab/Clam	Surface	Pesticides	alpha-BHC	pg/g	18	11	61%	66.7	135	31.8	43.8	8.17	596	41.7	77.8
Phase III	Crab/Clam	Surface	Pesticides	beta-BHC	pg/g	18	8	44%	131	197	46.5	<53	20.7	707	34.6	1090
Phase III	Crab/Clam	Surface	Pesticides	cis-Nonachlor	pg/g	18	15	83%	599	639	151	441	52.2	2,540	42.6	77.8
Phase III	Crab/Clam	Surface	PAHs	Total Alkylated PAHs	µg/kg	18	17	94%	6,600	8,150	1,920	4,030	256	34,000	45	45
Phase III	Crab/Clam	Surface	PAHs	Total HMW PAHs	µg/kg	18	17	94%	12,000	17,600	4,140	4,000	660	70,000	45	45
Phase III	Crab/Clam	Surface	PAHs	Total LMW PAHs	µg/kg	18	17	94%	2,570	4,450	1,050	360	69	17,000	45	45
Phase III	Crab/Clam	Surface	PAHs	Total PAH	µg/kg	18	17	94%	14,500	22,000	5,180	4,300	780	87,000	45	45
Phase III	Crab/Clam	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	18	17	94%	1,130	1,410	332	615	98	5,700	210	210
Phase III	Crab/Clam	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	18	18	100%	382	331	77.9	253	47.6	1,230	--	--
Phase III	Crab/Clam	Surface	Metals	Aluminum	mg/kg	18	18	100%	7,860	3,350	790	7,560	2,610	16,300	--	--
Phase III	Crab/Clam	Surface	Metals	Arsenic	mg/kg	18	18	100%	17.8	28.4	6.7	8.6	1.18	115	--	--
Phase III	Crab/Clam	Surface	Metals	Cadmium	mg/kg	18	18	100%	1.52	3.12	0.736	0.581	0.0858	13.7	--	--
Phase III	Crab/Clam	Surface	Metals	Chromium	mg/kg	18	18	100%	75.7	66.6	15.7	53.5	9.1	276	--	--
Phase III	Crab/Clam	Surface	Metals	Copper	mg/kg	18	18	100%	114	126	29.7	74.6	9.14	443	--	--
Phase III	Crab/Clam	Surface	Metals	Lead	mg/kg	18	18	100%	258	547	129	80.2	10.6	2190	--	--
Phase III	Crab/Clam	Surface	Metals	Mercury	ng/g	18	18	100%	1330	1750	413	727	54.6	7390	--	--
Phase III	Crab/Clam	Surface	Metals	Methyl mercury	ng/g	18	18	100%	1.12	2.72	0.642	0.409	0.065	11.9	--	--
Phase III	Crab/Clam	Surface	Metals	Nickel	mg/kg	18	18	100%	31.6	32.1	7.57	20.3	5.89	124	--	--
Phase III	Crab/Clam	Surface	Metals	Selenium	mg/kg	18	17	94%	0.71	0.789	0.186	0.502	0.141	3	0.484	0.484
Phase III	Crab/Clam	Surface	Metals	Silver	mg/kg	18	18	100%	0.984	1.31	0.308	0.608	0.0759	5.8	--	--
Phase III	Crab/Clam	Surface	Metals	Zinc	mg/kg	18	18	100%	658	1630	384	189	35.2	6810	--	--
Phase III	Crab/Clam	Surface	Grain Size	Fines	%	18	18	100%	24.7	16.2	3.82	23.5	2.6	51.8	--	--
Phase III	Crab/Clam	Surface	TOC	Total organic carbon (TOC)	mg/kg	18	18	100%	15,300	16,300	3,850	7,940	1,160	54,300	--	--
Phase III	Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	193	193	100%	93	204	14.7	40.7	0.12	1710	--	--
Phase III	Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	193	180	93%	230	297	21.4	130	6.4	2000	21	46
Phase III	Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	193	193	100%	460,000	657,000	47,300	261,000	2,480	5,030,000	--	--
Phase III	Phase III	Surface	Pesticides	Dieldrin	pg/g	192	182	95%	1720	3,580	258	905	39.4	37,400	39.7	335
Phase III	Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	188	43	23%	110	255	18.6	<79	29.5	2,400	37.9	939
Phase III	Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	192	191	99%	2,990	6,560	473	1,000	13	46,200	221	221

Table 4-4
Surface Sediment Summary Statistics – By Sampling Program

Phase	Sampling Program	Depth Group	Analyte Group	Analyte	Units	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase III	Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	193	193	100%	142,000	335,000	24,100	34,000	120	2,600,000	--	--
Phase III	Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	193	193	100%	99,800	228,000	16,400	26,000	93	1,800,000	--	--
Phase III	Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	192	184	96%	4,720	4,840	349	3,950	39	32,000	39.7	335
Phase III	Phase III	Surface	Pesticides	alpha-BHC	pg/g	191	118	62%	120	157	11.4	71.5	6.32	1,050	37.9	939
Phase III	Phase III	Surface	Pesticides	beta-BHC	pg/g	192	105	55%	116	161	11.6	79.2	6.24	1,320	37.9	939
Phase III	Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	187	146	78%	885	944	69	757	22.3	4,830	39	394
Phase III	Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	193	185	96%	14,200	23,200	1,670	6,250	39	168,000	35	1400
Phase III	Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	193	192	99%	10,800	10,900	786	7,100	37	75,000	41	41
Phase III	Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	193	185	96%	1250	1770	127	800	5.2	17,000	35	1400
Phase III	Phase III	Surface	PAHs	Total PAH	µg/kg	193	192	99%	12,100	12,400	893	8,000	37	91,000	41	41
Phase III	Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	193	145	75%	991	2,710	195	375	96	31,000	210	460
Phase III	Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	193	186	96%	369	471	33.9	201	6.45	2,910	14.6	135
Phase III	Phase III	Surface	Metals	Aluminum	mg/kg	193	193	100%	14,300	6,030	434	14,600	1650	35,000	--	--
Phase III	Phase III	Surface	Metals	Arsenic	mg/kg	193	193	100%	19.1	16.3	1.17	13.9	1.8	96.8	--	--
Phase III	Phase III	Surface	Metals	Cadmium	mg/kg	193	191	99%	2.15	3.34	0.241	0.94	0.0592	24.6	0.0867	0.103
Phase III	Phase III	Surface	Metals	Chromium	mg/kg	193	193	100%	130	127	9.14	98.6	3.95	777	--	--
Phase III	Phase III	Surface	Metals	Copper	mg/kg	193	193	100%	153	159	11.5	100	1.5	924	--	--
Phase III	Phase III	Surface	Metals	Lead	mg/kg	193	193	100%	158	177	12.7	114	2.18	1410	--	--
Phase III	Phase III	Surface	Metals	Mercury	ng/g	193	193	100%	2560	3120	224	1480	5.11	22,100	--	--
Phase III	Phase III	Surface	Metals	Methyl mercury	ng/g	193	192	99%	0.897	0.733	0.0528	0.785	0.027	4.8	0.058	0.058
Phase III	Phase III	Surface	Metals	Nickel	mg/kg	193	193	100%	40.3	27.9	2.01	39	3.83	282	--	--
Phase III	Phase III	Surface	Metals	Selenium	mg/kg	192	190	99%	1.08	1.2	0.0866	0.727	0.0939	7.58	0.347	0.412
Phase III	Phase III	Surface	Metals	Silver	mg/kg	193	192	99%	1.87	1.72	0.124	1.5	0.0448	12	0.103	0.103
Phase III	Phase III	Surface	Metals	Zinc	mg/kg	193	193	100%	271	240	17.2	220	8.18	1860	--	--
Phase III	Phase III	Surface	Grain Size	Fines	%	193	193	100%	58.3	26.5	1.91	63.8	4.3	96.8	--	--
Phase III	Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	193	191	99%	20,900	11,400	821	21,000	1,030	61,400	668	689
Phase III	SQT	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	43	43	100%	81.1	86.7	13.2	58.6	1.76	413	--	--
Phase III	SQT	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	43	42	98%	284	402	61.3	180	28	2500	40	40
Phase III	SQT	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	43	43	100%	533,000	681,000	104,000	424,000	30,300	4,370,000	--	--
Phase III	SQT	Surface	Pesticides	Dieldrin	pg/g	43	42	98%	1410	1300	198	1080	106	7830	50.3	50.3
Phase III	SQT	Surface	Pesticides	Heptachlor epoxide	pg/g	43	26	60%	101	104	15.8	83	40	552	33.8	92.4
Phase III	SQT	Surface	Pesticides	Hexachlorobenzene	pg/g	43	43	100%	2,390	4,980	759	1,270	207	31,200	--	--
Phase III	SQT	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	43	43	100%	92,600	138,000	21,000	39,000	2,800	600,000	--	--
Phase III	SQT	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	43	43	100%	69,700	100,000	15,300	31,000	2,300	490,000	--	--
Phase III	SQT	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	43	42	98%	6,420	3,940	600	5,700	460	16,000	50.3	50.3
Phase III	SQT	Surface	Pesticides	alpha-BHC	pg/g	43	43	100%	131	245	37.3	50.6	8.06	1260	--	--
Phase III	SQT	Surface	Pesticides	beta-BHC	pg/g	43	35	81%	114	218	33.2	66.5	6.63	1430	32	74.8
Phase III	SQT	Surface	Pesticides	cis-Nonachlor	pg/g	43	41	95%	973	603	92	939	79.9	2470	50.3	53.5
Phase III	SQT	Surface	PAHs	Total Alkylated PAHs	µg/kg	43	43	100%	9,730	12,900	1,970	4,990	215	69,700	--	--
Phase III	SQT	Surface	PAHs	Total HMW PAHs	µg/kg	43	43	100%	10,600	16,100	2,460	5,850	1,000	100,000	--	--
Phase III	SQT	Surface	PAHs	Total LMW PAHs	µg/kg	43	43	100%	1,300	2,050	313	730	41	12,000	--	--
Phase III	SQT	Surface	PAHs	Total PAH	µg/kg	43	43	100%	11,900	17,800	2,720	6,700	1,000	110,000	--	--
Phase III	SQT	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	42	36	86%	1,680	5,810	896	450	140	38,000	230	440
Phase III	SQT	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	43	42	98%	205	239	36.5	129	9.35	1290	31.1	31.1
Phase III	SQT	Surface	Metals	Aluminum	mg/kg	43	43	100%	13,600	5,150	785	13,000	4,670	23,300	--	--
Phase III	SQT	Surface	Metals	Arsenic	mg/kg	43	43	100%	14.7	11.7	1.79	11.2	2.39	61.5	--	--
Phase III	SQT	Surface	Metals	Cadmium	mg/kg	43	43	100%	1.91	3.09	0.471	1.04	0.137	17.8	--	--
Phase III	SQT	Surface	Metals	Chromium	mg/kg	43	43	100%	110	74.2	11.3	104	20.8	397	--	--
Phase III	SQT	Surface	Metals	Copper	mg/kg	43	43	100%	148	125	19	108	19	567	--	--
Phase III	SQT	Surface	Metals	Lead	mg/kg	43	43	100%	163	149	22.7	116	38.8	875	--	--

Table 4-4
Surface Sediment Summary Statistics – By Sampling Program

Phase	Sampling Program	Depth Group	Analyte Group	Analyte	Units	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase III	SQT	Surface	Metals	Mercury	ng/g	43	43	100%	1,830	1,480	226	1,580	169	8,380	--	--
Phase III	SQT	Surface	Metals	Methyl mercury	ng/g	43	43	100%	2.01	1.18	0.18	1.66	0.334	4.99	--	--
Phase III	SQT	Surface	Metals	Nickel	mg/kg	43	43	100%	47.2	31.4	4.79	39.5	16.8	182	--	--
Phase III	SQT	Surface	Metals	Selenium	mg/kg	43	43	100%	0.868	0.698	0.106	0.725	0.148	3.74	--	--
Phase III	SQT	Surface	Metals	Silver	mg/kg	43	43	100%	1.88	1.3	0.198	1.71	0.188	5.61	--	--
Phase III	SQT	Surface	Metals	Zinc	mg/kg	43	43	100%	276	166	25.3	236	79.6	752	--	--
Phase III	SQT	Surface	Grain Size	Fines	%	43	43	100%	58.9	24.8	3.78	62.1	5.9	95.9	--	--
Phase III	SQT	Surface	TOC	Total organic carbon (TOC)	mg/kg	43	43	100%	39,100	23,600	3,600	34,000	3,170	151,000	--	--

Notes:
Non-detects included at the 1/2 quantitation limit for mean, standard deviation, and standard error estimates.
Non-detects evaluated at full quantitation limit for median estimate. If the median is a non-detect, it is indicated by the "less than" symbol (<).
When all data are reported as non-detect, the calculated mean and standard deviation are calculated using the full quantitation limit; a “less than” symbol (<) was assigned to the mean to indicate all values are below the quantitation limit.
Total Petroleum Hydrocarbons (TPH) is the sum of gasoline range organics (GRO) and diesel range organics (DRO).
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.
Total 2,4' and 4,4' DDx is not evaluated for Phase I because 2,4' isomers were not analyzed in Phase I.

Acronyms and Abbreviations:
< = indicates the median is a non-detect or that the mean was calculated using all non-detects reported at the quantitation limit
% = percent
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligram per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/g = nanogram per gram
ng/kg = nanogram per kilogram
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
pg/g = picogram per gram
SQT = Sediment Quality Triad
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
µg/kg = microgram per kilogram

Table 4-5
Phase III Surface Sediment Summary Statistics – By Assessment Zone

Analyte Group	Analyte	Units	Assessment Zone	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	North	104	104	100%	118	252	24.7	51.9	1.19	1710	--	--
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Southeast	50	50	100%	53.8	49.6	7.02	47.1	0.12	261	--	--
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Southwest	90	90	100%	76.7	132	13.9	26.9	0.43	833	--	--
PCBs	Total PCBs (9)	µg/kg	North	104	98	94%	172	199	19.5	125	6.4	1,100	26	46
PCBs	Total PCBs (9)	µg/kg	Southeast	50	44	88%	160	149	21	135	6.9	750	21	40
PCBs	Total PCBs (9)	µg/kg	Southwest	90	87	97%	375	446	47	225	7.4	2,500	24	32
PCBs	Total PCBs congener (209 specified)	ng/kg	North	104	104	100%	436,000	708,000	69,400	234,000	9,070	5,030,000	--	--
PCBs	Total PCBs congener (209 specified)	ng/kg	Southeast	50	50	100%	353,000	296,000	41,900	367,000	2,480	1,400,000	--	--
PCBs	Total PCBs congener (209 specified)	ng/kg	Southwest	90	90	100%	630,000	828,000	87,300	373,000	5,320	4,370,000	--	--
Pesticides	Dieldrin	pg/g	North	104	99	95%	1,530	2,740	269	863	54	19,300	221	1,560
Pesticides	Dieldrin	pg/g	Southeast	49	47	96%	1,340	2,200	314	972	45	15,400	40	50
Pesticides	Dieldrin	pg/g	Southwest	90	84	93%	2,280	4,800	506	968	39	37,400	48	85
Pesticides	Heptachlor epoxide	pg/g	North	100	43	43%	106	140	14	<78.6	15	1,060	35	939
Pesticides	Heptachlor epoxide	pg/g	Southeast	49	22	45%	72.6	71.5	10.2	<54.7	29.5	354	33.8	394
Pesticides	Heptachlor epoxide	pg/g	Southwest	90	12	13%	134	346	37	<80.1	44	2,400	35	506
Pesticides	Hexachlorobenzene	pg/g	North	104	103	99%	1,700	2,240	220	1,080	27	14,100	221	221
Pesticides	Hexachlorobenzene	pg/g	Southeast	49	49	100%	1000	1140	163	688	13.2	6,650	--	--
Pesticides	Hexachlorobenzene	pg/g	Southwest	90	90	100%	5480	9650	1020	1,530	38.4	46,200	--	--
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	North	104	104	100%	39,200	50,000	4,900	27,000	400	390,000	--	--
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Southeast	50	50	100%	45,300	74,000	10,500	33,500	120	470,000	--	--
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Southwest	90	90	100%	292,000	458,000	48,300	99,000	1,000	2,600,000	--	--
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	North	104	104	100%	29,600	34,300	3,360	21,000	340	230,000	--	--
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Southeast	50	50	100%	33,200	49,600	7,020	25,500	93	310,000	--	--
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Southwest	90	90	100%	205,000	312,000	32,900	73,500	750	1,800,000	--	--
Pesticides	Total alpha + gamma chlordane	pg/g	North	104	100	96%	4,770	4,820	472	3,200	210	24,000	221	335
Pesticides	Total alpha + gamma chlordane	pg/g	Southeast	49	46	94%	5,110	3,370	481	5,300	39	14,000	40	50
Pesticides	Total alpha + gamma chlordane	pg/g	Southwest	90	88	98%	5,380	5,530	583	4,150	77	32,000	53	56
Pesticides	alpha-BHC	pg/g	North	103	65	63%	68	77	8	49	6	355	38	939
Pesticides	alpha-BHC	pg/g	Southeast	49	42	86%	64	65.2	9.31	46	8.17	361	39	47.7
Pesticides	alpha-BHC	pg/g	Southwest	90	61	68%	205	250	26	116	8	1,260	46	395
Pesticides	beta-BHC	pg/g	North	104	73	70%	99	89	9	78	10	412	38	939
Pesticides	beta-BHC	pg/g	Southeast	49	33	67%	47.2	27.8	3.97	50.1	6.24	127	32	72.6
Pesticides	beta-BHC	pg/g	Southwest	90	39	43%	163	232	25	<88.3	7	1,430	35	1,090
Pesticides	cis-Nonachlor	pg/g	North	101	85	84%	820	780	77.6	649	41.6	4270	39	280
Pesticides	cis-Nonachlor	pg/g	Southeast	49	44	90%	856	483	69	909	22.3	1880	39.7	50.3
Pesticides	cis-Nonachlor	pg/g	Southwest	88	65	74%	966	1130	121	704	50.2	4830	45.1	394
PAHs	Total Alkylated PAHs	µg/kg	North	104	100	96%	9,350	9,100	892	6,100	99	48,100	42	68
PAHs	Total Alkylated PAHs	µg/kg	Southeast	50	48	96%	7,060	10,600	1,500	4,840	39	71,400	40	41
PAHs	Total Alkylated PAHs	µg/kg	Southwest	90	87	97%	21,200	31,600	3,340	9,510	54	168,000	35	1400
PAHs	Total HMW PAHs	µg/kg	North	104	103	99%	11,800	10,900	1,070	7,850	71	53,000	45	45
PAHs	Total HMW PAHs	µg/kg	Southeast	50	49	98%	7,950	8,510	1,200	6,000	37	46,000	41	41
PAHs	Total HMW PAHs	µg/kg	Southwest	90	90	100%	12,000	15,800	1,670	6,950	67	100,000	--	--
PAHs	Total LMW PAHs	µg/kg	North	104	100	96%	1,150	1,120	110	790	14	7,500	42	65
PAHs	Total LMW PAHs	µg/kg	Southeast	50	48	96%	1,160	1,890	268	730	5.2	12,000	40	41
PAHs	Total LMW PAHs	µg/kg	Southwest	90	87	97%	1,780	3,020	318	885	7.4	17,000	35	1400
PAHs	Total PAH	µg/kg	North	104	103	99%	13,000	11,900	1,160	8,900	71	56,000	45	45
PAHs	Total PAH	µg/kg	Southeast	50	49	98%	9,080	10,200	1,440	6,650	37	51,000	41	41

Table 4-5
Phase III Surface Sediment Summary Statistics – By Assessment Zone

Analyte Group	Analyte	Units	Assessment Zone	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
PAHs	Total PAH	µg/kg	Southwest	90	90	100%	13,800	18,500	1,950	7,900	67	110,000	--	--
Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	ug/kg	North	104	82	79%	1,090	3,480	341	378	96	31,000	210	460
Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	ug/kg	Southeast	49	43	88%	1,380	5,410	773	340	98	38,000	210	400
Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	ug/kg	Southwest	90	66	73%	1,100	1,430	151	510	110	6,900	210	450
TPH	Total Petroleum Hydrocarbons	mg/kg	North	104	103	99%	237	201	20	186	7	1,240	28.5	28.5
TPH	Total Petroleum Hydrocarbons	mg/kg	Southeast	50	47	94%	234	274	38.8	131	42.2	1,290	14.6	135
TPH	Total Petroleum Hydrocarbons	mg/kg	Southwest	90	86	96%	553	614	64.7	404	6.45	2,910	14.7	31.1
Metals	Aluminum	mg/kg	North	104	104	100%	12,700	6,180	606	11,700	2,610	35,000	--	--
Metals	Aluminum	mg/kg	Southeast	50	50	100%	15,000	5,810	822	17,100	1,650	23,300	--	--
Metals	Aluminum	mg/kg	Southwest	90	90	100%	13,600	5,540	584	14,600	3,250	25,100	--	--
Metals	Arsenic	mg/kg	North	104	104	100%	12.6	7.49	0.74	11.1	1.18	59.3	--	--
Metals	Arsenic	mg/kg	Southeast	50	50	100%	17.3	15.9	2.25	13.6	1.8	85.4	--	--
Metals	Arsenic	mg/kg	Southwest	90	90	100%	25.8	22.3	2.35	19.1	2.26	115	--	--
Metals	Cadmium	mg/kg	North	104	104	100%	1.22	1.49	0.15	0.775	0.09	7.18	--	--
Metals	Cadmium	mg/kg	Southeast	50	48	96%	1.04	0.75	0.11	0.8	0.23	3.65	0.087	0.1
Metals	Cadmium	mg/kg	Southwest	90	90	100%	3.74	4.82	0.51	1.89	0.06	24.6	--	--
Metals	Chromium	mg/kg	North	104	104	100%	117	117	11.4	90.1	9.1	691	--	--
Metals	Chromium	mg/kg	Southeast	50	50	100%	104	53.8	7.61	97.4	3.95	280	--	--
Metals	Chromium	mg/kg	Southwest	90	90	100%	145	143	15.1	111	10.6	777	--	--
Metals	Copper	mg/kg	North	104	104	100%	96.4	79.5	7.8	85.9	8.85	466	--	--
Metals	Copper	mg/kg	Southeast	50	50	100%	112	71.3	10.1	99.1	1.5	319	--	--
Metals	Copper	mg/kg	Southwest	90	90	100%	237	207	21.9	187	8.9	924	--	--
Metals	Lead	mg/kg	North	104	104	100%	116	163	15.9	86.1	9.17	1410	--	--
Metals	Lead	mg/kg	Southeast	50	50	100%	126	72.4	10.2	111	2.18	441	--	--
Metals	Lead	mg/kg	Southwest	90	90	100%	253	303	31.9	189	12.8	2190	--	--
Metals	Mercury	ng/g	North	104	104	100%	1,610	1,660	163	1,240	54.6	10,400	--	--
Metals	Mercury	ng/g	Southeast	50	50	100%	1,800	1,600	226	1,450	5.11	9,440	--	--
Metals	Mercury	ng/g	Southwest	90	90	100%	3,630	3,970	419	2,470	34.2	22,100	--	--
Metals	Methyl mercury	ng/g	North	104	104	100%	0.928	0.78	0.08	0.717	0.07	4.43	--	--
Metals	Methyl mercury	ng/g	Southeast	50	49	98%	1.02	0.82	0.12	0.81	0.03	4.8	0.058	0.06
Metals	Methyl mercury	ng/g	Southwest	90	90	100%	1.3	1.55	0.16	0.9	0.06	11.9	--	--
Metals	Nickel	mg/kg	North	104	104	100%	32.7	23.8	2.33	28.7	5.45	171	--	--
Metals	Nickel	mg/kg	Southeast	50	50	100%	44.7	27.9	3.94	41	3.83	182	--	--
Metals	Nickel	mg/kg	Southwest	90	90	100%	47.8	34	3.58	45.8	8.31	282	--	--
Metals	Selenium	mg/kg	North	104	103	99%	0.657	0.35	0.03	0.574	0.12	1.49	0.484	0.48
Metals	Selenium	mg/kg	Southeast	50	48	96%	0.767	0.54	0.08	0.68	0.19	3.74	0.347	0.41
Metals	Selenium	mg/kg	Southwest	89	89	100%	1.63	1.62	0.17	1.05	0.09	7.58	--	--
Metals	Silver	mg/kg	North	104	104	100%	1.37	1.17	0.12	1.15	0.07	5.58	--	--
Metals	Silver	mg/kg	Southeast	50	49	98%	1.76	0.99	0.14	1.75	0.04	4.32	0.103	0.1
Metals	Silver	mg/kg	Southwest	90	90	100%	2.39	2.22	0.23	1.94	0.06	12	--	--
Metals	Zinc	mg/kg	North	104	104	100%	205	158	15.5	172	25.1	976	--	--
Metals	Zinc	mg/kg	Southeast	50	50	100%	223	97.8	13.8	219	8.18	551	--	--
Metals	Zinc	mg/kg	Southwest	90	90	100%	462	771	81.3	306	30.1	6810	--	--
Grain Size	Fines	% passed	North	104	104	100%	50.7	24.8	2.43	51.3	2.6	96.4	--	--
Grain Size	Fines	% passed	Southeast	50	50	100%	68.7	30.5	4.31	86.7	5.3	96.8	--	--
Grain Size	Fines	% passed	Southwest	90	90	100%	53.2	25.1	2.64	62.1	4.6	87.9	--	--

Table 4-5
Phase III Surface Sediment Summary Statistics – By Assessment Zone

Analyte Group	Analyte	Units	Assessment Zone	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
TOC	Total organic carbon (TOC)	mg/kg	North	104	104	100%	21,000	13,100	1,290	20,000	1,520	73,200	--	--
TOC	Total organic carbon (TOC)	mg/kg	Southeast	50	48	96%	22,600	11,600	1,640	22,000	1,190	51,800	668	689
TOC	Total organic carbon (TOC)	mg/kg	Southwest	90	90	100%	27,400	20,900	2,200	26,700	1,030	151,000	--	--

Notes:
Non-detects included at the 1/2 quantitation limit for mean, standard deviation, and standard error estimates.
Non-detects evaluated at full quantitation limit for median estimate. If the median is a non-detect, it is indicated by the "less than" symbol (<).
When all data are reported as non-detect, the calculated mean and standard deviation are calculated using the full quantitation limit; a “less than” symbol (<) was assigned to the mean to indicate all values are below the quantitation limit.
Total Petroleum Hydrocarbons (TPH) is the sum of gasoline range organics (GRO) and diesel range organics (DRO).
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.
Assessment zones are depicted on Figure 4-35.

Acronyms and Abbreviations:
< = indicates the median is a non-detect or that the mean was calculated using all non-detects reported at the quantitation limit
% = percent
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligram per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/g = nanogram per gram
ng/kg = nanogram per kilogram
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
pg/g = picogram per gram
SQT = Sediment Quality Triad
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
µg/kg = microgram per kilogram

Table 4-6
Surface Sediment Summary Statistics – By USEPA Subunit

Phase	Depth Group	Analyte Group	Analyte	Units	USEPA Subunit[a]	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	1	22	22	100%	98.2	127	27.2	58.4	3.58	592	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	2	30	30	100%	32.2	20.3	3.71	31.9	1.68	82.4	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	3	16	16	100%	71.4	30.2	7.55	79.3	15.3	134	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	4	15	15	100%	135	83.4	21.5	117	70.7	423	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	5	16	16	100%	58	38.4	9.6	52.7	0.947	164	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	6	8	8	100%	38.8	45.7	16.2	16.5	2.84	132	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	1	22	22	100%	1,740	2,950	629	970	37	14,000	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	2	30	30	100%	774	1,300	237	310	67	5,600	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	3	16	16	100%	674	727	182	575	79	3,250	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	4	15	15	100%	606	318	82.1	440	310	1,300	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	5	16	15	94%	527	338	84.4	430	42	1,400	260	260
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	6	8	7	88%	211	216	76.3	180	48	680	220	220
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	1	22	22	100%	1,580,000	1,800,000	384,000	898,000	66,700	7,700,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	2	30	30	100%	537,000	635,000	116,000	360,000	88,600	2,920,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	3	16	16	100%	630,000	546,000	136,000	479,000	88,900	2,420,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	4	15	15	100%	710,000	354,000	91,400	581,000	259,000	1,730,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	5	16	16	100%	509,000	360,000	89,900	487,000	4,530	1,680,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	6	8	8	100%	141,000	121,000	42,900	93,500	24,700	317,000	--	--
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	1	21	2	10%	26,200	51,200	11,200	<13000	1,500	11,000	6,100	460,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	2	30	4	13%	15,800	20,100	3,680	<18000	2,900	3,400	4,300	150,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	3	16	5	31%	9,310	6,770	1,690	<17500	670	4,000	9,500	44,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	4	15	8	53%	6,970	3,370	870	9,400	1,700	9,400	11,000	31,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	5	16	3	19%	8,500	5,680	1,420	<13500	3,300	12,000	7,100	53,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	6	8	0	0%	<16740	4640	1640	<18000			2600	32000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	1	22	10	45%	16,700	24,200	5,160	<10500	2,200	22,000	4,400	230,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	2	29	3	10%	8,670	10,300	1,920	<9400	2,400	7,900	2,200	75,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	3	15	2	13%	5,180	3,360	868	<9400	1,400	2,300	3,100	23,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	4	15	5	33%	3,940	1,550	399	<4400	3,300	4,300	3,500	16,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	5	14	3	21%	3,860	1,350	361	<6800	2,300	4,200	3,600	11,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	6	8	1	13%	3,760	2,360	834	<8550	1,200	1,200	2,600	16,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	1	22	4	18%	665,000	1,010,000	215,000	<335,000	1,600	5,700	6,600	7,400,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	2	30	1	3%	672,000	924,000	169,000	<955,000	2,200	2,200	5,800	7,400,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	3	16	0	0%	<662,000	272,000	67,900	<725,000	--	--	9,800	1,400,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	4	15	2	13%	220,000	262,000	67,600	<35,000	2,200	4,800	7,000	1,500,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	5	16	0	0%	<1,460,000	1,190,000	299,000	<775,000	--	--	7,000	8,900,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	6	8	0	0%	<644,000	198,000	70,000	<800,000	--	--	5,200	1,100,000
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	1	9	9	100%	109,000	69,400	23,100	100,000	25,000	210,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	2	10	10	100%	95,600	164,000	51,800	24,000	12,000	510,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	3	6	6	100%	31,700	18,400	7,520	26,500	14,000	59,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	4	8	8	100%	63,600	96,500	34,100	28,000	16,000	300,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	5	6	6	100%	32,300	17,400	7,120	30,000	13,000	62,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	6	1	1	100%	8,500	--	--	8,500	8,500	8,500	--	--
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	1	22	20	91%	131,000	202,000	43,000	103,000	25,000	1,000,000	120,000	170,000
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	2	30	25	83%	125,000	255,000	46,500	25,500	12,000	1,100,000	13,000	75,000
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	3	16	14	88%	31,900	17,800	4,450	30,500	12,000	64,500	18,000	21,000
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	4	15	15	100%	42,200	53,200	13,700	28,500	12,000	230,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	5	16	13	81%	35,400	45,500	11,400	27,000	12,000	200,000	14,000	31,000
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	6	8	4	50%	19,500	29,500	10,400	17,000	8,200	92,000	5,300	22,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	1	22	9	41%	15,100	25,200	5,370	<9250	--	32,000	4,400	230,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	2	30	10	33%	9,920	10,400	1,900	<9950	390	24,000	6,500	75,000

Table 4-6
Surface Sediment Summary Statistics – By USEPA Subunit

Phase	Depth Group	Analyte Group	Analyte	Units	USEPA Subunit[a]	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	3	16	5	31%	6,340	3,430	857	<11000	1,600	13,000	2,300	23,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	4	15	8	53%	7,440	5,900	1,520	8,800	1,700	26,000	5,900	22,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	5	16	6	38%	4,520	2,980	746	<6800	970	6,500	5,400	27,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	6	8	1	13%	4,210	2,330	822	<9100	580	580	2,800	16,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	1	22	3	14%	12,600	25,300	5,400	<5850	910	2,700	3,000	230,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	2	30	0	0%	<16420	10,300	1,880	<9350	--	--	2,200	75,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	3	16	4	25%	4,300	3,060	764	<6450	610	5,400	2,300	22,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	4	15	1	7%	3,110	1,930	498	<4400	590	590	3,200	16,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	5	16	1	6%	3,880	3,020	754	<6000	1,400	1,400	3,100	27,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	6	8	0	0%	<8600	2,170	769	<9100	--	--	2,600	16,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	1	21	1	5%	13,200	25,800	5,630	<6600	1,200	1,200	3,000	230,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	2	29	2	7%	8,480	10,400	1,930	<9400	2,400	4,600	2,200	75,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	3	15	3	20%	9,630	18,700	4,830	<8800	1,500	76,000	2,300	23,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	4	15	3	20%	2,660	1,740	450	<3600	1,700	2,700	3,100	16,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	5	15	2	13%	4,460	2,960	764	<7000	2,600	6,100	3,100	27,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	6	8	1	13%	4,300	2,170	769	<9100	1,300	1,300	2,800	16,000
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	1	22	22	100%	37,100	101,000	21,500	9,350	2,300	470,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	2	29	29	100%	8,010	6,330	1,180	5,900	1,950	31,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	3	16	16	100%	19,300	15,400	3,850	12,500	6,200	68,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	4	15	15	100%	14,500	6,150	1,590	13,000	6,400	29,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	5	16	16	100%	14,600	28,500	7,110	6,650	2,500	120,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	6	8	8	100%	10,800	12,300	4,340	5,630	1,770	35,000	--	--
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	1	22	21	95%	5,130	11,700	2,490	1,350	220	44,000	4,100	4,100
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	2	30	30	100%	1,230	932	170	740	220	3,700	--	--
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	3	16	16	100%	2,500	2,140	535	1,800	470	9,300	--	--
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	4	15	15	100%	1,790	846	218	1,800	650	3,400	--	--
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	5	16	15	94%	1,860	3,290	821	715	150	13,000	1,500	1,500
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	6	8	6	75%	1,070	1,080	383	770	380	3,100	940	1,100
Phase I/II	Surface	PAHs	Total PAH	µg/kg	1	22	22	100%	41,900	112,000	23,900	10,500	2,500	520,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	2	30	30	100%	8,940	7,120	1,300	6,500	400	34,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	3	16	16	100%	21,800	17,500	4,370	14,000	6,600	77,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	4	15	15	100%	16,400	6,990	1,800	15,000	7,100	33,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	5	16	16	100%	16,900	33,300	8,340	7,300	2,700	140,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	6	8	8	100%	11,800	13,500	4,780	6,130	1,770	38,000	--	--
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	1	22	22	100%	10,700	16,600	3,540	4,750	640	71,000	--	--
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	2	29	28	97%	5,080	7,760	1,440	1,800	580	29,000	270	270
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	3	16	16	100%	9,090	16,400	4,090	4,100	680	68,500	--	--
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	4	15	15	100%	7,840	12,200	3,150	3,900	2,100	51,000	--	--
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	5	16	15	94%	4,760	8,420	2,100	2,950	530	36,000	2,700	2,700
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	6	8	8	100%	1,490	1,840	649	785	250	5,800	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	1	22	22	100%	2,180	2,150	459	1,200	260	9,700	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	2	30	30	100%	1,110	1,440	263	640	150	8,000	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	3	16	16	100%	1,010	764	191	860	170	3,300	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	4	15	15	100%	1,190	754	195	1,000	190	3,500	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	5	16	16	100%	1,100	911	228	950	67	4,200	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	6	8	8	100%	619	543	192	400	190	1,700	--	--
Phase I/II	Surface	Metals	Aluminum	mg/kg	1	22	22	100%	14,500	5,730	1,220	14,200	3,290	31,500	--	--
Phase I/II	Surface	Metals	Aluminum	mg/kg	2	30	30	100%	15,100	4,500	822	15,700	3,200	25,400	--	--
Phase I/II	Surface	Metals	Aluminum	mg/kg	3	16	16	100%	14,400	5,240	1,310	14,700	4,210	23,400	--	--
Phase I/II	Surface	Metals	Aluminum	mg/kg	4	15	15	100%	13,600	1,970	509	13,400	10,300	17,200	--	--
Phase I/II	Surface	Metals	Aluminum	mg/kg	5	16	15	94%	13,500	4,930	1,230	14,200	8,040	19,500	1.1	1.1
Phase I/II	Surface	Metals	Aluminum	mg/kg	6	8	8	100%	11,000	3,740	1,320	10,500	8,010	19,700	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	1	22	22	100%	23.2	14.3	3.04	18.4	6	54.1	--	--

Table 4-6
Surface Sediment Summary Statistics – By USEPA Subunit

Phase	Depth Group	Analyte Group	Analyte	Units	USEPA Subunit[a]	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Surface	Metals	Arsenic	mg/kg	2	30	30	100%	12.7	5.28	0.965	11.5	1.5	24.3	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	3	16	16	100%	13.1	9.26	2.32	9.9	4.7	40.8	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	4	15	15	100%	11.2	1.51	0.389	10.8	9.4	15.2	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	5	16	16	100%	12.7	3.09	0.772	11.8	8	20.7	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	6	8	8	100%	10.1	4.51	1.59	8.63	5.7	17	--	--
Phase I/II	Surface	Metals	Cadmium	mg/kg	1	22	22	100%	4.48	5.12	1.09	2.4	0.52	21.5	--	--
Phase I/II	Surface	Metals	Cadmium	mg/kg	2	30	27	90%	1.64	2.03	0.371	1.05	0.3	8.8	0.091	1.5
Phase I/II	Surface	Metals	Cadmium	mg/kg	3	16	16	100%	1.59	1.64	0.411	1.25	0.29	7	--	--
Phase I/II	Surface	Metals	Cadmium	mg/kg	4	15	14	93%	1.7	0.786	0.203	1.9	0.66	2.9	0.11	0.11
Phase I/II	Surface	Metals	Cadmium	mg/kg	5	16	16	100%	1.75	1.34	0.336	1.4	0.23	5.7	--	--
Phase I/II	Surface	Metals	Cadmium	mg/kg	6	8	6	75%	0.648	0.585	0.207	0.478	0.24	1.7	0.04	0.39
Phase I/II	Surface	Metals	Chromium	mg/kg	1	22	22	100%	177	142	30.3	124	28	649	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	2	30	30	100%	90.4	52	9.49	76	28.5	265	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	3	16	16	100%	104	37.7	9.42	92.5	40.7	192	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	4	15	15	100%	131	39.3	10.2	119	75.2	243	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	5	16	16	100%	129	61.8	15.4	107	68.8	305	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	6	8	8	100%	78	44.5	15.7	64.2	33	165	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	1	22	22	100%	256	181	38.6	199	38.2	781	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	2	29	29	100%	132	83	15.4	92	35.7	369	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	3	15	15	100%	127	85.8	22.1	102	24.8	368	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	4	15	15	100%	125	31	8	123	65.2	186	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	5	16	16	100%	135	87.6	21.9	113	27.8	436	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	6	8	8	100%	55.5	41.3	14.6	32.2	23	132	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	1	22	22	100%	242	180	38.4	221	37.9	863	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	2	30	30	100%	148	160	29.2	100	33	882	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	3	16	16	100%	118	68.8	17.2	100	39.3	310	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	4	15	15	100%	138	41.3	10.7	129	70.7	224	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	5	16	16	100%	149	106	26.4	119	48.5	518	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	6	8	8	100%	64.2	35.5	12.6	63.1	22.4	119	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	1	22	22	100%	5,000	5,090	1,080	3,000	560	20,600	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	2	30	30	100%	1,730	1,290	235	1,200	365	5,600	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	3	16	16	100%	9,060	20,300	5,080	2,150	830	77,000	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	4	15	15	100%	2,670	1,250	322	2,400	1,040	6,400	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	5	16	16	100%	2,260	1,410	351	1,800	630	5,500	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	6	8	8	100%	989	930	329	640	270	3,000	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	1	22	22	100%	45.6	16.7	3.56	44.8	9.3	75.3	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	2	30	30	100%	34.4	9.02	1.65	33.3	17	66.1	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	3	16	16	100%	33.6	13.6	3.4	33.4	8.9	62.1	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	4	15	15	100%	33.4	4.22	1.09	34.8	24.4	39.5	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	5	16	16	100%	38.6	16.3	4.07	40	13.9	89.6	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	6	8	8	100%	21.2	4.16	1.47	20.1	16.2	28	--	--
Phase I/II	Surface	Metals	Selenium	mg/kg	1	22	16	73%	1.78	1.39	0.296	1.3	0.34	4.6	0.53	5
Phase I/II	Surface	Metals	Selenium	mg/kg	2	30	22	73%	1.09	0.927	0.169	1.05	0.2	4.2	0.51	1.3
Phase I/II	Surface	Metals	Selenium	mg/kg	3	16	12	75%	0.819	0.47	0.117	0.91	0.14	2	0.72	1.1
Phase I/II	Surface	Metals	Selenium	mg/kg	4	13	9	69%	0.536	0.153	0.0424	0.67	0.43	0.81	0.69	0.92
Phase I/II	Surface	Metals	Selenium	mg/kg	5	16	7	44%	0.819	0.758	0.19	<0.845	0.41	2.6	0.63	5.6
Phase I/II	Surface	Metals	Selenium	mg/kg	6	7	2	29%	1.08	0.776	0.293	<1	1	1.8	0.61	4
Phase I/II	Surface	Metals	Silver	mg/kg	1	19	19	100%	3.88	2.88	0.66	2.6	0.54	10.6	--	--

Table 4-6
Surface Sediment Summary Statistics – By USEPA Subunit

Phase	Depth Group	Analyte Group	Analyte	Units	USEPA Subunit[a]	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Surface	Metals	Silver	mg/kg	2	25	25	100%	2.11	1.17	0.235	1.8	0.36	5.3	--	--
Phase I/II	Surface	Metals	Silver	mg/kg	3	15	15	100%	3.15	3.71	0.957	1.9	0.73	15.9	--	--
Phase I/II	Surface	Metals	Silver	mg/kg	4	15	15	100%	2.26	0.437	0.113	2.3	1.45	3.1	--	--
Phase I/II	Surface	Metals	Silver	mg/kg	5	16	16	100%	2.02	0.918	0.23	2.05	0.32	4	--	--
Phase I/II	Surface	Metals	Silver	mg/kg	6	8	8	100%	0.827	0.615	0.218	0.54	0.29	1.9	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	1	22	22	100%	399	224	47.8	359	84.3	857	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	2	30	30	100%	259	242	44.1	189	74.7	1460	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	3	16	16	100%	235	138	34.4	200	65	606	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	4	15	15	100%	255	75.4	19.5	234	136	451	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	5	16	16	100%	204	55.6	13.9	195	73.5	330	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	6	8	8	100%	120	55	19.4	95.1	76.1	216	--	--
Phase I/II	Surface	Grain Size	Fines	%	1	22	22	100%	69.2	16	3.41	72.9	39.8	92.7	--	--
Phase I/II	Surface	Grain Size	Fines	%	2	30	30	100%	75.2	17.2	3.15	79	8.51	94.6	--	--
Phase I/II	Surface	Grain Size	Fines	%	3	16	16	100%	73.9	18.5	4.63	77.1	26.3	93.3	--	--
Phase I/II	Surface	Grain Size	Fines	%	4	15	15	100%	72	13.2	3.42	69.1	52.2	97	--	--
Phase I/II	Surface	Grain Size	Fines	%	5	16	16	100%	74.7	14.4	3.61	76.9	28.1	92.4	--	--
Phase I/II	Surface	Grain Size	Fines	%	6	8	8	100%	46.5	12.8	4.54	44.4	32.8	68.8	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	1	22	22	100%	29,200	15,400	3,270	27,400	1,800	58,100	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	2	30	30	100%	23,200	12,700	2,320	19,500	3,640	65,000	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	3	16	16	100%	22,600	9,700	2,430	22,200	6,900	42,000	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	4	15	15	100%	28,200	8,360	2,160	26,100	16,500	50,500	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	5	16	16	100%	24,200	10,200	2,550	22,000	7,600	51,000	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	6	8	8	100%	46.5	12.8	4.54	44.4	32.8	68.8	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	1	90	90	100%	76.7	132	13.9	26.9	0.434	833	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	2	10	10	100%	25.4	19.4	6.13	21.7	5.27	59.8	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	3	11	11	100%	68.4	56	16.9	61.5	2.2	201	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	4	43	43	100%	133	229	34.9	72.8	1.19	1100	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	5	50	50	100%	53.8	49.6	7.02	47.1	0.12	261	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	6	50	50	100%	116	295	41.7	24.5	1.77	1710	--	--
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	1	90	87	97%	375	446	47	225	7.4	2500	24	32
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	2	10	10	100%	107	44.3	14	115	52	180	--	--
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	3	11	11	100%	262	295	88.9	180	44	1100	--	--
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	4	43	42	98%	201	190	28.9	140	34	820	29	29
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	5	50	44	88%	160	149	21	135	6.9	750	21	40
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	6	50	45	90%	126	173	24.4	61.3	6.4	1000	26	46
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	1	90	90	100%	630,000	828,000	87,300	373,000	5,320	4,370,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	2	10	10	100%	214,000	94,200	29,800	218,000	84,300	386,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	3	11	11	100%	299,000	202,000	60,800	297,000	29,100	637,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	4	43	43	100%	592,000	907,000	138,000	376,000	10,500	5,030,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	5	50	50	100%	353,000	296,000	41,900	367,000	2,480	1,400,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	6	50	50	100%	331,000	551,000	77,900	142,000	9,070	2,560,000	--	--
Phase III	Surface	Pesticides	Dieldrin	pg/g	1	90	84	93%	2,280	4,800	506	968	39.4	37,400	47.7	85.4
Phase III	Surface	Pesticides	Dieldrin	pg/g	2	10	10	100%	1,060	648	205	885	332	2,500	--	--
Phase III	Surface	Pesticides	Dieldrin	pg/g	3	11	11	100%	1,150	1,040	314	1,030	81	3,930	--	--
Phase III	Surface	Pesticides	Dieldrin	pg/g	4	43	43	100%	2,170	3,470	530	1,260	111	19,300	--	--
Phase III	Surface	Pesticides	Dieldrin	pg/g	5	49	47	96%	1,340	2,200	314	972	44.5	15,400	39.7	50.3
Phase III	Surface	Pesticides	Dieldrin	pg/g	6	50	45	90%	1,060	2,150	304	413	53.7	13,000	221	1560
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	1	90	12	13%	134	346	36.5	<80.1	43.9	2,400	34.6	506
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	2	10	4	40%	200	354	112	<106	81.2	1,200	86.2	350
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	3	11	4	36%	60.6	37.7	11.4	<81.7	83.2	127	49.9	85.2
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	4	43	28	65%	132	175	26.6	100	14.6	1,060	35.4	390
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	5	49	22	45%	72.6	71.5	10.2	<54.7	29.5	354	33.8	394
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	6	46	11	24%	91.5	113	16.6	<51.2	40	371	37.9	939

Table 4-6
Surface Sediment Summary Statistics – By USEPA Subunit

Phase	Depth Group	Analyte Group	Analyte	Units	USEPA Subunit[a]	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	1	90	90	100%	5480	9650	1020	1530	38.4	46,200	--	--
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	2	10	10	100%	658	405	128	582	161	1,270	--	--
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	3	11	11	100%	1090	811	245	1070	92.9	2,990	--	--
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	4	43	43	100%	1870	2130	326	1110	42.1	10,300	--	--
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	5	49	49	100%	1000	1140	163	688	13.2	6,650	--	--
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	6	50	49	98%	1700	2530	358	944	27.3	14,100	221	221
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	1	90	90	100%	292,000	458,000	48,300	99,000	1,000	2,600,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	2	10	10	100%	64,800	81,000	25,600	33,500	12,000	280,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	3	11	11	100%	28,900	24,200	7,280	27,000	1,400	90,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	4	43	43	100%	41,100	28,100	4,290	38,000	920	130,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	5	50	50	100%	45,300	74,000	10,500	33,500	120	470,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	6	50	50	100%	39,900	66,500	9,400	17,000	400	390,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	1	90	90	100%	205,000	312,000	32,900	73,500	750	1,800,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	2	10	10	100%	48,400	60,800	19,200	25,500	8,100	210,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	3	11	11	100%	23,100	20,100	6,070	21,000	1,200	75,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	4	43	43	100%	31,900	22,100	3,360	29,000	710	100,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	5	50	50	100%	33,200	49,600	7,020	25,500	93	310,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	6	50	50	100%	29,100	44,200	6,260	12,700	340	230,000	--	--
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	1	90	88	98%	5,380	5,530	583	4,150	77	32,000	53.1	55.8
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	2	10	10	100%	5,140	3,690	1,170	4,550	630	13,000	--	--
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	3	11	11	100%	5,000	4,110	1,240	5,000	210	15,000	--	--
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	4	43	43	100%	7,320	5,490	838	7,100	230	24,000	--	--
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	5	49	46	94%	5,110	3,370	481	5,300	39	14,000	39.7	50.3
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	6	50	46	92%	2,520	2,930	414	1,400	220	13,000	221	335
Phase III	Surface	Pesticides	alpha-BHC	pg/g	1	90	61	68%	205	250	26.4	116	8.06	1260	46.2	395
Phase III	Surface	Pesticides	alpha-BHC	pg/g	2	10	4	40%	127	111	35.2	<106	46.8	382	86.2	350
Phase III	Surface	Pesticides	alpha-BHC	pg/g	3	11	6	55%	61.8	57.4	17.3	57.6	37.9	223	48.6	81.7
Phase III	Surface	Pesticides	alpha-BHC	pg/g	4	43	36	84%	62	38.8	5.92	58.6	9.17	172	39.4	268
Phase III	Surface	Pesticides	alpha-BHC	pg/g	5	49	42	86%	64	65.2	9.31	46	8.17	361	39	47.7
Phase III	Surface	Pesticides	alpha-BHC	pg/g	6	49	23	47%	75.1	102	14.5	<39.7	6.32	355	37.9	939
Phase III	Surface	Pesticides	beta-BHC	pg/g	1	90	39	43%	163	232	24.5	<88.3	6.63	1430	34.6	1,090
Phase III	Surface	Pesticides	beta-BHC	pg/g	2	10	3	30%	225	395	125	<106	68.6	1320	68.8	350
Phase III	Surface	Pesticides	beta-BHC	pg/g	3	11	5	45%	93.9	97.2	29.3	<74.3	57	296	48.6	81.7
Phase III	Surface	Pesticides	beta-BHC	pg/g	4	43	40	93%	99.6	54.2	8.27	98.4	20.7	205	40.9	53.5
Phase III	Surface	Pesticides	beta-BHC	pg/g	5	49	33	67%	47.2	27.8	3.97	50.1	6.24	127	32	72.6
Phase III	Surface	Pesticides	beta-BHC	pg/g	6	50	28	56%	99.9	110	15.5	67.3	9.63	412	37.9	939
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	1	88	65	74%	966	1130	121	704	50.2	4,830	45.1	394
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	2	10	8	80%	826	753	238	667	279	2,440	86.2	107
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	3	11	10	91%	1,050	1,150	347	843	102	4,270	49.9	49.9
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	4	43	38	88%	1,180	766	117	1110	52.2	3,060	40.9	212
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	5	49	44	90%	856	483	69	909	22.3	1,880	39.7	50.3
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	6	47	37	79%	439	467	68.1	269	41.6	1,930	39	280
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	1	90	87	97%	21,200	31,600	3,340	9,510	54	168,000	35	1,400
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	2	10	10	100%	4,230	2,820	893	3,910	684	7,950	--	--
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	3	11	11	100%	11,400	7,910	2,390	10,600	1,820	27,600	--	--
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	4	43	42	98%	8,710	6,670	1,020	6,620	527	33,800	45	45
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	5	50	48	96%	7,060	10,600	1,500	4,840	39	71,400	40	41
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	6	50	47	94%	9,450	11,000	1,560	5,520	99	48,100	42	68
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	1	90	90	100%	12,000	15,800	1,670	6,950	67	100,000	--	--
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	2	10	10	100%	5,440	3,860	1,220	4,250	1,200	11,000	--	--
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	3	11	11	100%	18,000	14,500	4,360	17,000	1,800	53,000	--	--
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	4	43	42	98%	13,200	9,750	1,490	10,000	1,100	46,000	45	45
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	5	50	49	98%	7,950	8,510	1,200	6,000	37	46,000	41	41

Table 4-6
Surface Sediment Summary Statistics – By USEPA Subunit

Phase	Depth Group	Analyte Group	Analyte	Units	USEPA Subunit[a]	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	6	50	50	100%	9,280	10,400	1,470	4,900	71	42,500	--	--
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	1	90	87	97%	1,780	3,020	318	885	7.4	17,000	35	1,400
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	2	10	10	100%	708	516	163	600	110	1,600	--	--
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	3	11	11	100%	1,610	1,080	327	1,500	130	3,200	--	--
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	4	43	42	98%	1,330	942	144	1,200	90	4,000	45	45
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	5	50	48	96%	1,160	1,890	268	730	5.2	12,000	40	41
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	6	50	47	94%	889	1,220	172	495	14	7,500	42	65
Phase III	Surface	PAHs	Total PAH	µg/kg	1	90	90	100%	13,800	18,500	1,950	7,900	67	110,000	--	--
Phase III	Surface	PAHs	Total PAH	µg/kg	2	10	10	100%	6,150	4,360	1,380	4,800	1400	13,000	--	--
Phase III	Surface	PAHs	Total PAH	µg/kg	3	11	11	100%	19,600	15,300	4,630	18,000	2000	56,000	--	--
Phase III	Surface	PAHs	Total PAH	µg/kg	4	43	42	98%	14,600	10,700	1,630	11,000	1100	50,000	45	45
Phase III	Surface	PAHs	Total PAH	µg/kg	5	50	49	98%	9,080	10,200	1,440	6,650	37	51,000	41	41
Phase III	Surface	PAHs	Total PAH	µg/kg	6	50	50	100%	10,200	11,400	1,610	5,450	71	46,000	--	--
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	1	90	66	73%	1,100	1,430	151	510	110	6,900	210	450
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	2	10	7	70%	283	165	52	370	110	540	300	460
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	3	11	9	82%	1,230	2,490	752	740	150	8,700	210	230
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	4	43	40	93%	1,100	2,460	375	500	96	16,000	210	290
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	5	49	43	88%	1,380	5,410	773	340	98	38,000	210	400
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	6	50	33	66%	1,040	4,350	616	280	110	31,000	210	460
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	1	90	86	96%	553	614	64.7	404	6.45	2,910	14.7	31.1
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	2	10	10	100%	83.2	55	17.4	72	11.1	201	--	--
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	3	11	11	100%	349	282	84.9	275	9.35	956	--	--
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	4	43	43	100%	189	108	16.4	165	47.6	507	--	--
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	5	50	47	94%	234	274	38.8	131	42.2	1290	14.6	135
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	6	50	49	98%	254	233	32.9	186	7.4	1240	28.5	28.5
Phase III	Surface	Metals	Aluminum	mg/kg	1	90	90	100%	13,600	5,540	584	14,600	3,250	25,100	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	2	10	10	100%	18,600	4,990	1,580	20,100	9,330	24,500	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	3	11	11	100%	12,400	5,310	1,600	11,800	3,580	20,700	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	4	43	43	100%	15,300	7,270	1,110	15,100	2,610	35,000	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	5	50	50	100%	15,000	5,810	822	17,100	1,650	23,300	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	6	50	50	100%	10,600	4,370	618	10,000	3,660	28,500	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	1	90	90	100%	25.8	22.3	2.35	19.1	2.26	115	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	2	10	10	100%	14.2	2.99	0.944	14.8	8.97	17.5	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	3	11	11	100%	10.1	4.17	1.26	9.84	3.24	16.8	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	4	43	43	100%	13.9	9.45	1.44	12.6	1.18	59.3	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	5	50	50	100%	17.3	15.9	2.25	13.6	1.8	85.4	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	6	50	50	100%	12	5.88	0.832	10.2	2.65	29.7	--	--
Phase III	Surface	Metals	Cadmium	mg/kg	1	90	90	100%	3.74	4.82	0.508	1.89	0.0592	24.6	--	--
Phase III	Surface	Metals	Cadmium	mg/kg	2	10	10	100%	0.858	0.411	0.13	0.889	0.392	1.69	--	--
Phase III	Surface	Metals	Cadmium	mg/kg	3	11	11	100%	1.42	1.87	0.563	0.766	0.145	6.43	--	--
Phase III	Surface	Metals	Cadmium	mg/kg	4	43	43	100%	1.51	1.53	0.234	1.08	0.0858	7.18	--	--
Phase III	Surface	Metals	Cadmium	mg/kg	5	50	48	96%	1.04	0.747	0.106	0.8	0.234	3.65	0.0867	0.103
Phase III	Surface	Metals	Cadmium	mg/kg	6	50	50	100%	0.919	1.34	0.189	0.493	0.112	6.8	--	--
Phase III	Surface	Metals	Chromium	mg/kg	1	90	90	100%	145	143	15.1	111	10.6	777	--	--
Phase III	Surface	Metals	Chromium	mg/kg	2	10	10	100%	77.1	27.4	8.68	80.8	32.2	115	--	--
Phase III	Surface	Metals	Chromium	mg/kg	3	11	11	100%	111	79.6	24	108	11.1	319	--	--
Phase III	Surface	Metals	Chromium	mg/kg	4	43	43	100%	140	107	16.3	116	9.1	520	--	--
Phase III	Surface	Metals	Chromium	mg/kg	5	50	50	100%	104	53.8	7.61	97.4	3.95	280	--	--
Phase III	Surface	Metals	Chromium	mg/kg	6	50	50	100%	97.9	129	18.3	54.3	12	691	--	--
Phase III	Surface	Metals	Copper	mg/kg	1	90	90	100%	237	207	21.9	187	8.9	924	--	--
Phase III	Surface	Metals	Copper	mg/kg	2	10	10	100%	89.2	35.2	11.1	95.6	42.2	142	--	--
Phase III	Surface	Metals	Copper	mg/kg	3	11	11	100%	99.3	66.8	20.1	66.9	11.1	240	--	--
Phase III	Surface	Metals	Copper	mg/kg	4	43	43	100%	121	69	10.5	111	9.14	319	--	--

Table 4-6
Surface Sediment Summary Statistics – By USEPA Subunit

Phase	Depth Group	Analyte Group	Analyte	Units	USEPA Subunit[a]	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase III	Surface	Metals	Copper	mg/kg	5	50	50	100%	112	71.3	10.1	99.1	1.5	319	--	--
Phase III	Surface	Metals	Copper	mg/kg	6	50	50	100%	74.5	85.3	12.1	46.1	8.85	466	--	--
Phase III	Surface	Metals	Lead	mg/kg	1	90	90	100%	253	303	31.9	189	12.8	2,190	--	--
Phase III	Surface	Metals	Lead	mg/kg	2	10	10	100%	98.7	36.2	11.5	110	46.6	147	--	--
Phase III	Surface	Metals	Lead	mg/kg	3	11	11	100%	217	400	121	77.9	10.2	1410	--	--
Phase III	Surface	Metals	Lead	mg/kg	4	43	43	100%	132	93.6	14.3	115	10.6	597	--	--
Phase III	Surface	Metals	Lead	mg/kg	5	50	50	100%	126	72.4	10.2	111	2.18	441	--	--
Phase III	Surface	Metals	Lead	mg/kg	6	50	50	100%	80.6	107	15.2	51.9	9.17	732	--	--
Phase III	Surface	Metals	Mercury	ng/g	1	90	90	100%	3,630	3,970	419	2,470	34.2	22,100	--	--
Phase III	Surface	Metals	Mercury	ng/g	2	10	10	100%	1,310	723	229	1,300	381	2,630	--	--
Phase III	Surface	Metals	Mercury	ng/g	3	11	11	100%	1,680	2,070	625	1,060	151	7,770	--	--
Phase III	Surface	Metals	Mercury	ng/g	4	43	43	100%	1,930	1,760	268	1,670	54.6	10,400	--	--
Phase III	Surface	Metals	Mercury	ng/g	5	50	50	100%	1,800	1,600	226	1,450	5.11	9,440	--	--
Phase III	Surface	Metals	Mercury	ng/g	6	50	50	100%	1,310	1,450	205	778	61.8	6,260	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	1	90	90	100%	1.3	1.55	0.163	0.9	0.056	11.9	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	2	10	10	100%	1.55	1.26	0.4	1.12	0.312	4.12	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	3	11	11	100%	1.07	0.835	0.252	0.988	0.21	2.9	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	4	43	43	100%	1.01	0.773	0.118	0.889	0.065	4.43	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	5	50	49	98%	1.02	0.817	0.116	0.81	0.027	4.8	0.058	0.058
Phase III	Surface	Metals	Methyl mercury	ng/g	6	50	50	100%	0.828	0.782	0.111	0.661	0.096	4.36	--	--
Phase III	Surface	Metals	Nickel	mg/kg	1	90	90	100%	47.8	34	3.58	45.8	8.31	282	--	--
Phase III	Surface	Metals	Nickel	mg/kg	2	10	10	100%	45	3.64	1.15	46.2	39.9	49.4	--	--
Phase III	Surface	Metals	Nickel	mg/kg	3	11	11	100%	34.3	15.6	4.71	32.2	5.45	57.2	--	--
Phase III	Surface	Metals	Nickel	mg/kg	4	43	43	100%	38.4	20	3.04	36.6	5.89	123	--	--
Phase III	Surface	Metals	Nickel	mg/kg	5	50	50	100%	44.7	27.9	3.94	41	3.83	182	--	--
Phase III	Surface	Metals	Nickel	mg/kg	6	50	50	100%	27.3	27.1	3.84	20.8	6.27	171	--	--
Phase III	Surface	Metals	Selenium	mg/kg	1	89	89	100%	1.63	1.62	0.172	1.05	0.0939	7.58	--	--
Phase III	Surface	Metals	Selenium	mg/kg	2	10	10	100%	0.662	0.244	0.0772	0.733	0.265	0.898	--	--
Phase III	Surface	Metals	Selenium	mg/kg	3	11	11	100%	0.605	0.268	0.0809	0.527	0.254	1.21	--	--
Phase III	Surface	Metals	Selenium	mg/kg	4	43	42	98%	0.78	0.362	0.0551	0.76	0.148	1.49	0.484	0.484
Phase III	Surface	Metals	Selenium	mg/kg	5	50	48	96%	0.767	0.537	0.076	0.68	0.192	3.74	0.347	0.412
Phase III	Surface	Metals	Selenium	mg/kg	6	50	50	100%	0.562	0.32	0.0452	0.459	0.121	1.48	--	--
Phase III	Surface	Metals	Silver	mg/kg	1	90	90	100%	2.39	2.22	0.234	1.94	0.0645	12	--	--
Phase III	Surface	Metals	Silver	mg/kg	2	10	10	100%	1.44	0.542	0.171	1.5	0.508	2.38	--	--
Phase III	Surface	Metals	Silver	mg/kg	3	11	11	100%	1.49	1.43	0.43	0.942	0.129	5.1	--	--
Phase III	Surface	Metals	Silver	mg/kg	4	43	43	100%	1.77	1.11	0.169	1.55	0.0759	5.58	--	--
Phase III	Surface	Metals	Silver	mg/kg	5	50	49	98%	1.76	0.988	0.14	1.75	0.0448	4.32	0.103	0.103
Phase III	Surface	Metals	Silver	mg/kg	6	50	50	100%	1.01	1.07	0.151	0.593	0.0687	4.93	--	--
Phase III	Surface	Metals	Zinc	mg/kg	1	90	90	100%	462	771	81.3	306	30.1	6810	--	--
Phase III	Surface	Metals	Zinc	mg/kg	2	10	10	100%	204	66.3	21	211	103	300	--	--
Phase III	Surface	Metals	Zinc	mg/kg	3	11	11	100%	208	118	35.6	166	28.9	483	--	--
Phase III	Surface	Metals	Zinc	mg/kg	4	43	43	100%	256	148	22.6	234	35.2	867	--	--
Phase III	Surface	Metals	Zinc	mg/kg	5	50	50	100%	223	97.8	13.8	219	8.18	551	--	--
Phase III	Surface	Metals	Zinc	mg/kg	6	50	50	100%	161	164	23.1	112	25.1	976	--	--
Phase III	Surface	Grain Size	Fines	%	1	90	90	100%	53.2	25.1	2.64	62.1	4.6	87.9	--	--
Phase III	Surface	Grain Size	Fines	%	2	10	10	100%	74.5	22.3	7.05	85.3	30.2	93.2	--	--
Phase III	Surface	Grain Size	Fines	%	3	11	11	100%	54.4	20.6	6.21	58.7	11.5	84.2	--	--
Phase III	Surface	Grain Size	Fines	%	4	43	43	100%	61.2	24.7	3.77	64.6	2.6	96.4	--	--
Phase III	Surface	Grain Size	Fines	%	5	50	50	100%	68.7	30.5	4.31	86.7	5.3	96.8	--	--

Table 4-6
Surface Sediment Summary Statistics – By USEPA Subunit

Phase	Depth Group	Analyte Group	Analyte	Units	USEPA Subunit[a]	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase III	Surface	Grain Size	Fines	%	6	50	50	100%	40.7	21.8	3.09	39.9	4.3	91.5	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	1	90	90	100%	27,400	20,900	2,200	26,700	1,030	151,000	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	2	10	10	100%	21,600	8,290	2,620	26,400	6,590	30,300	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	3	11	11	100%	23,200	15,200	4,600	20,900	1,520	54,900	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	4	43	43	100%	24,200	14,900	2,270	23,500	1,690	73,200	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	5	50	48	96%	22,600	11,600	1,640	22,000	1,190	51,800	668	689
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	6	50	50	100%	17,900	10,300	1,450	16,400	2,300	53,700	--	--

Notes:
[a]USEPA Subunits 1 through 6 are shown on Figure 2-8. Only sample within the NBSA boundary are included.
Non-detects included at the 1/2 quantitation limit for mean, standard deviation, and standard error estimates.
Non-detects evaluated at full quantitation limit for median estimate. If the median is a non-detect, it is indicated by the "less than" symbol (<).

When all data are reported as non-detect, the calculated mean and standard deviation are calculated using the full quantitation limit; a “less than” symbol (<) was assigned to the mean to indicate all values are below the quantitation limit.
Total Petroleum Hydrocarbons (TPH) is the sum of gasoline range organics (GRO) and diesel range organics (DRO).
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Acronyms and Abbreviations:
< = indicates the median is a non-detect or that the mean was calculated using all non-detects reported at the quantitation limit
% = percent
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligram per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/g = nanogram per gram
ng/kg = nanogram per kilogram
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
pg/g = picogram per gram
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
µg/kg = microgram per kilogram

Table 4-7
Surface Sediment Summary Statistics – By Geomorphic Area

Phase	Depth Group	Analyte Group	Analyte	Units	Geomorphic Unit	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Historically Disturbed Subtidal Flats	17	17	100%	107	95	23	78.1	11.1	423	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Industrial Waterfront	10	10	100%	73	71.3	22.5	54.4	1.68	230	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Intertidal Area	3	3	100%	94.7	79.8	46.1	132	3.08	149	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Navigation Channel	29	29	100%	55.4	42.8	7.95	42.6	8.54	160	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Port Channel	10	10	100%	59	25.5	8.07	53.1	19.6	98.9	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Sub-Tidal Flats	28	28	100%	76	110	20.8	58.8	0.947	592	--	--
Phase I/II	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Transitional Slopes	10	10	100%	37.1	22.3	7.04	33.4	5.01	82.1	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Historically Disturbed Subtidal Flats	17	17	100%	657	366	88.7	580	130	1,300	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Industrial Waterfront	10	10	100%	2,390	4,270	1350	565	67	14,000	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Intertidal Area	3	3	100%	674	629	363	680	42	1,300	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Navigation Channel	29	29	100%	557	607	113	300	79	2,900	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Port Channel	10	10	100%	949	1190	377	600	290	4,300	--	--
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Sub-Tidal Flats	28	26	93%	684	942	178	393	37	4,200	220	260
Phase I/II	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Transitional Slopes	10	10	100%	963	1640	518	480	180	5,600	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Historically Disturbed Subtidal Flats	17	17	100%	751,000	344,000	83,500	693,000	152,000	1,680,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Industrial Waterfront	10	10	100%	1,780,000	2,390,000	754,000	644,000	88,600	7,700,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Intertidal Area	3	3	100%	695,000	907,000	524,000	317,000	38,100	1,730,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Navigation Channel	29	29	100%	683,000	936,000	174,000	348,000	88,900	3,710,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Port Channel	10	10	100%	836,000	777,000	246,000	508,000	309,000	2,920,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Sub-Tidal Flats	28	28	100%	532,000	615,000	116,000	456,000	4,530	2,910,000	--	--
Phase I/II	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Transitional Slopes	10	10	100%	519,000	332,000	105,000	435,000	134,000	1,200,000	--	--
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	Historically Disturbed Subtidal Flats	17	6	35%	5,640	2,850	691	<7600	1,500	9,400	6,100	21,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	Industrial Waterfront	9	1	11%	21,100	28,500	9,510	<13000	6,200	6,200	2,600	150,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	Intertidal Area	3	0	0%	<21400	4,370	2,520	<19000	--	--	14,000	31,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	Navigation Channel	29	8	28%	10,900	13,800	2,550	<17000	670	11,000	5,800	150,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	Port Channel	10	2	20%	12,200	9,850	3,120	<15000	3,400	4,000	8,300	60,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	Sub-Tidal Flats	28	4	14%	20,100	43,300	8,190	<18000	1,700	12,000	5,300	460,000
Phase I/II	Surface	Pesticides	Dieldrin	pg/g	Transitional Slopes	10	1	10%	16,600	21,100	6,670	<19000	3,300	3,300	7,100	140,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	Historically Disturbed Subtidal Flats	16	9	56%	5,270	3,630	907	6,600	2,200	15,000	3,800	11,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	Industrial Waterfront	10	2	20%	11,900	14,200	4,490	<8100	4,200	18,000	2,200	79,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	Intertidal Area	3	0	0%	<10900	2,310	1,330	<9700	--	--	7,000	16,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	Navigation Channel	28	7	25%	6,950	7,480	1,410	<9200	1,400	22,000	3,100	75,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	Port Channel	9	1	11%	6,920	4,970	1,660	<8800	3,200	3,200	4,200	31,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	Sub-Tidal Flats	27	4	15%	9,930	22,100	4,260	<8600	1,200	4,300	2,800	230,000
Phase I/II	Surface	Pesticides	Heptachlor epoxide	pg/g	Transitional Slopes	10	1	10%	9,460	10,800	3,410	<10500	11,000	11,000	3,600	73,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	Historically Disturbed Subtidal Flats	17	4	24%	144,000	204,000	49,500	<21,000	1,600	5,700	6,600	1,000,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	Industrial Waterfront	10	0	0%	<918,000	592,000	187,000	<260,000	--	--	5,200	3,200,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	Intertidal Area	3	0	0%	<854,000	75,100	43,300	<940,000	--	--	680,000	940,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	Navigation Channel	29	2	7%	564,000	968,000	180,000	<850,000	2,200	2,300	5,800	7,400,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	Port Channel	10	0	0%	<952,000	391,000	123,000	<1,250,000	--	--	10,000	2,300,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	Sub-Tidal Flats	28	1	4%	729,000	1,030,000	195,000	<800,000	2,200	2,200	7,000	8,900,000
Phase I/II	Surface	Pesticides	Hexachlorobenzene	pg/g	Transitional Slopes	10	0	0%	<1,550,000	1,030,000	326,000	<890,000	--	--	7,000	5,700,000
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Historically Disturbed Subtidal Flats	11	11	100%	81,600	91,500	27,600	33,000	19,000	300,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Industrial Waterfront	5	5	100%	57,300	85,800	38,400	26,000	8,500	210,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Navigation Channel	12	12	100%	98,500	149,000	43,000	30,000	14,000	510,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Port Channel	4	4	100%	38,300	18,900	9,430	37,500	19,000	59,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Sub-Tidal Flats	5	5	100%	33,600	18,100	8,080	26,000	16,000	62,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Transitional Slopes	3	3	100%	51,000	59,900	34,600	20,000	13,000	120,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Historically Disturbed Subtidal Flats	17	17	100%	60,900	60,500	14,700	35,000	19,000	230,000	--	--
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Industrial Waterfront	10	9	90%	111,000	148,000	46,700	53,800	8,500	490,000	170,000	170,000
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Intertidal Area	3	1	33%	22,500	24,700	14,300	<19000	51,000	51,000	14,000	19,000
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Navigation Channel	29	25	86%	98,800	212,000	39,400	28,000	12,000	1,100,000	18,000	24,000
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Port Channel	10	9	90%	34,200	11,800	3,740	32,000	19,000	55,000	60,000	60,000
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Sub-Tidal Flats	28	23	82%	72,400	186,000	35,200	29,000	8,200	1,000,000	5,300	120,000
Phase I/II	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Transitional Slopes	10	7	70%	107,000	245,000	77,400	26,000	13,000	800,000	13,000	75,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Historically Disturbed Subtidal Flats	17	11	65%	4,710	5,820	1,410	5,300	--	26,000	6,600	13,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Industrial Waterfront	10	5	50%	15,200	14,700	4,660	13,000	390	32,000	6,600	79,000

Table 4-7
Surface Sediment Summary Statistics – By Geomorphic Area

Phase	Depth Group	Analyte Group	Analyte	Units	Geomorphic Unit	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Intertidal Area	3	0	0%	<12900	4,000	2,310	<9700	--	--	7,000	22,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Navigation Channel	29	11	38%	7,630	7,680	1,430	<9400	1,600	24,000	2,300	75,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Port Channel	10	4	40%	9,050	4,260	1,350	<12500	4,600	13,000	6,900	31,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Sub-Tidal Flats	28	5	18%	10,700	21,600	4,070	<9250	1,700	7,300	2,800	230,000
Phase I/II	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Transitional Slopes	10	3	30%	8,640	11,000	3,470	<9600	970	3,200	6,500	73,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	Historically Disturbed Subtidal Flats	17	2	12%	2,550	1,510	366	<3800	590	910	3,000	11,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	Industrial Waterfront	10	1	10%	9,160	14,600	4,630	<3900	2,600	2,600	2,200	79,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	Intertidal Area	3	0	0%	<10900	2,310	1,330	<9700	--	--	7,000	16,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	Navigation Channel	29	3	10%	5,320	6,950	1,290	<7700	610	1,700	2,300	75,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	Port Channel	10	1	10%	6,680	4,790	1,520	<7850	5,400	5,400	4,200	31,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	Sub-Tidal Flats	28	2	7%	9,880	21,800	4,120	<8850	1,400	2,700	2,800	230,000
Phase I/II	Surface	Pesticides	alpha-BHC	pg/g	Transitional Slopes	10	0	0%	<17140	11,000	3,490	<9600	--	--	3,600	73,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	Historically Disturbed Subtidal Flats	16	4	25%	2,620	1,590	397	<3250	1,200	6,100	3,000	11,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	Industrial Waterfront	9	1	11%	10,900	15,100	5,020	<6600	1,300	1,300	2,200	79,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	Intertidal Area	3	0	0%	<10900	2,310	1,330	<9700	--	--	7,000	16,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	Navigation Channel	28	2	7%	5,400	7,030	1,330	<7600	1,500	3,100	2,300	75,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	Port Channel	9	2	22%	14,900	23,400	7,810	<15000	2,400	76,000	4,200	31,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	Sub-Tidal Flats	28	2	7%	9,930	21,800	4,120	<8850	1,700	2,600	2,800	230,000
Phase I/II	Surface	Pesticides	beta-BHC	pg/g	Transitional Slopes	10	1	10%	8,830	10,900	3,440	<9600	4,600	4,600	3,600	73,000
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	Historically Disturbed Subtidal Flats	17	17	100%	11,900	6,920	1,680	9,600	4,800	29,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	Industrial Waterfront	10	10	100%	71,800	146,000	46,100	14,500	2,300	470,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	Intertidal Area	3	3	100%	12,500	11,500	6,610	10,000	2,500	25,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	Navigation Channel	29	29	100%	12,600	13,000	2,420	8,700	2,500	68,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	Port Channel	9	9	100%	10,900	8,240	2,750	9,300	3,600	31,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	Sub-Tidal Flats	28	28	100%	14,700	22,200	4,200	7,800	1,770	120,000	--	--
Phase I/II	Surface	PAHs	Total HMW PAHs	µg/kg	Transitional Slopes	10	10	100%	6,080	2,910	919	5,500	1,950	10,000	--	--
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	Historically Disturbed Subtidal Flats	17	17	100%	1,620	928	225	1,500	690	3,900	--	--
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	Industrial Waterfront	10	10	100%	9,970	16,500	5,210	2,650	220	44,000	--	--
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	Intertidal Area	3	3	100%	1,750	1,390	801	2,500	150	2,600	--	--
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	Navigation Channel	29	29	100%	1,720	1,710	318	1,100	220	9,300	--	--
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	Port Channel	10	10	100%	1,250	1,030	325	980	370	3,700	--	--
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	Sub-Tidal Flats	28	25	89%	1,830	2,580	488	970	370	13,000	940	4,100
Phase I/II	Surface	PAHs	Total LMW PAHs	µg/kg	Transitional Slopes	10	9	90%	894	482	152	763	400	1,900	1,500	1,500
Phase I/II	Surface	PAHs	Total PAH	µg/kg	Historically Disturbed Subtidal Flats	17	17	100%	13,600	7,890	1,910	11,300	5,500	33,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	Industrial Waterfront	10	10	100%	81,500	162,000	51,200	17,000	2,500	520,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	Intertidal Area	3	3	100%	14,600	12,700	7,350	13,000	2,700	28,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	Navigation Channel	29	29	100%	14,300	14,700	2,720	10,000	2,800	77,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	Port Channel	10	10	100%	10,900	9,290	2,940	9,550	400	34,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	Sub-Tidal Flats	28	28	100%	16,600	25,900	4,900	8,680	1,770	140,000	--	--
Phase I/II	Surface	PAHs	Total PAH	µg/kg	Transitional Slopes	10	10	100%	6,850	3,240	1,030	6,100	2,750	11,000	--	--
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Historically Disturbed Subtidal Flats	17	17	100%	4,660	3,430	831	3,850	640	14,000	--	--
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Industrial Waterfront	10	9	90%	13,200	21,300	6,730	5,000	860	68,500	270	270
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Intertidal Area	3	3	100%	19,100	27,700	16,000	5,800	530	51,000	--	--
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Navigation Channel	29	29	100%	7,140	14,800	2,750	2,100	680	71,000	--	--
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Port Channel	9	9	100%	7,100	7,340	2,450	4,300	1,300	25,000	--	--
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Sub-Tidal Flats	28	27	96%	4,530	7,310	1,380	2,650	250	36,000	2,700	2,700
Phase I/II	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Transitional Slopes	10	10	100%	6,690	7,780	2,460	2,600	580	24,000	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Historically Disturbed Subtidal Flats	17	17	100%	1,230	711	173	1,000	700	3,500	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Industrial Waterfront	10	10	100%	1,690	1,200	380	1,400	280	3,500	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Intertidal Area	3	3	100%	1,450	1,810	1,050	770	67	3,500	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Navigation Channel	29	29	100%	997	1,110	206	640	170	5,400	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Port Channel	10	10	100%	1,710	2,240	707	1,010	610	8,000	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Sub-Tidal Flats	28	28	100%	1,420	1,870	354	1,000	190	9,700	--	--
Phase I/II	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Transitional Slopes	10	10	100%	991	592	187	705	150	2,000	--	--
Phase I/II	Surface	Metals	Aluminum	mg/kg	Historically Disturbed Subtidal Flats	17	17	100%	12,800	2,080	503	13,300	8,780	16,300	--	--
Phase I/II	Surface	Metals	Aluminum	mg/kg	Industrial Waterfront	10	10	100%	14,400	8,930	2,830	14,800	3,200	31,500	--	--
Phase I/II	Surface	Metals	Aluminum	mg/kg	Intertidal Area	3	3	100%	12,200	4,630	2,670	11,500	8,040	17,200	--	--

Table 4-7
Surface Sediment Summary Statistics – By Geomorphic Area

Phase	Depth Group	Analyte Group	Analyte	Units	Geomorphic Unit	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Surface	Metals	Aluminum	mg/kg	Navigation Channel	29	29	100%	14,000	3,890	723	14,800	4,210	21,700	--	--
Phase I/II	Surface	Metals	Aluminum	mg/kg	Port Channel	10	10	100%	19,200	2,700	854	19,100	14,700	25,400	--	--
Phase I/II	Surface	Metals	Aluminum	mg/kg	Sub-Tidal Flats	28	27	96%	13,300	4,800	907	13,500	3,290	20,500	1.1	1.1
Phase I/II	Surface	Metals	Aluminum	mg/kg	Transitional Slopes	10	10	100%	14,200	2,760	874	14,500	7,960	17,300	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	Historically Disturbed Subtidal Flats	17	17	100%	16.3	11.5	2.79	11.9	9	54.1	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	Industrial Waterfront	10	10	100%	19.5	14.3	4.52	18.4	1.5	47.1	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	Intertidal Area	3	3	100%	12.1	4.31	2.49	11.7	8	16.6	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	Navigation Channel	29	29	100%	12.1	6.48	1.2	10.8	4.7	32.2	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	Port Channel	10	10	100%	14.8	5.51	1.74	12.1	9.5	27.6	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	Sub-Tidal Flats	28	28	100%	14.7	9.83	1.86	11.8	5.7	51.8	--	--
Phase I/II	Surface	Metals	Arsenic	mg/kg	Transitional Slopes	10	10	100%	13.5	5.69	1.8	11.7	5.75	23.7	--	--
Phase I/II	Surface	Metals	Cadmium	mg/kg	Historically Disturbed Subtidal Flats	17	17	100%	2.06	0.908	0.22	1.8	0.905	4.3	--	--
Phase I/II	Surface	Metals	Cadmium	mg/kg	Industrial Waterfront	10	10	100%	3.19	3.4	1.08	1.6	0.52	11	--	--
Phase I/II	Surface	Metals	Cadmium	mg/kg	Intertidal Area	3	3	100%	1.18	0.891	0.515	1.3	0.23	2	--	--
Phase I/II	Surface	Metals	Cadmium	mg/kg	Navigation Channel	29	28	97%	1.72	2.74	0.508	0.75	0.29	12.3	0.14	0.14
Phase I/II	Surface	Metals	Cadmium	mg/kg	Port Channel	10	8	80%	2.17	2.47	0.78	1.6	0.78	8.8	0.091	1.5
Phase I/II	Surface	Metals	Cadmium	mg/kg	Sub-Tidal Flats	28	25	89%	2.45	4.13	0.78	1.4	0.24	21.5	0.04	0.39
Phase I/II	Surface	Metals	Cadmium	mg/kg	Transitional Slopes	10	10	100%	2.12	2.1	0.665	1.3	0.77	7.8	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	Historically Disturbed Subtidal Flats	17	17	100%	125	38.4	9.31	113	75.9	243	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	Industrial Waterfront	10	10	100%	133	94.2	29.8	124	28.5	329	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	Intertidal Area	3	3	100%	124	56.7	32.7	120	68.8	182	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	Navigation Channel	29	29	100%	103	79.6	14.8	84.4	40.7	402	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	Port Channel	10	10	100%	124	57.1	18.1	97.6	77.6	265	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	Sub-Tidal Flats	28	28	100%	138	118	22.2	118	28	649	--	--
Phase I/II	Surface	Metals	Chromium	mg/kg	Transitional Slopes	10	10	100%	102	51.1	16.2	83	33	218	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	Historically Disturbed Subtidal Flats	17	17	100%	146	57.9	14.1	127	98.3	332	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	Industrial Waterfront	10	10	100%	206	132	41.8	189	38.2	429	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	Intertidal Area	3	3	100%	106	68.5	39.6	132	27.8	157	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	Navigation Channel	27	27	100%	137	129	24.9	92	24.8	598	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	Port Channel	10	10	100%	160	84.4	26.7	119	90.2	369	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	Sub-Tidal Flats	28	28	100%	153	154	29.1	121	23	781	--	--
Phase I/II	Surface	Metals	Copper	mg/kg	Transitional Slopes	10	10	100%	139	87.5	27.7	101	35.7	291	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	Historically Disturbed Subtidal Flats	17	17	100%	151	68.2	16.5	127	83.8	364	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	Industrial Waterfront	10	10	100%	211	125	39.5	202	37.9	453	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	Intertidal Area	3	3	100%	120	72.3	41.7	119	48.5	193	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	Navigation Channel	29	29	100%	123	94.5	17.5	94.3	39.3	448	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	Port Channel	10	10	100%	207	241	76.1	119	83.9	882	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	Sub-Tidal Flats	28	28	100%	168	174	32.9	120	22.4	863	--	--
Phase I/II	Surface	Metals	Lead	mg/kg	Transitional Slopes	10	10	100%	123	61.1	19.3	99.9	33	214	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	Historically Disturbed Subtidal Flats	17	17	100%	2,840	1,030	251	2,300	1,700	4,900	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	Industrial Waterfront	10	10	100%	12,200	23,300	7,370	3,600	560	77,000	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	Intertidal Area	3	3	100%	1,710	1,140	658	1,600	630	2,900	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	Navigation Channel	29	29	100%	2,360	3,680	684	1,300	520	20,600	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	Port Channel	10	10	100%	5,660	11,700	3,700	1,850	1,000	38,800	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	Sub-Tidal Flats	28	28	100%	2,450	2,120	400	2,000	270	9,500	--	--
Phase I/II	Surface	Metals	Mercury	ng/g	Transitional Slopes	10	10	100%	2,210	1,770	560	1,400	365	5,600	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	Historically Disturbed Subtidal Flats	17	17	100%	38.3	11.3	2.75	37.3	25	75.3	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	Industrial Waterfront	10	10	100%	38.5	18.1	5.74	39.4	13.8	70.3	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	Intertidal Area	3	3	100%	26.5	12	6.91	28	13.9	37.7	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	Navigation Channel	29	29	100%	33.6	13.3	2.47	31.2	8.9	71.8	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	Port Channel	10	10	100%	41.3	10.2	3.24	37.7	29	66.1	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	Sub-Tidal Flats	28	28	100%	35.2	15.7	2.96	35	9.3	89.6	--	--
Phase I/II	Surface	Metals	Nickel	mg/kg	Transitional Slopes	10	10	100%	37.4	9.14	2.89	39.6	17	48.1	--	--
Phase I/II	Surface	Metals	Selenium	mg/kg	Historically Disturbed Subtidal Flats	17	11	65%	0.829	0.812	0.197	0.76	0.34	3.3	0.53	5
Phase I/II	Surface	Metals	Selenium	mg/kg	Industrial Waterfront	10	7	70%	1.39	1.09	0.345	1.25	0.2	3.2	0.53	4
Phase I/II	Surface	Metals	Selenium	mg/kg	Intertidal Area	2	2	100%	1.33	0.665	0.47	1.33	0.86	1.8	--	--
Phase I/II	Surface	Metals	Selenium	mg/kg	Navigation Channel	29	22	76%	0.959	0.607	0.113	0.93	0.14	2.3	0.72	4.6

Table 4-7
Surface Sediment Summary Statistics – By Geomorphic Area

Phase	Depth Group	Analyte Group	Analyte	Units	Geomorphic Unit	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase I/II	Surface	Metals	Selenium	mg/kg	Port Channel	10	9	90%	1.39	1.18	0.372	1.1	0.26	4.2	1.1	1.1
Phase I/II	Surface	Metals	Selenium	mg/kg	Sub-Tidal Flats	26	12	46%	1.25	1.34	0.264	<0.905	0.43	4.6	0.61	5.6
Phase I/II	Surface	Metals	Selenium	mg/kg	Transitional Slopes	10	5	50%	0.76	0.572	0.181	0.875	0.41	2.1	0.51	0.96
Phase I/II	Surface	Metals	Silver	mg/kg	Historically Disturbed Subtidal Flats	14	14	100%	2.23	0.417	0.111	2.13	1.6	3.1	--	--
Phase I/II	Surface	Metals	Silver	mg/kg	Industrial Waterfront	10	10	100%	3.71	4.67	1.48	2.8	0.36	15.9	--	--
Phase I/II	Surface	Metals	Silver	mg/kg	Intertidal Area	3	3	100%	1.77	1.39	0.805	1.9	0.32	3.1	--	--
Phase I/II	Surface	Metals	Silver	mg/kg	Navigation Channel	24	24	100%	2.61	2.46	0.502	1.75	0.73	10.6	--	--
Phase I/II	Surface	Metals	Silver	mg/kg	Port Channel	9	9	100%	2.99	1.25	0.418	2.7	1.7	5.2	--	--
Phase I/II	Surface	Metals	Silver	mg/kg	Sub-Tidal Flats	28	28	100%	2.1	1.63	0.309	2.05	0.29	7.5	--	--
Phase I/II	Surface	Metals	Silver	mg/kg	Transitional Slopes	10	10	100%	2.47	1.3	0.411	2.2	0.585	5.3	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	Historically Disturbed Subtidal Flats	17	17	100%	266	82.5	20	240	171	451	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	Industrial Waterfront	10	10	100%	327	186	58.7	314	90.1	606	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	Intertidal Area	3	3	100%	203	123	71.2	216	73.5	319	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	Navigation Channel	29	29	100%	234	171	31.8	186	65	857	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	Port Channel	10	10	100%	399	382	121	261	175	1460	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	Sub-Tidal Flats	28	28	100%	244	178	33.7	200	76.1	833	--	--
Phase I/II	Surface	Metals	Zinc	mg/kg	Transitional Slopes	10	10	100%	236	109	34.6	193	74.7	410	--	--
Phase I/II	Surface	Grain Size	Fines	% passed	Historically Disturbed Subtidal Flats	17	17	100%	70.2	8.82	2.14	70.3	45.3	82	--	--
Phase I/II	Surface	Grain Size	Fines	% passed	Industrial Waterfront	10	10	100%	70	27	8.53	75.1	8.51	97	--	--
Phase I/II	Surface	Grain Size	Fines	% passed	Intertidal Area	3	3	100%	56.7	28	16.2	57.8	28.1	84.1	--	--
Phase I/II	Surface	Grain Size	Fines	% passed	Navigation Channel	29	29	100%	73.7	13.7	2.54	77.9	26.3	86.2	--	--
Phase I/II	Surface	Grain Size	Fines	% passed	Port Channel	10	10	100%	88.8	5.2	1.64	90.1	78.2	93.6	--	--
Phase I/II	Surface	Grain Size	Fines	% passed	Sub-Tidal Flats	28	28	100%	64.5	19.1	3.62	65.6	32.8	94.7	--	--
Phase I/II	Surface	Grain Size	Fines	% passed	Transitional Slopes	10	10	100%	71.3	13.9	4.39	74.3	50.5	94.6	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	Historically Disturbed Subtidal Flats	17	17	100%	27,100	10,000	2,430	27,500	12,000	50,500	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	Industrial Waterfront	10	10	100%	27,800	17,000	5,360	32,300	3,640	58,100	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	Intertidal Area	3	3	100%	19,200	10,500	6,050	22,000	7,600	28,000	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	Navigation Channel	29	29	100%	23,100	10,900	2,030	20,000	6,900	52,600	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	Port Channel	10	10	100%	30,600	14,100	4,460	28,100	15,000	65,000	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	Sub-Tidal Flats	28	28	100%	27,000	23,800	4,500	22,000	1,800	135,000	--	--
Phase I/II	Surface	TOC	Total organic carbon (TOC)	mg/kg	Transitional Slopes	10	10	100%	22,700	13,000	4,110	18,500	5,800	51,000	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Historically Disturbed Subtidal Flats	27	27	100%	162	232	45	78	6	1,100	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Industrial Waterfront	31	31	100%	45.6	53.3	9.56	32.1	2.83	271	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Intertidal Area	9	9	100%	47	38.6	12.9	31.7	3.79	110	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Navigation Channel	22	22	100%	60.5	77.7	16.6	41.2	2.2	341	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Port Channel	3	3	100%	39.2	17.9	10.3	29.7	28.1	59.8	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Sub-Tidal Flats	151	151	100%	90.8	208	16.9	33.7	0.12	1710	--	--
Phase III	Surface	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Transitional Slopes	11	11	100%	68.9	53.3	16.1	49.6	11.4	188	--	--
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Historically Disturbed Subtidal Flats	27	27	100%	397	504	97	190	29	2,500	--	--
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Industrial Waterfront	31	31	100%	304	399	71.7	185	14	2,000	--	--
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Intertidal Area	9	8	89%	138	135	45.1	140	20	435	21	21
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Navigation Channel	22	22	100%	239	275	58.7	170	44	1,100	--	--
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Port Channel	3	3	100%	99.3	37.2	21.5	110	58	130	--	--
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Sub-Tidal Flats	151	137	91%	201	265	21.6	120	6.4	1,500	21	46
Phase III	Surface	PCBs	Total PCBs (9 Aroclors)	µg/kg	Transitional Slopes	11	11	100%	307	241	72.8	270	28	800	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Historically Disturbed Subtidal Flats	27	27	100%	916,000	1,010,000	194,000	535,000	82,600	4,370,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Industrial Waterfront	31	31	100%	564,000	842,000	151,000	323,000	30,300	4,000,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Intertidal Area	9	9	100%	210,000	179,000	59,600	162,000	42,400	638,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Navigation Channel	22	22	100%	292,000	234,000	49,800	267,000	29,100	1,060,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Port Channel	3	3	100%	203,000	88,500	51,100	248,000	101,000	260,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Sub-Tidal Flats	151	151	100%	439,000	651,000	52,900	236,000	2,480	5,030,000	--	--
Phase III	Surface	PCBs	Total PCBs congener (209 specified)	ng/kg	Transitional Slopes	11	11	100%	404,000	287,000	86,500	404,000	44,300	946,000	--	--
Phase III	Surface	Pesticides	Dieldrin	pg/g	Historically Disturbed Subtidal Flats	27	27	100%	2,790	3,510	676	1,710	312	13,700	--	--
Phase III	Surface	Pesticides	Dieldrin	pg/g	Industrial Waterfront	31	31	100%	1,970	3,640	655	1,000	106	20,900	--	--
Phase III	Surface	Pesticides	Dieldrin	pg/g	Intertidal Area	9	7	78%	887	522	174	877	410	1,760	1020	1560
Phase III	Surface	Pesticides	Dieldrin	pg/g	Navigation Channel	22	22	100%	1,340	1,690	359	1,020	81	8,060	--	--
Phase III	Surface	Pesticides	Dieldrin	pg/g	Port Channel	3	3	100%	1,730	692	400	1,530	1160	2,500	--	--

Table 4-7
Surface Sediment Summary Statistics – By Geomorphic Area

Phase	Depth Group	Analyte Group	Analyte	Units	Geomorphic Unit	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase III	Surface	Pesticides	Dieldrin	pg/g	Sub-Tidal Flats	150	139	93%	1,610	3,890	318	777	39.4	37,400	39.7	335
Phase III	Surface	Pesticides	Dieldrin	pg/g	Transitional Slopes	11	11	100%	1,820	1,300	392	1,300	600	4,300	--	--
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	Historically Disturbed Subtidal Flats	27	10	37%	167	452	86.9	<78.6	66.8	2,400	39.5	394
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	Industrial Waterfront	31	19	61%	178	234	42	103	47.8	1,170	34.6	189
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	Intertidal Area	9	6	67%	131	165	54.9	115	51.2	552	37.5	120
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	Navigation Channel	22	6	27%	68.2	41.3	8.81	<87.6	81.2	127	49.9	350
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	Port Channel	3	2	67%	450	650	375	107	97.1	1,200	107	107
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	Sub-Tidal Flats	146	36	25%	91.6	193	16	<60.7	14.6	1,970	34.7	939
Phase III	Surface	Pesticides	Heptachlor epoxide	pg/g	Transitional Slopes	11	2	18%	67.6	69.9	21.1	<85.5	90.5	128	33.8	506
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	Historically Disturbed Subtidal Flats	27	27	100%	3,620	6,360	1,220	1,380	170	31,200	--	--
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	Industrial Waterfront	31	31	100%	1,940	4,360	783	984	169	24,800	--	--
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	Intertidal Area	9	9	100%	1,110	591	197	1,270	298	1,960	--	--
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	Navigation Channel	22	22	100%	1,080	1,310	280	770	92.9	6,190	--	--
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	Port Channel	3	3	100%	1,070	313	181	1,240	713	1,270	--	--
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	Sub-Tidal Flats	150	149	99%	3,370	7,290	595	957	13.2	46,200	221	221
Phase III	Surface	Pesticides	Hexachlorobenzene	pg/g	Transitional Slopes	11	11	100%	2,340	2,540	767	1,210	414	8,920	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Historically Disturbed Subtidal Flats	27	27	100%	113,000	153,000	29,400	50,000	11,000	600,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Industrial Waterfront	31	31	100%	84,200	124,000	22,200	37,000	5,700	540,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Intertidal Area	9	9	100%	95,500	130,000	43,300	33,000	7,900	390,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Navigation Channel	22	22	100%	70,300	116,000	24,700	30,000	1,400	510,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Port Channel	3	3	100%	72,700	33,500	19,400	90,000	34,000	94,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Sub-Tidal Flats	151	151	100%	156,000	374,000	30,400	30,000	120	2,600,000	--	--
Phase III	Surface	Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	Transitional Slopes	11	11	100%	130,000	143,000	43,000	88,000	25,000	510,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Historically Disturbed Subtidal Flats	27	27	100%	85,300	114,000	22,000	42,000	8,800	490,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Industrial Waterfront	31	31	100%	64,300	93,600	16,800	29,000	4,200	400,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Intertidal Area	9	9	100%	68,100	82,400	27,500	28,000	6,200	230,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Navigation Channel	22	22	100%	59,100	109,000	23,300	23,500	1,200	500,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Port Channel	3	3	100%	54,300	24,900	14,400	64,000	26,000	73,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Sub-Tidal Flats	151	151	100%	107,000	253,000	20,600	23,000	93	1,800,000	--	--
Phase III	Surface	Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	Transitional Slopes	11	11	100%	95,500	101,000	30,500	66,000	19,000	360,000	--	--
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Historically Disturbed Subtidal Flats	27	27	100%	7,440	4,810	925	7,200	1,350	17,000	--	--
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Industrial Waterfront	31	31	100%	6,830	5,240	941	6,200	460	22,000	--	--
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Intertidal Area	9	9	100%	5,420	3,640	1,210	5,100	1,600	13,000	--	--
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Navigation Channel	22	22	100%	5,070	4,020	857	4,600	210	16,000	--	--
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Port Channel	3	3	100%	8,630	4,170	2,410	8,200	4,700	13,000	--	--
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Sub-Tidal Flats	150	141	94%	4,050	4,680	382	2,850	39	32,000	39.7	335
Phase III	Surface	Pesticides	Total alpha + gamma chlordane	pg/g	Transitional Slopes	11	11	100%	6,860	3,880	1,170	5,900	1,400	14,000	--	--
Phase III	Surface	Pesticides	alpha-BHC	pg/g	Historically Disturbed Subtidal Flats	27	26	96%	163	255	49.1	78.6	24.3	1260	78.6	78.6
Phase III	Surface	Pesticides	alpha-BHC	pg/g	Industrial Waterfront	31	23	74%	76.5	123	22.1	42.9	8.61	596	40.2	189
Phase III	Surface	Pesticides	alpha-BHC	pg/g	Intertidal Area	9	5	56%	151	333	111	51.2	33.9	1040	47.7	120
Phase III	Surface	Pesticides	alpha-BHC	pg/g	Navigation Channel	22	12	55%	86.6	66.5	14.2	84	37.9	248	48.6	350
Phase III	Surface	Pesticides	alpha-BHC	pg/g	Port Channel	3	2	67%	225	165	95.1	240	240	382	107	107
Phase III	Surface	Pesticides	alpha-BHC	pg/g	Sub-Tidal Flats	149	94	63%	117	165	13.5	62	6.32	1050	37.9	939
Phase III	Surface	Pesticides	alpha-BHC	pg/g	Transitional Slopes	11	10	91%	155	131	39.5	111	24.8	377	90.9	90.9
Phase III	Surface	Pesticides	beta-BHC	pg/g	Historically Disturbed Subtidal Flats	27	17	63%	101	69	13.3	96	25.7	244	39.4	376
Phase III	Surface	Pesticides	beta-BHC	pg/g	Industrial Waterfront	31	19	61%	115	157	28.2	69.5	13.4	707	32	1090
Phase III	Surface	Pesticides	beta-BHC	pg/g	Intertidal Area	9	6	67%	226	457	152	57.1	56.8	1430	47.7	77.8
Phase III	Surface	Pesticides	beta-BHC	pg/g	Navigation Channel	22	9	41%	97.3	80.6	17.2	<91	57	296	48.6	350
Phase III	Surface	Pesticides	beta-BHC	pg/g	Port Channel	3	2	67%	563	668	386	316	316	1320	107	107
Phase III	Surface	Pesticides	beta-BHC	pg/g	Sub-Tidal Flats	150	87	58%	109	147	12	70.5	6.24	999	37.9	939
Phase III	Surface	Pesticides	beta-BHC	pg/g	Transitional Slopes	11	8	73%	101	94.3	28.4	85.5	28	304	85.5	506
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	Historically Disturbed Subtidal Flats	27	27	100%	1,300	740	142	1200	308	2,810	--	--
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	Industrial Waterfront	31	26	84%	906	799	144	851	79.9	2,800	45.7	189
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	Intertidal Area	9	8	89%	792	617	206	749	269	2,050	77.8	77.8
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	Navigation Channel	22	20	91%	1,080	1,200	256	798	102	4,830	49.9	86.2
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	Port Channel	3	2	67%	1,250	1,190	689	1,270	1,270	2,440	107	107
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	Sub-Tidal Flats	145	108	74%	695	750	62.3	564	22.3	4,660	39	394

Table 4-7
Surface Sediment Summary Statistics – By Geomorphic Area

Phase	Depth Group	Analyte Group	Analyte	Units	Geomorphic Unit	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase III	Surface	Pesticides	cis-Nonachlor	pg/g	Transitional Slopes	11	11	100%	1,760	1,390	420	1,080	239	4,390	--	--
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	Historically Disturbed Subtidal Flats	27	27	100%	10,700	9,380	1,810	6,490	2,260	37,800	--	--
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	Industrial Waterfront	31	31	100%	6,430	6,780	1,220	4,990	215	34,000	--	--
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	Intertidal Area	9	9	100%	4,340	2,910	971	4,050	334	10,200	--	--
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	Navigation Channel	22	22	100%	8,060	7,300	1,560	5,460	684	27,600	--	--
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	Port Channel	3	3	100%	6,750	1,480	854	7,200	5,100	7,950	--	--
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	Sub-Tidal Flats	151	142	94%	15,500	25,800	2,100	6,550	39	168,000	35	1400
Phase III	Surface	PAHs	Total Alkylated PAHs	µg/kg	Transitional Slopes	11	11	100%	19,000	21,900	6,600	8,510	2,240	69,700	--	--
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	Historically Disturbed Subtidal Flats	27	27	100%	12,300	13,800	2,660	8,300	2,200	75,000	--	--
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	Industrial Waterfront	31	31	100%	10,400	14,300	2,570	4,800	660	70,000	--	--
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	Intertidal Area	9	9	100%	5,290	3,690	1,230	4,100	980	13,500	--	--
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	Navigation Channel	22	22	100%	11,200	12,300	2,620	5,350	1,200	53,000	--	--
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	Port Channel	3	3	100%	9,000	3,460	2,000	11,000	5,000	11,000	--	--
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	Sub-Tidal Flats	151	149	99%	10,500	10,000	816	7,000	37	46,000	41	45
Phase III	Surface	PAHs	Total HMW PAHs	µg/kg	Transitional Slopes	11	11	100%	19,000	29,200	8,790	8,000	2,100	100,000	--	--
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	Historically Disturbed Subtidal Flats	27	27	100%	1,700	3,120	600	1,000	300	17,000	--	--
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	Industrial Waterfront	31	31	100%	1,980	3,560	639	740	41	17,000	--	--
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	Intertidal Area	9	9	100%	571	536	179	450	69	1,900	--	--
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	Navigation Channel	22	22	100%	1,120	968	206	615	110	3,200	--	--
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	Port Channel	3	3	100%	1,190	475	274	1,300	670	1,600	--	--
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	Sub-Tidal Flats	151	142	94%	1,190	1,500	122	770	5	12,000	35	1400
Phase III	Surface	PAHs	Total LMW PAHs	µg/kg	Transitional Slopes	11	11	100%	2,160	3,410	1,030	810	210	12,000	--	--
Phase III	Surface	PAHs	Total PAH	µg/kg	Historically Disturbed Subtidal Flats	27	27	100%	13,900	16,700	3,210	9,200	2,500	91,000	--	--
Phase III	Surface	PAHs	Total PAH	µg/kg	Industrial Waterfront	31	31	100%	12,400	17,800	3,200	5,500	780	87,000	--	--
Phase III	Surface	PAHs	Total PAH	µg/kg	Intertidal Area	9	9	100%	5,840	4,250	1,420	4,600	1,000	15,500	--	--
Phase III	Surface	PAHs	Total PAH	µg/kg	Navigation Channel	22	22	100%	12,300	13,100	2,800	5,950	1,400	56,000	--	--
Phase III	Surface	PAHs	Total PAH	µg/kg	Port Channel	3	3	100%	10,200	3,960	2,280	12,000	5,700	13,000	--	--
Phase III	Surface	PAHs	Total PAH	µg/kg	Sub-Tidal Flats	151	149	99%	11,700	11,300	918	7,700	37	51,000	41	45
Phase III	Surface	PAHs	Total PAH	µg/kg	Transitional Slopes	11	11	100%	21,000	32,000	9,650	8,800	2,300	110,000	--	--
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Historically Disturbed Subtidal Flats	26	22	85%	1,210	1,270	248	900	140	5,600	320	440
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Industrial Waterfront	31	29	94%	1,010	1,020	183	490	98	3,200	210	230
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Intertidal Area	9	9	100%	601	294	97.9	630	260	1,200	--	--
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Navigation Channel	22	17	77%	1,020	2,070	442	395	110	8,700	210	450
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Port Channel	3	2	67%	407	154	88.8	480	480	510	460	460
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Sub-Tidal Flats	151	108	72%	1,140	4,190	341	310	96	38,000	210	460
Phase III	Surface	Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	Transitional Slopes	11	11	100%	1,610	1,980	597	860	180	6,900	--	--
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Historically Disturbed Subtidal Flats	27	26	96%	260	286	55.1	157	65.2	1440	31.1	31.1
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Industrial Waterfront	31	31	100%	398	408	73.3	258	38.9	1550	--	--
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Intertidal Area	9	9	100%	269	237	78.9	237	11.4	781	--	--
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Navigation Channel	22	22	100%	316	299	63.7	250	9.35	1000	--	--
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Port Channel	3	3	100%	114	75.2	43.4	73.3	68.2	201	--	--
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Sub-Tidal Flats	151	144	95%	360	497	40.4	182	6.45	2910	14.6	135
Phase III	Surface	TPH	Total Petroleum Hydrocarbons	mg/kg	Transitional Slopes	11	11	100%	312	281	84.6	173	73.6	919	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	15,700	3,660	705	14,900	7,540	21,800	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	Industrial Waterfront	31	31	100%	10,500	5,410	971	8,440	4,330	28,500	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	Intertidal Area	9	9	100%	9,720	4,790	1,600	7,270	5,530	18,700	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	Navigation Channel	22	22	100%	15,400	5,740	1,220	15,500	3,580	24,500	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	Port Channel	3	3	100%	21,400	3,110	1,800	21,700	18,100	24,300	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	Sub-Tidal Flats	151	151	100%	13,500	6,150	501	13,700	1,650	35,000	--	--
Phase III	Surface	Metals	Aluminum	mg/kg	Transitional Slopes	11	11	100%	18,400	3,510	1,060	19,400	9,400	21,900	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	18.1	10.9	2.1	14	7.67	61.5	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	Industrial Waterfront	31	31	100%	15.2	22.1	3.97	8.67	2.39	115	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	Intertidal Area	9	9	100%	11.4	4.48	1.49	10	6.76	20.2	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	Navigation Channel	22	22	100%	12.7	5.14	1.1	12.5	3.24	27.3	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	Port Channel	3	3	100%	16.3	1.39	0.801	16.7	14.8	17.5	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	Sub-Tidal Flats	151	151	100%	20.1	18.3	1.49	13.3	1.18	96.8	--	--
Phase III	Surface	Metals	Arsenic	mg/kg	Transitional Slopes	11	11	100%	19.2	9.85	2.97	16.9	9.32	45.6	--	--

Table 4-7
Surface Sediment Summary Statistics – By Geomorphic Area

Phase	Depth Group	Analyte Group	Analyte	Units	Geomorphic Unit	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase III	Surface	Metals	Cadmium	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	3.22	3.96	0.762	1.52	0.432	17.8	--	--
Phase III	Surface	Metals	Cadmium	mg/kg	Industrial Waterfront	31	31	100%	1.54	2.44	0.438	0.799	0.137	13.7	--	--
Phase III	Surface	Metals	Cadmium	mg/kg	Intertidal Area	9	9	100%	0.854	0.577	0.192	0.829	0.234	2.24	--	--
Phase III	Surface	Metals	Cadmium	mg/kg	Navigation Channel	22	22	100%	1.69	2.79	0.594	0.811	0.145	12.6	--	--
Phase III	Surface	Metals	Cadmium	mg/kg	Port Channel	3	3	100%	1.25	0.378	0.218	1.04	1.03	1.69	--	--
Phase III	Surface	Metals	Cadmium	mg/kg	Sub-Tidal Flats	151	149	99%	2.05	3.5	0.284	0.834	0.0592	24.6	0.0867	0.103
Phase III	Surface	Metals	Cadmium	mg/kg	Transitional Slopes	11	11	100%	2.82	2.57	0.774	1.82	0.486	7.84	--	--
Phase III	Surface	Metals	Chromium	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	159	119	22.9	110	41.4	520	--	--
Phase III	Surface	Metals	Chromium	mg/kg	Industrial Waterfront	31	31	100%	85.8	55.6	9.98	70.3	18.1	276	--	--
Phase III	Surface	Metals	Chromium	mg/kg	Intertidal Area	9	9	100%	83.1	42.4	14.1	69.6	37.3	165	--	--
Phase III	Surface	Metals	Chromium	mg/kg	Navigation Channel	22	22	100%	105	78.2	16.7	84.7	11.1	329	--	--
Phase III	Surface	Metals	Chromium	mg/kg	Port Channel	3	3	100%	101	12.6	7.27	97.7	90.5	115	--	--
Phase III	Surface	Metals	Chromium	mg/kg	Sub-Tidal Flats	151	151	100%	128	134	10.9	95.6	3.95	777	--	--
Phase III	Surface	Metals	Chromium	mg/kg	Transitional Slopes	11	11	100%	140	72.8	21.9	137	49	273	--	--
Phase III	Surface	Metals	Copper	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	165	128	24.6	117	64.2	567	--	--
Phase III	Surface	Metals	Copper	mg/kg	Industrial Waterfront	31	31	100%	158	150	26.9	108	14.5	619	--	--
Phase III	Surface	Metals	Copper	mg/kg	Intertidal Area	9	9	100%	96.2	63.7	21.2	57.7	36.8	205	--	--
Phase III	Surface	Metals	Copper	mg/kg	Navigation Channel	22	22	100%	113	83.5	17.8	95.6	11.1	388	--	--
Phase III	Surface	Metals	Copper	mg/kg	Port Channel	3	3	100%	115	6.03	3.48	114	109	121	--	--
Phase III	Surface	Metals	Copper	mg/kg	Sub-Tidal Flats	151	151	100%	149	169	13.7	94.2	1.5	924	--	--
Phase III	Surface	Metals	Copper	mg/kg	Transitional Slopes	11	11	100%	205	135	40.7	185	57.4	444	--	--
Phase III	Surface	Metals	Lead	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	153	77.7	15	130	59.9	433	--	--
Phase III	Surface	Metals	Lead	mg/kg	Industrial Waterfront	31	31	100%	244	429	77.1	108	26.1	2190	--	--
Phase III	Surface	Metals	Lead	mg/kg	Intertidal Area	9	9	100%	96.6	61.3	20.4	64.7	41.2	196	--	--
Phase III	Surface	Metals	Lead	mg/kg	Navigation Channel	22	22	100%	166	285	60.7	106	10.2	1410	--	--
Phase III	Surface	Metals	Lead	mg/kg	Port Channel	3	3	100%	133	12.1	7	126	126	147	--	--
Phase III	Surface	Metals	Lead	mg/kg	Sub-Tidal Flats	151	151	100%	156	172	14	105	2.18	875	--	--
Phase III	Surface	Metals	Lead	mg/kg	Transitional Slopes	11	11	100%	185	89.6	27	175	59.7	314	--	--
Phase III	Surface	Metals	Mercury	ng/g	Historically Disturbed Subtidal Flats	27	27	100%	2,810	2,210	424	1,970	386	8,380	--	--
Phase III	Surface	Metals	Mercury	ng/g	Industrial Waterfront	31	31	100%	1,570	1,560	280	1,060	142	7,390	--	--
Phase III	Surface	Metals	Mercury	ng/g	Intertidal Area	9	9	100%	1,410	746	249	1,730	523	2,590	--	--
Phase III	Surface	Metals	Mercury	ng/g	Navigation Channel	22	22	100%	1,670	1,820	388	1,190	151	7,770	--	--
Phase III	Surface	Metals	Mercury	ng/g	Port Channel	3	3	100%	2,080	607	350	2,190	1,430	2,630	--	--
Phase III	Surface	Metals	Mercury	ng/g	Sub-Tidal Flats	151	151	100%	2,520	3,310	269	1,480	5.11	22,100	--	--
Phase III	Surface	Metals	Mercury	ng/g	Transitional Slopes	11	11	100%	3,320	2,780	837	2,430	608	9,510	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	Historically Disturbed Subtidal Flats	27	27	100%	1.21	1.14	0.219	0.82	0.034	4.99	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	Industrial Waterfront	31	31	100%	1.71	2.21	0.397	1.21	0.194	11.9	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	Intertidal Area	9	9	100%	1.21	1.05	0.351	1.48	0.11	3.02	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	Navigation Channel	22	22	100%	1.2	0.829	0.177	1.05	0.21	3.37	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	Port Channel	3	3	100%	2.17	1.71	0.988	1.48	0.912	4.12	--	--
Phase III	Surface	Metals	Methyl mercury	ng/g	Sub-Tidal Flats	151	150	99%	0.884	0.776	0.0631	0.755	0.027	4.8	0.058	0.058
Phase III	Surface	Metals	Methyl mercury	ng/g	Transitional Slopes	11	11	100%	1.53	0.859	0.259	1.4	0.561	3.67	--	--
Phase III	Surface	Metals	Nickel	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	48.4	16.6	3.2	45	28.2	96	--	--
Phase III	Surface	Metals	Nickel	mg/kg	Industrial Waterfront	31	31	100%	48.7	54.1	9.71	26.9	10.3	282	--	--
Phase III	Surface	Metals	Nickel	mg/kg	Intertidal Area	9	9	100%	25.7	13.5	4.49	17.4	15.7	50.9	--	--
Phase III	Surface	Metals	Nickel	mg/kg	Navigation Channel	22	22	100%	42	14.2	3.04	46	5.45	62.4	--	--
Phase III	Surface	Metals	Nickel	mg/kg	Port Channel	3	3	100%	44.9	4.56	2.63	46.1	39.9	48.8	--	--
Phase III	Surface	Metals	Nickel	mg/kg	Sub-Tidal Flats	151	151	100%	37.5	25.8	2.1	34.2	3.83	182	--	--
Phase III	Surface	Metals	Nickel	mg/kg	Transitional Slopes	11	11	100%	55.4	12.1	3.64	53.7	37.9	78.4	--	--
Phase III	Surface	Metals	Selenium	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	1.02	0.592	0.114	0.833	0.471	3.1	--	--
Phase III	Surface	Metals	Selenium	mg/kg	Industrial Waterfront	30	30	100%	0.801	0.691	0.126	0.563	0.141	3	--	--
Phase III	Surface	Metals	Selenium	mg/kg	Intertidal Area	9	9	100%	0.569	0.296	0.0987	0.52	0.219	1.05	--	--
Phase III	Surface	Metals	Selenium	mg/kg	Navigation Channel	22	22	100%	0.688	0.356	0.0758	0.652	0.254	1.82	--	--
Phase III	Surface	Metals	Selenium	mg/kg	Port Channel	3	3	100%	0.878	0.00153	0.000882	0.878	0.877	0.88	--	--
Phase III	Surface	Metals	Selenium	mg/kg	Sub-Tidal Flats	151	148	98%	1.13	1.34	0.109	0.672	0.0939	7.58	0.347	0.484
Phase III	Surface	Metals	Selenium	mg/kg	Transitional Slopes	11	11	100%	1.2	0.673	0.203	1.05	0.371	2.42	--	--

Table 4-7
Surface Sediment Summary Statistics – By Geomorphic Area

Phase	Depth Group	Analyte Group	Analyte	Units	Geomorphic Unit	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
Phase III	Surface	Metals	Silver	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	2.51	1.4	0.269	2.12	0.228	5.61	--	--
Phase III	Surface	Metals	Silver	mg/kg	Industrial Waterfront	31	31	100%	1.34	1.17	0.21	1.27	0.117	5.8	--	--
Phase III	Surface	Metals	Silver	mg/kg	Intertidal Area	9	9	100%	1.08	0.751	0.25	0.904	0.241	2.45	--	--
Phase III	Surface	Metals	Silver	mg/kg	Navigation Channel	22	22	100%	1.77	1.71	0.366	1.42	0.129	7.84	--	--
Phase III	Surface	Metals	Silver	mg/kg	Port Channel	3	3	100%	1.93	0.401	0.231	1.78	1.62	2.38	--	--
Phase III	Surface	Metals	Silver	mg/kg	Sub-Tidal Flats	151	150	99%	1.72	1.7	0.139	1.42	0.0448	12	0.103	0.103
Phase III	Surface	Metals	Silver	mg/kg	Transitional Slopes	11	11	100%	3.36	1.9	0.574	3.59	0.968	7.38	--	--
Phase III	Surface	Metals	Zinc	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	300	131	25.3	257	139	681	--	--
Phase III	Surface	Metals	Zinc	mg/kg	Industrial Waterfront	31	31	100%	598	1270	228	206	70.3	6810	--	--
Phase III	Surface	Metals	Zinc	mg/kg	Intertidal Area	9	9	100%	211	101	33.8	190	110	420	--	--
Phase III	Surface	Metals	Zinc	mg/kg	Navigation Channel	22	22	100%	226	125	26.6	211	28.9	596	--	--
Phase III	Surface	Metals	Zinc	mg/kg	Port Channel	3	3	100%	268	34.8	20.1	273	231	300	--	--
Phase III	Surface	Metals	Zinc	mg/kg	Sub-Tidal Flats	151	151	100%	249	210	17.1	201	8.18	1170	--	--
Phase III	Surface	Metals	Zinc	mg/kg	Transitional Slopes	11	11	100%	390	213	64.4	366	123	752	--	--
Phase III	Surface	Grain Size	Fines	% passed	Historically Disturbed Subtidal Flats	27	27	100%	73.5	13.6	2.61	73.5	43.6	93.3	--	--
Phase III	Surface	Grain Size	Fines	% passed	Industrial Waterfront	31	31	100%	38.6	25.4	4.55	34.8	6.9	91.5	--	--
Phase III	Surface	Grain Size	Fines	% passed	Intertidal Area	9	9	100%	43.5	28.8	9.6	33.2	5.3	95.9	--	--
Phase III	Surface	Grain Size	Fines	% passed	Navigation Channel	22	22	100%	63.9	22.4	4.77	63.9	11.5	93.2	--	--
Phase III	Surface	Grain Size	Fines	% passed	Port Channel	3	3	100%	86.8	4.74	2.74	88.7	81.4	90.3	--	--
Phase III	Surface	Grain Size	Fines	% passed	Sub-Tidal Flats	151	151	100%	54.1	27.3	2.22	58.2	2.6	96.8	--	--
Phase III	Surface	Grain Size	Fines	% passed	Transitional Slopes	11	11	100%	74.7	18.5	5.59	81	26.9	90.2	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	Historically Disturbed Subtidal Flats	27	27	100%	33,100	26,200	5,050	25,700	10,300	151,000	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	Industrial Waterfront	31	31	100%	24,400	18,100	3,250	19,700	1,160	60,700	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	Intertidal Area	9	9	100%	26,200	19,400	6,450	28,200	1,190	66,500	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	Navigation Channel	22	22	100%	22,900	12,100	2,580	23,400	1,520	54,900	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	Port Channel	3	3	100%	27,700	2,250	1,300	26,800	26,100	30,300	--	--
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	Sub-Tidal Flats	151	149	99%	21,100	13,400	1,090	20,000	1,030	73,200	668	689
Phase III	Surface	TOC	Total organic carbon (TOC)	mg/kg	Transitional Slopes	11	11	100%	31,600	9,470	2,850	31,900	20,000	50,100	--	--

Notes:
Only samples within the NBSA boundary are included.
Non-detects included at the 1/2 quantitation limit for mean, standard deviation, and standard error estimates.
Non-detects evaluated at full quantitation limit for median estimate. If the median is a non-detect, it is indicated by the "less than" symbol (<).
When all data are reported as non-detect, the calculated mean and standard deviation are calculated using the full quantitation limit; a “less than” symbol (<) was assigned to the mean to indicate all values are below the quantitation limit.
Total Petroleum Hydrocarbons (TPH) is the sum of gasoline range organics (GRO) and diesel range organics (DRO).
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Acronyms and Abbreviations:
< = indicates the median is a non-detect or that the mean was calculated using all non-detects reported at the quantitation limit
% = percent
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligram per kilogram
ng/g = nanogram per gram
(ND=0) = Only detected isomers were included in the summation
ng/kg = nanogram per kilogram
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
pg/g = picogram per gram
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (D
µg/kg = microgram per kilogram

Table 4-8
Results of Temporal Comparison of Phase I/II and Phase III Co-located Samples

Analyte	Frequency of Detection	Model Type	Intercept[a]	β[a]	p-value[b]	95% Confidence Limits on β		Percent Decrease from 2005 to 2016[c]			Half-life (Years)		
								Mean	95% Confidence Limits		Mean	95% Confidence Limits	
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	100%	A	3.85	-0.034	**0.032**	-0.065	-0.003	**31%**	**3%**	**51%**	20	11	230
		B	6.0189	-0.029	0.0548	-0.060	0.001	28%	-1%	48%	--	--	--
Total PCB Congeners (209)	100%	A	12.8	-0.0555	**0.0001**	-0.082	-0.029	**46%**	**27%**	**60%**	12	8.4	24
		B	14.9654	-0.0512	**0.0003**	-0.078	-0.025	**43%**	**24%**	**57%**	14	8.9	28
Total Aroclor PCBs (Sum of 9 Aroclors)	94%	A	6.19	-0.114	**<.0001**	-0.144	-0.084	**71%**	**60%**	**79%**	6.1	4.8	8.2
		B	10.5113	-0.110	**<.0001**	-0.137	-0.083	**70%**	**60%**	**78%**	6.3	5	8.4
Total DDx (4,4') (ND=0)	93%	A	10.45	-0.0466	**0.013**	-0.083	-0.010	**40%**	**11%**	**60%**	15	8.4	68
		B	13.1833	-0.0437	**0.0196**	-0.080	-0.007	**38%**	**8%**	**58%**	16	8.7	94
bis(2-Ethylhexyl)phthalate[d]	87%	A	8.13	-0.188	**<.0001**	-0.220	-0.156	**87%**	**82%**	**91%**	3.7	3.2	4.5
		B	10.464	-0.188	**<.0001**	-0.221	-0.155	**87%**	**82%**	**91%**	3.7	3.1	4.5
Total HMW PAHs[e]	100%	A	9.38	-0.0459	**0.0005**	-0.070	-0.021	**40%**	**21%**	**54%**	15	9.8	32
		B	12.2318	-0.0395	**0.0002**	-0.059	-0.020	**35%**	**20%**	**48%**	18	12	35
Total LMW PAHs[e]	95%	A	7.38	-0.0637	**<.0001**	-0.093	-0.034	**50%**	**32%**	**64%**	11	7.5	20
		B	11.046	-0.0593	**<.0001**	-0.083	-0.036	**48%**	**32%**	**60%**	12	8.4	19
Total PAHs[e]	100%	A	9.49	-0.0473	**0.0003**	-0.072	-0.023	**41%**	**22%**	**55%**	15	9.6	31
		B	12.3847	-0.0409	**0.0001**	-0.060	-0.021	**36%**	**21%**	**49%**	17	11	33
Total Organic Carbon	100%	A	9.95	-0.00866	0.338	-0.027	0.009	9%	-11%	25%	--	--	--
Aluminum	100%	A	9.39	0.0037	0.458	-0.006	0.014	-4%	-16%	7%	--	--	--
Arsenic	100%	A	2.51	0.0178	**0.008**	0.005	0.031	**-22%**	**-40%**	**-6%**	--	--	--
		C	5.5698	0.0153	**0.0096**	0.004	0.027	**-18%**	**-34%**	**-4%**	--	--	--
Cadmium	98%	A	0.34	-0.0288	**0.022**	-0.053	-0.004	**27%**	**5%**	**44%**	24	13	160
		C	5.7695	-0.0363	**0.0021**	-0.059	-0.014	**33%**	**14%**	**48%**	19	12	50
Chromium	100%	A	4.71	-0.0205	**0.017**	-0.037	-0.004	**20%**	**4%**	**33%**	34	19	180
		C	9.4903	-0.0244	**0.0004**	-0.037	-0.012	**24%**	**12%**	**34%**	28	19	60
Copper	100%	A	4.72	-0.0234	**0.005**	-0.039	-0.008	**23%**	**8%**	**35%**	30	18	91
		C	9.3702	-0.0275	**<.0001**	-0.040	-0.015	**26%**	**15%**	**36%**	25	17	46
Lead	100%	A	4.78	-0.0229	**0.011**	-0.040	-0.006	**22%**	**6%**	**36%**	30	17	120
		C	8.9821	-0.0265	**0.0013**	-0.042	-0.011	**25%**	**11%**	**37%**	26	17	63
Mercury	100%	A	7.65	-0.0295	**0.0226**	-0.055	-0.004	**28%**	**5%**	**45%**	23	13	160
		C	11.2677	-0.0323	**0.0129**	-0.057	-0.007	**30%**	**8%**	**47%**	21	12	97
Nickel	100%	A	3.46	-0.00419	0.471	-0.016	0.007	5%	-9%	16%	--	--	--
		C	7.9986	-0.00812	**0.0172**	-0.015	-0.002	**9%**	**2%**	**15%**	85	47	460
Silver	100%	A	0.499	-0.0333	**0.002**	-0.054	-0.013	**31%**	**13%**	**45%**	21	13	55
		C	5.6647	-0.037	**0.0002**	-0.056	-0.019	**34%**	**19%**	**46%**	19	12	37
Zinc	100%	A	5.33	-0.00897	0.24	-0.024	0.006	9%	-7%	23%	--	--	--
		C	9.795	-0.013	**0.0361**	-0.025	-0.001	**13%**	**1%**	**24%**	54	28	810

Table 4-8
Results of Temporal Comparison of Phase I/II and Phase III Co-located Samples

Notes:

[a] Parameter estimates from the following model types:
Model A: $\log_e$(concentration) = intercept + (β* year0) + γi, where year0 = 0 in 2005 and γi is the random intercept for co-location i.
Model B: $\log_e$(concentration) = intercept + (β* year0) + (βNORM* $\log_e$(fraction organic carbon)) + γi
Model C: $\log_e$(concentration) = intercept + (β* year0) + (βNORM* $\log_e$(fraction aluminum)) + γi

[b] Null hypothesis: β = 0. p-value is **bolded** where significant (α= 0.05) indicating β is different from 0.

[c] Negative percent indicates increase.

[d] Differences may be uncertain due to frequency of detection less than 90%.

[e] Results may be uncertain. A potential bias was noted when PAH results were compared to USEPA split sample PAH results.

The following COCs were not evaluated because they were not analyzed in Phase I/II: methyl mercury, cis-nonachlor, total alkylated PAHs.

Alpha + gamma chlordane wasnot evaluated due to the low detection frequency caused by elevated detection limits (as much as 100 times higher than the Phase III program) in the Phase I program.

alpha-BHC and beta-BHC were not evaluated due to low frequency of detection particularly among Phase I/II data where detection limits were elevated compared to Phase III data.

Dieldrin was not evaluated. It was not detected during the Phase I program and detection limits were as much as 100 times higher than in the Phase III program. Phase II detection limits were also elevated compared to Phase III. Phase II detection frequency was 78% while Phase III detection frequency was 97%.

Heptachlor epoxide was not evaluated due to low frequency of detection in surface sediment.

Hexachlorobenzene was not evaluated. It was detected in greater than 99% of Phase III surface sediment but frequency of detection was low in Phase I/II due to elevated detection limits.

Total DDx (2,4' and 4,4') was not evaluated because the 2,4' isomers were not analyzed during the Phase I program.

TPH was not evaluated due to differences in analytical methods between sampling periods.

Selenium was not evaluated due to low frequency of detection in the Phase I program.

The co-located locations are shown on Figure 4-2.

Non-detect data were excluded from the analysis.

None of the 2014 Clam/Crab or 2015 SQT sediment locations were co-located with Phase I/II samples. Therefore, data from those programs are not included in the analyses.

Acronyms and Abbreviations:

< = less than
-- not calculated when model does not indicate statitically significant decrease in concentration
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
BHC = benzene hexachloride
HMW = high-molecular weight
LMW = low-molecular weight
$\log_e$ = natural logarithm
(ND=0) = Only detected isomers were included in the summation
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
SQT = sediment quality triad
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
TPH = total petroleum hydrocarbons (sum of gasoline range organics and diesel range organics)

Table 4-9
Temporal Trends in Co-located Samples

Co-located Stations	Fraction Remaining: Organics: 2,3,7,8-TCDD	Total PCBs (9)	Total PCBs congener (209 specified)	Total DDx (4,4') Total Fraction (ND=0)	Total HMW PAHs[a]	Total LMW PAHs[a]	Total PAH[a]	bis(2-Ethylhexyl) phthalate (DEHP)	Metals: Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Zinc	Geographic Area	USEPA Subunit	Geomorphic Unit	USACE Accumulation Area
045_403	0.37	0.27	0.64	0.59	1.21	1.02	1.21	0.06	1.39	0.74	0.89	1.00	1.07	0.63	1.10	0.76	1.02	North	6	Subtidal Flats	No
046_106_300	0.86	0.67	0.41	0.60	0.39	0.40	0.40	0.06	1.73	1.94	1.50	1.42	1.34	0.49	1.19	1.45	1.42	North	3	Navigation Channel	No
050_396	1.36	0.52	4.34	0.54	1.60	1.53	1.60	0.33	1.11	0.94	1.38	1.41	1.67	1.29	0.90	1.04	1.12	North	6	Subtidal Flats	No
051_076_335	0.96	0.39	0.80	1.03	0.72	0.83	0.74	0.08	1.12	0.80	0.89	0.90	0.86	0.73	0.99	0.72	0.94	North	4	Subtidal Flats	Yes
052_078_326	0.96	0.36	0.87	1.40	1.38	1.00	1.37	0.15	1.14	1.49	0.84	0.85	1.15	0.61	0.85	0.68	1.25	North	4	Historically Disturbed Subtidal Flats	Yes
053_389	0.59	0.24	0.34	0.62	0.27	0.26	0.27	-	1.19	0.33	0.72	0.52	0.23	0.28	1.11	0.25	0.80	North	6	Subtidal Flats	No
054_382	2.93	0.13	0.68	-	0.82	-	0.91	-	1.65	4.50	0.85	0.66	0.47	23.19	0.70	0.59	0.87	North	6	Subtidal Flats	No
055_104_294	0.87	0.38	0.70	1.00	0.69	0.43	0.63	0.07	1.34	1.30	0.80	0.71	0.73	0.93	0.96	0.52	0.89	North	3	Navigation Channel	No
056_077_330	0.74	0.12	0.51	0.91	1.23	0.89	1.13	0.06	0.99	0.51	0.79	0.77	0.72	0.82	0.90	1.03	0.74	North	4	Historically Disturbed Subtidal Flats	Yes
057_079_325	0.77	0.16	0.75	1.11	1.00	1.20	1.00	0.07	2.18	0.77	1.24	1.26	1.18	0.68	1.51	0.83	1.37	North	4	Subtidal Flats	No
060_080_317	0.76	0.24	0.61	1.67	0.71	0.44	0.67	0.12	1.29	1.19	1.07	1.11	1.05	0.60	1.41	0.74	1.27	North	4	Subtidal Flats	No
062_378	0.76	-	0.64	-	0.45	0.30	0.42	-	1.00	0.74	0.57	0.95	0.56	0.53	1.09	0.33	0.83	North	6	Subtidal Flats	No
063_101_292	0.67	0.48	0.63	-	0.43	0.31	0.42	0.18	0.93	1.29	0.78	0.87	0.78	0.84	1.21	0.55	0.94	North	3	Navigation Channel	Yes
064_374	0.84	-	0.79	-	0.14	-	0.14	-	1.68	0.36	0.28	0.30	0.36	0.30	0.32	0.20	0.32	North	6	Subtidal Flats	No
066_290	0.05	0.13	0.11	0.02	1.83	1.33	1.81	-	1.63	1.08	0.85	1.09	1.35	0.32	1.31	0.56	1.32	North	3	Navigation Channel	No
093_327	2.59	1.35	2.96	0.43	0.67	0.73	0.65	0.31	1.84	2.51	2.14	1.73	1.54	1.51	1.37	2.13	1.88	North	4	Historically Disturbed Subtidal Flats	Yes
103_289	1.50	0.56	0.36	0.18	0.09	0.05	0.09	-	0.69	0.35	0.27	0.45	0.26	0.13	0.61	-	0.44	North	3	Navigation Channel	No
105_394	0.72	0.65	1.00	1.88	0.50	0.72	0.50	0.14	0.64	0.50	0.84	0.63	0.56	0.77	0.82	0.78	0.74	North	6	Industrial Waterfront	No
032_073_359	0.89	0.09	0.75	0.79	1.14	1.18	1.14	0.08	1.13	0.49	0.82	0.77	0.94	0.82	1.28	0.57	1.13	Central	5	Subtidal Flats	No
037_352	0.79	0.15	0.79	0.59	0.62	0.48	0.61	0.11	0.99	0.42	0.65	0.64	0.79	0.79	0.99	0.57	0.90	Central	5	Subtidal Flats	Yes
039_342	0.56	0.20	0.52	0.94	0.50	0.13	0.43	0.09	1.60	0.65	0.91	0.95	1.10	0.82	1.29	1.01	1.16	Central	5	Subtidal Flats	No
040_350	0.66	-	1.48	0.03	0.38	0.43	0.36	-	4.13	0.46	0.74	0.66	0.52	0.95	0.74	4.25	2.85	Central	5	Subtidal Flats	No
091_364	0.76	0.47	1.10	1.42	0.85	0.93	0.86	0.14	1.31	0.80	1.03	0.94	1.10	0.63	1.43	0.88	1.19	Central	5	Historically Disturbed Subtidal Flats	Yes
092_344	0.64	0.66	0.74	1.11	0.63	0.60	0.60	0.32	1.14	0.97	1.05	1.00	0.94	0.47	1.21	1.13	1.07	Central	5	Historically Disturbed Subtidal Flats	Yes
003_247	1.76	0.70	1.58	1.33	1.83	1.39	1.72	-	1.32	1.76	1.14	0.98	1.08	1.97	0.62	1.54	0.82	South	1	Subtidal Flats	No
004_242	0.62	0.34	0.18	0.15	0.44	0.43	0.46	0.03	1.23	1.72	0.82	0.83	0.82	0.61	1.22	0.51	0.91	South	1	Navigation Channel	Yes
005_070_226	0.86	0.63	0.57	1.82	1.37	1.20	1.36	0.21	1.09	1.12	0.94	0.80	0.87	1.04	0.72	0.96	0.89	South	1	Historically Disturbed Subtidal Flats	Yes
012_222	0.33	0.14	0.28	-	0.07	0.15	0.08	0.17	0.44	0.33	0.41	0.61	0.72	0.30	0.59	0.50	0.66	South	1	Industrial Waterfront	Yes
013_218	0.79	1.49	0.81	0.31	1.58	0.63	1.45	0.15	0.84	1.02	0.84	0.74	0.90	1.00	0.89	0.75	0.92	South	1	Subtidal Flats	No
014_216	0.72	0.27	0.34	1.36	0.76	0.74	0.77	0.28	1.13	0.96	1.06	1.03	1.14	1.23	1.12	0.92	1.05	South	1	Subtidal Flats	No
015_211	1.14	0.04	0.21	-	0.54	-	0.62	0.04	1.67	0.35	0.78	0.66	0.70	0.50	0.65	0.41	0.62	South	1	Subtidal Flats	No
019_200	0.01	0.01	0.02	0.07	0.05	0.01	0.04	-	0.27	0.05	0.08	0.07	0.06	0.13	0.25	0.06	0.09	South	1	Subtidal Flats	No
020_187	0.55	0.31	0.55	0.60	0.46	0.41	0.45	0.40	0.93	0.90	0.75	0.75	1.51	0.75	1.13	0.66	0.96	South	1	Historically Disturbed Subtidal Flats	Yes
023_184	2.33	0.58	2.05	0.68	0.61	0.48	0.62	0.20	1.56	1.46	1.17	0.89	0.94	1.60	0.95	0.78	1.03	South	1	Subtidal Flats	No
089_237	3.09	0.76	0.63	3.79	1.24	0.81	1.18	0.28	2.10	2.90	2.13	1.84	1.59	2.54	1.18	1.95	1.55	South	1	Transitional Slopes	Yes
090_227	0.50	0.21	0.10	1.00	0.89	0.94	0.89	-	1.02	0.30	0.61	0.59	0.66	0.40	1.74	0.63	0.72	South	1	Historically Disturbed Subtidal Flats	Yes
118_232	2.60	0.67	0.42	2.67	1.23	1.73	1.31	0.38	1.87	2.68	1.54	1.49	1.05	1.09	1.45	1.33	1.40	South	1	Navigation Channel	Yes

Table 4-9
Temporal Trends in Co-located Samples

Notes:

[a]A potential bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.
The following COCs were not evaluated because they were not analyzed in Phase I/II: methyl mercury, cis-nonachlor, total alkylated PAHs.
The following COCs were not evaluated due to low frequency of detection in at least one of the three sampling programs: alpha+gamma chlordane, alpha-BHC, beta-BHC, dieldrin, heptachlor epoxide, hexachlorobenzene and selenium.

Total DDx (2,4' and 4,4') was not evaluated because the 2,4' isomers were not analyzed during the Phase I program.
TPH was not evaluated due to differences in analytical methods between sampling periods.

Color-coding: <0.5 | 0.5 to ≤ 1.0 | 1.0 to ≤ 1.5 | 1.5 to ≤ 2.0 | > 2.0
Bolded co-located stations show concentration increases (fraction remaining >1) for 50% or more of the evaluated contaminants.
The fraction remaining was calculated as the contaminant concentration in Phase III divided by the contaminant concentration in Phase I or Phase II (with the earlier dated Phase I data used when available).
Only detected results were included in this analysis. When one or both time points were non-detect values, the fractions remaining are not shown.

Acronyms and Abbreviations:

< = less than
> = greater than
≤ = less than or equal to
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
(ND=0) = Only detected isomers were included in the summation
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
TPH = total petroleum hydrocarbons (sum of gasoline range organics and diesel range organics)
USACE = U.S. Army Corps of Engineers
USEPA = U.S. Environmental Protection Agency

Table 4-10
Results of Two-Way ANOVA Model Comparing Concentrations from Phase I/II and Phase III Time Periods while controlling for Variation Attributable to Spatially Based Subunits[a]

Analyte	Frequency of Detection	Model Type	p-value[b]	Percent Decrease from Phase I/II to Phase III Sampling Period[c]		
				Mean	95% Confidence Limits	
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	100%	A	**0.013**	**36.3%**	**9%**	**55%**
		B	0.115	22.2%	-6%	43%
Total Aroclor PCBs (Sum of 9 Aroclors)	100%	A	**<.0001**	**72.6%**	**64%**	**79%**
		B	**<.0001**	**68.6%**	**60%**	**75%**
Total PCB Congeners (209)	100%	A	**<.0001**	**51.0%**	**32%**	**64%**
		B	**0.0002**	**42.1%**	**23%**	**57%**
Total DDx (4,4') (ND=0)	95%	A	0.065	28.1%	-2%	49%
		B	0.3972	12.2%	-19%	35%
Total HMW PAHs[d]	99%	A	**0.0024**	**38.2%**	**16%**	**55%**
		B	**0.0218**	**27.2%**	**5%**	**44%**
Total LMW PAHs[d]	97%	A	**0.0001**	**45.4%**	**26%**	**60%**
		B	**0.001**	**36.1%**	**16%**	**51%**
Total PAHs[d]	99%	A	**0.0029**	**38.0%**	**15%**	**55%**
		B	**0.027**	**26.9%**	**4%**	**45%**
bis(2-Ethylhexyl)phthalate	85%	A	**<.0001**	**86.9%**	**83%**	**90%**
		B	**<.0001**	**85.3%**	**81%**	**89%**
Total Organic Carbon	99%	A	**0.032**	**19.8%**	**2%**	**34%**
Aluminum	100%	A	0.623	2.9%	-9%	14%
Arsenic	100%	A	0.687	-3.3%	-21%	12%
		C	0.3371	-5.9%	-19%	6%
Cadmium	98%	A	**0.0259**	**26.1%**	**4%**	**43%**
		C	**0.020**	**23.4%**	**4%**	**39%**
Chromium	100%	A	**0.021**	**19.9%**	**3%**	**34%**
		C	**0.004**	**17.2%**	**6%**	**27%**
Copper	100%	A	**0.021**	**22.8%**	**4%**	**38%**
		C	**0.009**	**19.9%**	**5%**	**32%**
Lead	100%	A	0.082	17.1%	-2%	33%
		C	0.075	**14.6%**	**-2%**	**28%**
Mercury	100%	A	**0.0004**	**38.9%**	**20%**	**53%**
		C	**<.0001**	**36.7%**	**21%**	**49%**
Nickel	100%	A	0.600	-3.7%	-19%	9%
		C	0.165	-6.4%	-16%	3%
Silver	99%	A	**0.0002**	**38.0%**	**21%**	**52%**
		C	**<.0001**	**34.3%**	**22%**	**45%**
Zinc	100%	A	0.285	9.1%	-8%	24%
		C	0.320	6.5%	-7%	18%

Table 4-10
Results of Two-Way ANOVA Model Comparing Concentrations from Phase I/II and Phase III Time Periods while controlling for Variation Attributable to Spatially Based Subunits[a]

Notes:

[a] The six spatially based USEPA subunits are shown on Figure 2-8.

[b] p-value of F-test for sampling period. Bolded when significant.

[c] Based on difference of the least square log mean estimates from the model. Negative values indicate an increase.

[d] Results may be uncertain. A potential bias was noted when PAH results were compared to USEPA split sample PAH results.

Model A: $\log_e$(concentration) = Intercept + subunit + sampling period (phase I/II vs. Phase III)

Model B: $\log_e$(concentration) = Intercept + subunit + sampling period (phase I/II vs. Phase III) + $\log_e$(Total Organic Carbon)

Model C: $\log_e$(concentration) = Intercept + subunit + sampling period (phase I/II vs. Phase III) + $\log_e$(Aluminum)

Interaction term (subunit X sampling period) was tested for model A but found to be insignificant for all chemicals.
1/2 the quantitation limit was substituted for non-detects.

The following COCs were not evaluated because they were not analyzed in Phase I/II: methyl mercury, cis-nonachlor, total alkylated PAHs.
Alpha + gamma chlordane was not evaluated due to the low detection frequency caused by elevated detection limits (as much as 100 times higher than the Phase III program) in the Phase I program.
alpha-BHC and beta-BHC were not evaluated due to low frequency of detection particularly among Phase I/II data where detection limits were elevated compared to Phase III data.
Dieldrin was not evaluated. It was not detected during the Phase I program and detection limits were as much as 100 times higher than in the Phase III program. Phase II detection limits were also elevated compared to Phase III. Phase II detection frequency was 78% while Phase III detection frequency was 97%.
Heptachlor epoxide was not evaluated due to low frequency of detection in surface sediment.
Hexachlorobenzene was not evaluated. It was detected in greater than 99% of Phase III surface sediment but frequency of detection was low in Phase I/II due to elevated detection limits.
Total DDx (2,4' and 4,4') was not evaluated because the 2,4' isomers were not analyzed during the Phase I program.
TPH was not evaluated due to differences in analytical methods between sampling periods.
Selenium was not evaluated due to low frequency of detection in the Phase I program.
Sample NB02SED072D-01 had an aluminum result that was non-detect and an extreme outlier compared to the detected results. The sample was excluded from the analysis of aluminum and from all results of Model C.

Acronyms and Abbreviations:

< = less than
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
ANOVA = analysis of variance
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
$\log_e$ = natural logarithm
(ND=0) = Only detected isomers were included in the summation
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
TPH = total petroleum hydrocarbons (sum of gasoline range organics and diesel range organics)
USEPA = U.S. Environmental Protection Agency

Table 4-11
Summary of USEPA REMAP Data 2008 to 2013

Year of Sampling NY/NJ Harbor	Analyte Group	Analyte	Units	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
2008	Metals	Arsenic	mg/kg	11	11	100%	9.93	2.17	9.8	6	14	--	--
2008	Metals	Cadmium	mg/kg	11	11	100%	1.08	0.556	0.93	0.49	2.6	--	--
2008	Metals	Chromium	mg/kg	11	11	100%	74.8	19.6	69	49	110	--	--
2008	Metals	Copper	mg/kg	11	11	100%	109	64.7	94	45	290	--	--
2008	Metals	Lead	mg/kg	11	11	100%	101	50.3	88	45	240	--	--
2008	Metals	Mercury	ng/g	11	11	1	1360	593	1300	700	2900	--	--
2008	Metals	Nickel	mg/kg	11	11	100%	28.5	10.4	29	13	55	--	--
2008	Metals	Selenium	mg/kg	11	0	0%	<1.928	--	<1.9	--	--	1.8	2
2008	Metals	Silver	mg/kg	11	11	100%	3.95	0.989	4	2.1	5.8	--	--
2008	Metals	Zinc	mg/kg	11	11	100%	236	215	170	86	870	--	--
2008	PAHs	Total HMW PAHs	µg/kg	11	11	100%	2380	6310	379	108	21400	--	--
2008	PAHs	Total LMW PAHs	µg/kg	11	6	55%	392	1170	26	23	3920	19	28
2008	PAHs	Total PAHs	µg/kg	11	11	100%	2770	7480	402	108	25300	--	--
2008	PCBs (Aroclors)	Total PCBs[a]	µg/kg	11	0	0%	--	--	--	--	--	0	0
2008	Pesticides	BHC, beta-BHC & gamma-BHC mix, unspecified	pg/g	11	0	0%	<1814	--	<1900	--	--	950	2300
2008	Pesticides	cis-Nonachlor	pg/g	11	0	0%	<938	--	<950	--	--	710	1200
2008	Pesticides	Dieldrin	pg/g	11	0	0%	<1900	--	<1900	--	--	1400	2300
2008	Pesticides	Heptachlor epoxide	pg/g	11	0	0%	<938	--	<950	--	--	710	1200
2008	Pesticides	Hexachlorobenzene	pg/g	11	0	0%	<938	--	<950	--	--	710	1200
2008	Pesticides	Total alpha + gamma chlordane	pg/g	11	0	0%	<938	--	<950	--	--	710	1200
2008	Pesticides	Total DDx (2,4' & 4,4') (ND=0)	pg/g	11	2	18%	1540	1670	<1900	1800	6500	1400	2300
2008	Pesticides	Total DDx (4,4') (ND=0)	pg/g	11	2	18%	1540	1670	<1900	1800	6500	1400	2300
2013	Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin	ng/kg	11	11	100%	45.4	33.1	32	4.3	110	--	--
2013	Metals	Arsenic	mg/kg	11	11	100%	12.1	4.52	12.4	4.4	19.4	--	--
2013	Metals	Cadmium	mg/kg	11	11	100%	1.12	0.445	1.1	0.2	1.9	--	--
2013	Metals	Chromium	mg/kg	11	11	100%	116	41.3	109	35.2	180	--	--
2013	Metals	Copper	mg/kg	11	11	100%	84.1	42	83.3	17.1	169	--	--
2013	Metals	Lead	mg/kg	11	11	100%	93.1	41.3	89.7	24.6	181	--	--
2013	Metals	Mercury	ng/g	11	11	100%	1470	556	1680	220	2140	--	--
2013	Metals	Nickel	mg/kg	11	11	100%	47.6	20.7	50.3	13.6	75.9	--	--
2013	Metals	Selenium	mg/kg	11	11	100%	0.645	0.35	0.7	0.1	1.3	--	--
2013	Metals	Silver	mg/kg	11	11	100%	1.29	0.575	1.4	0.2	2.3	--	--
2013	Metals	Zinc	mg/kg	11	11	100%	180	84.1	184	45.9	362	--	--
2013	PAHs	Total HMW PAHs	µg/kg	11	11	100%	2590	3570	1150	626	12800	--	--
2013	PAHs	Total LMW PAHs	µg/kg	11	11	100%	362	371	254	67.7	1420	--	--
2013	PAHs	Total PAHs	µg/kg	11	11	100%	2960	3920	1330	734	14300	--	--
2013	PCBs (Aroclors)	Total PCBs[a]	µg/kg	11	5	45%	1.8	2.33	0	2.3	6.5	0	0
2013	Pesticides	BHC, beta-BHC & gamma-BHC mix, unspecified	pg/g	11	0	0%	<1000	--	<1000	--	--	1000	1000
2013	Pesticides	cis-Nonachlor	pg/g	11	0	0%	<1000	--	<1000	--	--	1000	1000
2013	Pesticides	Dieldrin	pg/g	11	0	0%	<1000	--	<1000	--	--	1000	1000

Table 4-11
Summary of USEPA REMAP Data 2008 to 2013

Year of Sampling NY/NJ Harbor	Analyte Group	Analyte	Units	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect
2013	Pesticides	Heptachlor epoxide	pg/g	11	0	0%	<1000	--	<1000	--	--	1000	1000
2013	Pesticides	Hexachlorobenzene	pg/g	11	0	0%	<1000	--	<1000	--	--	1000	1000
2013	Pesticides	Total alpha + gamma chlordane	pg/g	11	0	0%	<1000	--	<1000	--	--	1000	1000
2013	Pesticides	Total DDx (2,4' & 4,4') (ND=0)	pg/g	11	6	55%	4150	5030	2200	2200	13700	1000	1000
2013	Pesticides	Total DDx (4,4') (ND=0)	pg/g	11	6	55%	3070	3060	2200	2200	8300	1000	1000

Notes:
[a]Non-detect values for total PCBs were reported as 0, and no reporting limits were recorded.
Non-detects are included at 1/2 reporting limit for mean and standard deviation estimates. Where the frequency of detection is 0, the mean is reported as <mean reporting limit.
Non-detects evaluated at full reporting limit for median estimate. When frequency of detection is less than 50%, the median is reported as <median reporting limit.

Acronyms and Abbreviations:
< indicates the mean or median is less than the reporting limit
-- = not calculated
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
ND = nondetect
(ND=0) = Only detected isomers were included in the summation
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
mg/kg = milligram per kilogram
ng/g = nanogram per gram
ng/kg = nanogram per kilogram
pg/g = picograms per gram
µg/kg = microgram per kilogram
REMAP = Regional Environmental Monitoring and Assessment Program
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
USEPA = U.S. Environmental Protection Agency

Table 4-12
Phase III Surface Sediment –
Geomorphic Area Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Spatial Group - Geomorphic Units	Sample Size	2,3,7,8-TCDD (ng/kg)	Total PCBs (9 Aroclors) (µg/kg)	Total PCBs (209 Congeners) (ng/kg)	Total DDX (2,4' & 4,4') (ND=0) (pg/g)	Total DDX (4,4') (ND=0) (pg/g)	Total Alpha + Gamma Chlordane (pg/g)
Arithmetic	**Phase III**	**0-0.5 feet**	**Baywide**	**254**	**87.1**	**239**	**480,000**	**131,000**	**93,100**	**5,070**
Arithmetic	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	> 162	> 397	> 916,000	113,000	85,300	> 7,440
Arithmetic	Phase III	0-0.5 feet	Industrial Waterfront	31	45.6	304	564,000	84,200	64,300	6,830
Arithmetic	Phase III	0-0.5 feet	Intertidal Area	9	47	138	210,000	95,500	68,100	5,420
Arithmetic	Phase III	0-0.5 feet	Navigational Area	22	60.5	239	292,000	70,300	59,100	5,070
Arithmetic	Phase III	0-0.5 feet	Port Channel	3	39.2	99.3	203,000	72,700	54,300	8,630
Arithmetic	Phase III	0-0.5 feet	Subtidal Flats	151	90.8	< 201	< 439,000	156,000	107,000	< 4,050
Arithmetic	Phase III	0-0.5 feet	Transitional Slopes	11	68.8	307	404,000	130,000	95,500	6,860
Geometric	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	> 81.1	> 239	> 571,000	66,600	51,100	> 5,890
Geometric	Phase III	0-0.5 feet	Industrial Waterfront	31	24.2	171	271,000	38,600	29,800	4,460
Geometric	Phase III	0-0.5 feet	Intertidal Area	9	31.1	75.3	158,000	42,400	33,400	4,330
Geometric	Phase III	0-0.5 feet	Navigational Area	22	32.1	162	213,000	31,200	24,300	3,410
Geometric	Phase III	0-0.5 feet	Port Channel	3	36.8	94	187,000	66,000	49,500	7,940
Geometric	Phase III	0-0.5 feet	Subtidal Flats	151	24.9	< 101	< 175,000	27,900	20,800	< 1,820
Geometric	Phase III	0-0.5 feet	Transitional Slopes	11	53.9	206	289,000	82,300	61,800	5,730
Model Significance Testing			**ANOVA[b] Model Significance p-value**		**0.002[e]**	**0.002**	**0.003**	0.12	0.061	**<.0001[e]**
			Historically Disturbed > Subtidal Flats		**	**	**			**
	Pairwise Differences[c]		**Historically Disturbed > Industrial Waterfront**		*					
	*** Significant at α = 0.05**		**Industrial Waterfront > Subtidal Flats**							**
	**** Significant at α = 0.01**		**Transitional Slopes > Intertidal Area**							
			Transitional Slopes > Subtidal Flats							

Mean Statistic[a] (Normalized Data)	Phase	Depth	Spatial Group - Geomorphic Units	Sample Size	2,3,7,8-TCDD (ng/kg-oc)	Total PCBs (9 Aroclors) (µg/kg-oc)	Total PCBs (209 Congeners) (ng/kg-oc)	Total DDX (2,4' & 4,4') (ND=0) (pg/g)	Total DDX (4,4') (ND=0) (pg/g)	Total Alpha + Gamma Chlordane (pg/g-oc)
Arithmetic	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	5,650	13,100	31,900,000	3,240,000	2,490,000	268,000
Arithmetic	Phase III	0-0.5 feet	Industrial Waterfront	31	2,370	18,600	30,700,000	3,610,000	2,740,000	> 473,000
Arithmetic	Phase III	0-0.5 feet	Intertidal Area	9	2,500	5,580	11,600,000	5,280,000	3,660,000	803,000
Arithmetic	Phase III	0-0.5 feet	Navigational Area	22	3,030	11,700	13,300,000	2,730,000	2,250,000	213,000
Arithmetic	Phase III	0-0.5 feet	Port Channel	3	1,390	3,660	7,280,000	2,690,000	2,010,000	312,000
Arithmetic	Phase III	0-0.5 feet	Subtidal Flats	151	4,240	< 10,700	20,700,000	6,130,000	4,240,000	< 194,000
Arithmetic	Phase III	0-0.5 feet	Transitional Slopes	11	2,180	10,100	11,800,000	3,850,000	2,840,000	215,000
Geometric	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	2,870	8,460	20,200,000	2,360,000	1,810,000	209,000
Geometric	Phase III	0-0.5 feet	Industrial Waterfront	31	1,490	10,500	16,600,000	2,370,000	1,830,000	> 273,000
Geometric	Phase III	0-0.5 feet	Intertidal Area	9	1,790	4,570	9,090,000	2,440,000	1,920,000	249,000
Geometric	Phase III	0-0.5 feet	Navigational Area	22	1,710	8,610	11,400,000	1,660,000	1,300,000	182,000
Geometric	Phase III	0-0.5 feet	Port Channel	3	1,330	3,400	6,750,000	2,390,000	1,790,000	287,000
Geometric	Phase III	0-0.5 feet	Subtidal Flats	151	1,550	< 6,330	10,900,000	1,730,000	1,290,000	< 114,000
Geometric	Phase III	0-0.5 feet	Transitional Slopes	11	1,780	6,790	9,520,000	2,720,000	2,040,000	189,000
Model Significance Testing			**Significance of Geomorphic Unit in ANCOVA[d] Model (p-value)**		0.371	**0.026**	0.058	0.732	0.647	**0.001**
	Pairwise Differences[c]		**Industrial Waterfront > Subtidal Flats**							**
	*** Significant at α = 0.05**		**Historically Disturbed > Subtidal Flats**							
	**** Significant at α = 0.01**		**Industrial Waterfront > Navigation Channel**							
			Industrial Waterfront > Historically Disturbed							
			Subtidal Flats > Navigation Channel							

Table 4-12
Phase III Surface Sediment –
Geomorphic Area Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Spatial Group - Geomorphic Units	Sample Size	Cis-Nonachlor (pg/g)	Dieldrin (pg/g)	Hexachloro-benzene (pg/g)	Total PAHs (µg/kg)	Total HMW PAHs (µg/kg)	Total LMW PAHs (µg/kg)	Total Alkylated PAHs (µg/kg)	TPH (mg/kg)	Bis(2-ethylhexyl)phthalate (µg/kg)
Arithmetic	**Phase III**	**0-0.5 feet**	**Baywide**	**254**	**879**	**1740**	**2,870**	**12,200**	**10,900**	**1,350**	**12,900**	**342**	**1120**
Arithmetic	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	> 1300	> 2790	3,620	13,900	12,300	1,700	10,700	260	1210
Arithmetic	Phase III	0-0.5 feet	Industrial Waterfront	31	906	1970	1,940	12,400	10,400	1,980	6,430	398	1010
Arithmetic	Phase III	0-0.5 feet	Intertidal Area	9	792	887	1,110	5,840	5,290	571	4,340	269	601
Arithmetic	Phase III	0-0.5 feet	Navigational Area	22	1080	1340	1,080	12,300	11,200	1,120	8,060	316	1020
Arithmetic	Phase III	0-0.5 feet	Port Channel	3	1250	1730	1,070	10,200	9,000	1,190	6,750	114	407
Arithmetic	Phase III	0-0.5 feet	Subtidal Flats	151	< 695	< 1610	3,370	11,700	10,500	1,190	15,500	360	< 1140
Arithmetic	Phase III	0-0.5 feet	Transitional Slopes	11	1760	1820	2,340	21,000	19,000	2,160	19,000	312	1610
Geometric	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	> 1080	> 1660	1,670	10,300	9,150	1,080	8,140	180	756
Geometric	Phase III	0-0.5 feet	Industrial Waterfront	31	479	1030	889	6,300	5,530	722	3,800	241	574
Geometric	Phase III	0-0.5 feet	Intertidal Area	9	529	773	930	4,620	4,240	408	3,250	167	539
Geometric	Phase III	0-0.5 feet	Navigational Area	22	618	855	686	7,590	6,770	754	5,310	162	399
Geometric	Phase III	0-0.5 feet	Port Channel	3	549	1640	1,040	9,620	8,460	1,120	6,630	100	383
Geometric	Phase III	0-0.5 feet	Subtidal Flats	151	< 304	< 557	896	5,780	5,240	578	4,970	172	< 360
Geometric	Phase III	0-0.5 feet	Transitional Slopes	11	1310	1450	1,480	11,100	9,960	1,150	10,500	223	885
Model Significance Testing			**ANOVA[b] Model Significance p-value**		**<.0001[e]**	**0.0002[e]**	0.084	0.282	0.300	0.139	**0.015[e]**	0.796	**0.005**
	Pairwise Differences[c] *** Significant at α = 0.05** **** Significant at α = 0.01**		**Historically Disturbed > Subtidal Flats**		**	**							*
			Historically Disturbed > Industrial Waterfront										
			Industrial Waterfront > Subtidal Flats										
			Transitional Slopes > Intertidal Area										
			Transitional Slopes > Subtidal Flats		**								

Mean Statistic[a] (Normalized Data)	Phase	Depth	Spatial Group - Geomorphic Units	Sample Size	Cis-Nonachlor (pg/g-oc)	Dieldrin (pg/g-oc)	Hexachloro-benzene (pg/g-oc)	Total PAHs (µg/kg-oc)	Total HMW PAHs (µg/kg-oc)	Total LMW PAHs (µg/kg-oc)	Total Alkylated PAHs (µg/kg-oc)	TPH (mg/kg-oc)	Bis(2-ethylhexyl)phthalate (µg/kg-oc)
Arithmetic	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	47,300	101,000	105,000	487,000	432,000	56,400	345,000	8,610	47,200
Arithmetic	Phase III	0-0.5 feet	Industrial Waterfront	31	50,900	92,900	79,000	562,000	482,000	79,700	323,000	28,600	70,600
Arithmetic	Phase III	0-0.5 feet	Intertidal Area	9	112,000	73,500	78,300	327,000	305,000	27,300	230,000	35,600	58,600
Arithmetic	Phase III	0-0.5 feet	Navigational Area	22	46,600	57,300	45,300	809,000	740,000	64,300	541,000	16,300	41,400
Arithmetic	Phase III	0-0.5 feet	Port Channel	3	45,000	62,700	39,500	367,000	322,000	42,800	243,000	4,190	14,500
Arithmetic	Phase III	0-0.5 feet	Subtidal Flats	151	< 32,800	< 80,000	149,000	707,000	629,000	79,200	727,000	19,300	52,800
Arithmetic	Phase III	0-0.5 feet	Transitional Slopes	11	54,800	56,300	69,500	540,000	487,000	55,300	522,000	9,840	47,600
Geometric	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	38,100	58,800	59,100	363,000	324,000	38,400	288,000	6,390	26,700
Geometric	Phase III	0-0.5 feet	Industrial Waterfront	31	29,400	63,500	54,500	386,000	339,000	44,300	233,000	14,800	35,200
Geometric	Phase III	0-0.5 feet	Intertidal Area	9	30,400	44,400	53,400	265,000	244,000	23,400	187,000	9,600	31,000
Geometric	Phase III	0-0.5 feet	Navigational Area	22	32,900	45,600	36,600	404,000	361,000	40,200	283,000	8,630	21,300
Geometric	Phase III	0-0.5 feet	Port Channel	3	19,900	59,400	37,600	347,000	306,000	40,400	240,000	3,620	13,800
Geometric	Phase III	0-0.5 feet	Subtidal Flats	151	< 19,400	< 34,800	55,900	359,000	326,000	35,900	309,000	10,700	22,400
Geometric	Phase III	0-0.5 feet	Transitional Slopes	11	43,300	48,000	48,900	366,000	328,000	37,800	348,000	7,360	29,200
Model Significance Testing			**Significance of Geomorphic Unit in ANCOVA[d] Model (p-value)**		**0.009**	**0.019**	0.778	0.957	0.970	0.728	0.834	0.457	0.069
	Pairwise Differences[c] *** Significant at α = 0.05** **** Significant at α = 0.01**		**Industrial Waterfront > Subtidal Flats**										
			Historically Disturbed > Subtidal Flats		*								
			Industrial Waterfront > Navigation Channel										
			Industrial Waterfront > Historically Disturbed										
			Subtidal Flats > Navigation Channel										

Table 4-12
Phase III Surface Sediment –
Geomorphic Area Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Spatial Group - Geomorphic Units	Sample Size	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (ng/g)	Methyl Mercury (ng/g)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
Arithmetic	**Phase III**	**0-0.5 feet**	**Baywide**	**254**	**18.3**	**2.06**	**123**	**149**	**166**	**2,350**	**1.1**	**40.9**	**1.02**	**1.81**	**300**
Arithmetic	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	18.1	> 3.22	159	165	153	2,810	1.21	> 48.4	1.02	> 2.51	300
Arithmetic	Phase III	0-0.5 feet	Industrial Waterfront	31	< 15.2	1.54	85.8	158	244	1,570	1.71	48.7	0.801	1.34	598
Arithmetic	Phase III	0-0.5 feet	Intertidal Area	9	11.4	0.854	83.1	96.2	96.6	1,400	1.21	25.7	0.569	1.08	211
Arithmetic	Phase III	0-0.5 feet	Navigational Area	22	12.7	1.69	105	113	166	1,670	1.2	42	0.688	1.77	226
Arithmetic	Phase III	0-0.5 feet	Port Channel	3	16.3	1.25	101	115	133	2,080	2.17	44.9	0.878	1.93	268
Arithmetic	Phase III	0-0.5 feet	Subtidal Flats	151	20.1	2.05	128	149	156	2,520	< 0.884	< 37.5	1.13	1.72	< 249
Arithmetic	Phase III	0-0.5 feet	Transitional Slopes	11	19.2	2.82	140	205	185	3,320	1.53	55.4	1.2	> 3.36	390
Geometric	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	16.1	> 1.93	129	136	139	2,120	0.833	> 46	0.9	> 2.08	277
Geometric	Phase III	0-0.5 feet	Industrial Waterfront	31	< 9.93	0.897	70.5	104	125	1,070	1.06	33.6	0.581	0.924	267
Geometric	Phase III	0-0.5 feet	Intertidal Area	9	10.7	0.717	74.6	80.2	82.1	1,210	0.683	23.2	0.501	0.852	192
Geometric	Phase III	0-0.5 feet	Navigational Area	22	11.6	0.912	83.8	88.7	101	1,170	0.936	38.1	0.613	1.27	194
Geometric	Phase III	0-0.5 feet	Port Channel	3	16.3	1.22	101	115	133	2,020	1.77	44.8	0.878	1.9	266
Geometric	Phase III	0-0.5 feet	Subtidal Flats	151	14.8	0.9	84.5	83.9	91.7	1,200	< 0.62	< 30.8	0.731	1	< 178
Geometric	Phase III	0-0.5 feet	Transitional Slopes	11	17.5	1.87	124	166	163	2,430	1.34	54.2	1.04	> 2.84	336
Model Significance Testing			**ANOVA[b] Model Significance p-value**		**0.026**	**0.015**	0.070	0.103	0.137	**0.009[e]**	**0.007**	**0.001**	0.092	**0.001**	**0.010**
			Historically Disturbed > Subtidal Flats			*						*		*	
			Historically Disturbed > Industrial Waterfront												
			Industrial Waterfront > Subtidal Flats								*				
			Transitional Slopes > Intertidal Area									*			
			Transitional Slopes > Subtidal Flats											*	

Pairwise Differences[c]
*** Significant at α = 0.05**
**** Significant at α = 0.01**

Mean Statistic[a] (Normalized Data)	Phase	Depth	Spatial Group - Geomorphic Units	Sample Size	Arsenic (mg/kg-Al)	Cadmium (mg/kg-Al)	Chromium (mg/kg-Al)	Copper (mg/kg-Al)	Lead (mg/kg-Al)	Mercury (ng/g-Al)	Methyl Mercury (ng/g-Al)	Nickel (mg/kg-Al)	Selenium (mg/kg-Al)	Silver (mg/kg-Al)	Zinc (mg/kg-Al)
Arithmetic	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	1130	196	10,100	10,300	9,820	177,000	76.3	3,210	63.9	158	19,200
Arithmetic	Phase III	0-0.5 feet	Industrial Waterfront	31	1340	133	8,020	> 15,100	> 21,300	144,000	> 149	> 4,770	71.6	120	> 51,000
Arithmetic	Phase III	0-0.5 feet	Intertidal Area	9	1250	85.8	9,750	9,830	9,980	156,000	125	2,630	58.8	104	22,400
Arithmetic	Phase III	0-0.5 feet	Navigational Area	22	< 856	104	7,130	7,750	17,200	107,000	74	2,950	46.5	110	15,200
Arithmetic	Phase III	0-0.5 feet	Port Channel	3	775	58.2	4,770	5,420	6,270	98,400	111	2,120	41.7	90.3	12,600
Arithmetic	Phase III	0-0.5 feet	Subtidal Flats	151	> 1470	132	8,710	9,990	10,700	169,000	< 64.1	< 2,790	80.4	113	< 17,700
Arithmetic	Phase III	0-0.5 feet	Transitional Slopes	11	1060	153	7,570	11,100	10,000	177,000	81.8	3,080	65.1	180	21,200
Geometric	Phase III	0-0.5 feet	Historically Disturbed Subtidal Flats	27	1050	126	8,430	8,930	9,060	139,000	54.5	3,010	58.9	136	18,100
Geometric	Phase III	0-0.5 feet	Industrial Waterfront	31	1050	95.3	7,480	> 11,000	> 13,300	114,000	> 113	> 3,570	61.4	98.1	> 28,400
Geometric	Phase III	0-0.5 feet	Intertidal Area	9	1200	80.6	8,390	9,020	9,230	136,000	76.7	2,600	56.3	95.7	21,600
Geometric	Phase III	0-0.5 feet	Navigational Area	22	< 827	64.8	5,950	6,290	7,140	82,800	66.4	2,700	43.5	89.9	13,800
Geometric	Phase III	0-0.5 feet	Port Channel	3	768	57.5	4,740	5,400	6,250	95,200	83.5	2,110	41.4	89.6	12,600
Geometric	Phase III	0-0.5 feet	Subtidal Flats	151	> 1240	76.4	7,080	7,030	7,680	100,000	< 51.9	< 2,580	61.3	83.8	< 15,000
Geometric	Phase III	0-0.5 feet	Transitional Slopes	11	973	104	6,890	9,200	9,040	135,000	74.5	3,010	57.6	158	18,700
Model Significance Testing			**Significance of Geomorphic Unit in ANCOVA[d] Model (p-value)**		**0.028**	0.108	0.180	**0.006**	**0.005**	0.267	**<.0001**	**0.003**	0.22	0.060	**<.0001**
			Industrial Waterfront > Subtidal Flats					**	**		**	**			
			Historically Disturbed > Subtidal Flats												
			Industrial Waterfront > Navigation Channel					*	*						
			Industrial Waterfront > Historically Disturbed								**				*
			Subtidal Flats > Navigation Channel		*										

Pairwise Differences[c]
*** Significant at α = 0.05**
**** Significant at α = 0.01**

Table 4-12
Phase III Surface Sediment –
Geomorphic Area Comparison

Notes:

[a]Arithmetic means and geometric means for each geomorphic unit are shown on both a raw and normalized basis. Organic compounds are normalized by TOC. Metals are normalized by aluminum.

[b]The ANOVA model tests if concentration is dependent upon geomorphic unit. The p-value for the significance of the F statistic is shown. Values that are significant at α = 0.05 are shown in bold. Modeling and post hoc testing was conducted on natural log-transformed data. If Levene's test is significant and the group standard deviations differ by more than a factor of two, the p-value is reported for the Welch ANOVA test which is robust to the equal variance assumption. The Port Channel means are shown for information but the Port Channels were not included in the ANOVA evaluation due to the small sample size.

[c]Multiple pairwise comparison testing was conducted using the Tukey-Kramer method for unbalanced design (i.e. unequal sample size among groups). Only comparisons that were significant for at least one chemical are listed. In some cases of overall model significance where the p-values are close to the significance threshold (0.05), post hoc testing may not be produce significant comparison results, an outcome that can occur with an unbalanced design.

[d]The ANCOVA model tests if concentration is dependent upon geomorphic unit while controlling for the normalization variable (either TOC or aluminum) which is added as a covariate to the model. The p-value for the significance of the geomorphic unit in the model is shown. Values that are significant at α = 0.05 are shown in bold. Normalization variables were significant for all ANCOVA models. Modeling and post hoc testing was conducted on natural log-transformed data. The Port Channel means are shown for information but the Port Channels were not included in the ANCOVA evaluation due to the small sample size.

[e]The reported p-value is based on the Welch ANOVA test (see also note b). When the Welch's test is significant but the equal variance ANOVA p-value is insignificant, no post hoc testing was conducted.

The Nelson-Hsu analysis of means test was also conducted for each model and tests whether any individual group mean is greater than the overall (i.e. Bay-wide) mean(α=0.05). The symbol > to the left of a group mean indicates that it is greater than the overall mean. The symbol < to the left of the group mean indicates that it is less than the overall mean. The ANCOVA tests the means after controlling for the normalization variable.

1/2 the quantitation limit was substituted for non-detects. Only chemicals with a frequency of detection greater than 70% were included in the analyses.

Analysis includes all Phase III surface sediment data collected 2014-2016 including the Crab/Clam and Sediment Quality Triad sampling programs.

A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

The geomorphic units are depicted in Figure 2-1.

Acronyms and Abbreviations:

< = group mean less than overall mean (Nelson-Hsu Test)
> = group mean greater than overall mean (Nelson-Hsu Test)
<.0001 = p-value is less than 0.0001
Al = aluminum
ANCOVA = analysis of covariance
ANOVA = analysis of variance
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/g = nanograms per gram
ng/kg = nanograms per kilogram
oc = organic carbon
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
pg/g = picograms per gram
TCDD = tetrachlorodibenzo-p-dioxin
TOC = total organic carbon
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
TPH = total petroleum hydrocarbons
µg/kg = micrograms per kilogram

Legend for Shading

1	**Lowest Arithmetic or Geometric Mean**
2	
3	
4	
5	
6	**Greatest Arithmetic or Geometric Mean**

Table 4-13
Phase III Stratified Mean Surface Sediment Concentrations

Analyte Group	Analyte	Units	Number of Samples[a]	Number of Detects	Stratified Mean[b]	Standard Error	95LCL	95UCL	Median	Minimum Detect	Maximum Detect
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	254	254	68.9	8.25	55.3	82.5	42.8	0.12	1,710
PCBs	Total PCBs (9)	µg/kg	254	239	192	12.8	171	213	140	6.4	2,500
PCBs	Total PCBs congener (209 specified)	ng/kg	254	254	390,000	29,300	342,000	439,000	278,000	2,480	5,030,000
Pesticides	alpha-BHC	pg/g	252	172	113	12.2	93.2	133	63	6.32	1,260
Pesticides	beta-BHC	pg/g	253	148	140	37.9	77.7	202	74.8	6.24	1,430
Pesticides	cis-Nonachlor	pg/g	248	202	853	79.7	722	984	781	22.3	4,830
Pesticides	Dieldrin	pg/g	253	240	1,500	155	1,240	1,750	947	39.4	37,400
Pesticides	Hexachlorobenzene	pg/g	253	252	2,030	225	1,660	2,400	1,040	13.2	46,200
Pesticides	Total alpha + gamma chlordane	pg/g	253	244	5,040	401	4,380	5,700	4,300	39	32,000
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	pg/g	254	254	100,000	12,800	79,000	121,000	34,500	120	2,600,000
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	pg/g	254	254	72,000	9,050	57,100	86,900	26,000	93	1,800,000
PAHs	Total Alkylated PAHs	µg/kg	254	245	9,840	837	8,470	11,200	5,990	38.5	168,000
PAHs	Total HMW PAHs	µg/kg	254	252	9,240	642	8,180	10,300	6,980	37	100,000
PAHs	Total LMW PAHs	µg/kg	254	245	1,150	102	982	1,320	785	5.2	17,000
PAHs	Total PAH	µg/kg	254	252	10,400	731	9,200	11,600	7,700	37	110,000
Semivolatiles	bis(2-Ethylhexyl)phthalate (DEHP)	µg/kg	253	198	905	185	601	1210	400	96	38,000
TPH	Total Petroleum Hydrocarbons	mg/kg	254	246	257	17.3	229	285	190	6.45	2,910
Metals	Aluminum	mg/kg	254	254	15,100	540	14,200	16,000	14,000	1650	35,000
Metals	Arsenic	mg/kg	254	254	16.7	0.738	15.4	17.9	13.3	1.18	115
Metals	Cadmium	mg/kg	254	252	1.59	0.122	1.39	1.79	0.905	0.0592	24.6
Metals	Chromium	mg/kg	254	254	108	5.5	98.9	117	95.8	3.95	777
Metals	Copper	mg/kg	254	254	126	6.35	115	136	100	1.5	924
Metals	Lead	mg/kg	254	254	142	9.5	126	157	111	2.18	2,190
Metals	Mercury	ng/g	254	254	1,970	128	1,760	2,180	1,480	5.11	22,100
Metals	Methyl mercury	ng/g	254	253	1.21	0.128	0.998	1.42	0.833	0.027	11.9
Metals	Nickel	mg/kg	254	254	41.7	1.31	39.6	43.9	37.9	3.83	282
Metals	Selenium	mg/kg	253	250	0.878	0.0458	0.803	0.953	0.704	0.0939	7.58
Metals	Silver	mg/kg	254	253	1.67	0.0828	1.54	1.81	1.46	0.0448	12
Metals	Zinc	mg/kg	254	254	261	18.6	230	291	220	8.18	6,810
Grain Size	Fines	%	254	254	61.7	2.43	57.7	65.7	61.1	2.6	96.8
TOC	Total organic carbon (TOC)	mg/kg	254	252	22,800	1,030	21,100	24,500	22,200	1,030	151,000

Table 4-13
Phase III Stratified Mean Surface Sediment Concentrations

Notes:

a Sample counts and statistics include sediment samples collected during all Phase III sampling activities, including the 2014 Crab and Clam sampling program, the 2015 SQT sampling program, and the 2016 Phase III surface sediment sampling program. Sample counts exclude samples with analytical results that were rejected in the data validation process.

[b] The stratified mean is a spatially weighted average (i.e., the average of each USEPA subunit average, weighted by the area of the subunit) using the USEPA subunits depicted on Figure 2-8.

One half the quantitation limit was substituted for non-detect data.

A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Acronyms and Abbreviations:

-- Not calculated due to low frequency of detection.
% = percent
95LCL = One-sided 95% Lower Confidence Limit
95UCL = One-sided 95% Upper Confidence Limit
BHC = benzene hexachloride
HMW = high-molecular weight
LMW = low-molecular weight
mg/kg = milligrams per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/kg = nanograms per kilogram
PAHs = polycyclic aromatic hydrocarbons
PCB = polychlorinated biphenyl
pg/g = picogram per gram
SQT = Sediment Quality Triad
TOC = total organic carbon
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
TPH = Total Petroleum Hydrocarbons, the sum of gasoline range organics (GRO) and diesel range organics (DRO).
USEPA = U.S. Environmental Protection Agency
µg/kg = micrograms per kilogram

Table 4-14
Phase III Surface Sediment – USEPA Subunit Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Spatial Group - USEPA Subunits	Sample Size	2,3,7,8-TCDD (ng/kg)	Total PCBs (9 Aroclors) (µg/kg)	Total PCBs (209 Congeners) (ng/kg)	Total DDX (2,4' & 4,4') (ND=0) (pg/g)	Total DDX (4,4') (ND=0) (pg/g)	Total Alpha + Gamma Chlordane (pg/g)	Cis-Nonachlor (pg/g)	Dieldrin (pg/g)	Hexachloro-benzene (pg/g)
Arithmetic	**Phase III**	**0-0.5 feet**	**Baywide**	**254**	**87.1**	**239**	**480,000**	**131,000**	**93,100**	**5,070**	**879**	**1740**	**2870**
Arithmetic	Phase III	0-0.5 feet	1	90	76.7	> 375	630,000	> 292,000	> 205,000	5,380	966	2280	> 5480
Arithmetic	Phase III	0-0.5 feet	2	10	25.4	107	214,000	64,800	48,400	5,140	826	1060	658
Arithmetic	Phase III	0-0.5 feet	3	11	68.4	262	299,000	28,900	23,100	5,000	1050	1150	1090
Arithmetic	Phase III	0-0.5 feet	4	43	> 134	201	592,000	41,100	31,900	> 7,320	> 1180	2170	1870
Arithmetic	Phase III	0-0.5 feet	5	50	53.8	160	353,000	< 45,300	< 33,200	5,110	856	1340	1000
Arithmetic	Phase III	0-0.5 feet	6	50	116	< 126	331,000	< 39,900	< 29,100	< 2,520	< 439	< 1060	1700
Geometric	Phase III	0-0.5 feet	1	90	23.8	> 183	266,000	> 80,200	> 58,800	2,640	377	756	> 1370
Geometric	Phase III	0-0.5 feet	2	10	18.6	97.9	194,000	39,900	29,600	3,840	458	897	540
Geometric	Phase III	0-0.5 feet	3	11	43.8	175	206,000	18,100	14,300	3,020	578	734	767
Geometric	Phase III	0-0.5 feet	4	43	> 60.7	145	305,000	29,800	23,000	> 5,050	> 738	1210	1130
Geometric	Phase III	0-0.5 feet	5	50	26.3	101	184,000	< 19,900	< 15,300	2,900	551	752	598
Geometric	Phase III	0-0.5 feet	6	50	29.3	< 69.6	137,000	< 16,700	< 12,700	< 1,350	< 241	< 470	813
Model Significance Testing	**ANOVA[b] Model Significance p-value**				**0.032**	**0.0004[e]**	0.062	**<.0001**	**<.0001**	**0.001**	**0.007**	**0.009[e]**	**.011[e]**
	Pairwise Differences[c] *** Significant at α = 0.05** **** Significant at α = 0.01**			**4 > 1**	*								
				4 > 6		*					**	**	
				1 > 2									
				1 > 3									
				1 > 4				**	*				
				1 > 5		*		**	**				*
				1 > 6		**		**	**				
				5 > 6									

Mean Statistic[a] (Normalized Data)	Phase	Depth	Spatial Group - USEPA Subunits	Sample Size	2,3,7,8-TCDD (ng/kg-oc)	Total PCBs (9 Aroclors) (µg/kg-oc)	Total PCBs (209 Congeners) (ng/kg-oc)	Total DDX (2,4' & 4,4') (ND=0) (pg/g-oc)	Total DDX (4,4') (ND=0) (pg/g-oc)	Total Alpha + Gamma Chlordane (pg/g-oc)	Cis-Nonachlor (pg/g-oc)	Dieldrin (pg/g-oc)	Hexachloro-benzene (pg/g-oc)
Arithmetic	Phase III	0-0.5 feet	1	90	< 2,570	> 15,100	23,600,000	> 10,300,000	> 7,140,000	211000	34000	85,100	> 188,000
Arithmetic	Phase III	0-0.5 feet	2	10	1,090	6,330	10,600,000	2,700,000	2,010,000	216000	36900	48,800	29,200
Arithmetic	Phase III	0-0.5 feet	3	11	4,190	14,000	14,400,000	1,310,000	1,030,000	222000	48800	54,200	50,500
Arithmetic	Phase III	0-0.5 feet	4	43	> 5,720	12,900	28,900,000	2,080,000	1,600,000	> 343000	> 54100	> 98,100	87,300
Arithmetic	Phase III	0-0.5 feet	5	50	2,450	8,370	17,200,000	< 2,120,000	< 1,590,000	421000	60400	88,300	< 60,900
Arithmetic	Phase III	0-0.5 feet	6	50	6,520	< 8,380	19,900,000	< 2,490,000	< 1,800,000	< 145000	25500	61,200	114,000
Geometric	Phase III	0-0.5 feet	1	90	< 1,220	> 9,410	13,700,000	> 4,120,000	> 3,020,000	136000	19600	38,800	> 70,500
Geometric	Phase III	0-0.5 feet	2	10	946	4,970	9,840,000	2,030,000	1,510,000	195000	23300	45,600	27,400
Geometric	Phase III	0-0.5 feet	3	11	2,560	10,300	12,100,000	1,060,000	838,000	177000	33800	43,000	44,900
Geometric	Phase III	0-0.5 feet	4	43	> 3,150	7,540	15,800,000	1,540,000	1,190,000	> 262000	> 38300	> 62,800	58,700
Geometric	Phase III	0-0.5 feet	5	50	1,490	5,750	10,500,000	< 1,130,000	< 871,000	167000	31700	43,200	< 34,400
Geometric	Phase III	0-0.5 feet	6	50	1,960	< 4,670	9,220,000	< 1,120,000	< 853,000	< 90600	16800	31,500	54,500
Model Significance Testing	**p-value for Subunit in ANCOVA[d] Model**				**0.003**	**0.0001**	0.18	**<.0001**	**<.0001**	**0.0007**	**0.005**	**0.069**	**0.014**
	Pairwise Differences[c] *** Significant at α = 0.05** **** Significant at α = 0.01**			**4 > 1**	**					*	*		
				4 > 6						**	*	*	
				1 > 2									
				1 > 3				*	*				
				1 > 4				**	**				
				1 > 5		*		**	**				*
				1 > 6		**		**	**				
				5 > 6									
				All (1,3,4,5,6) > 2									

Table 4-14
Phase III Surface Sediment – USEPA Subunit Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Spatial Group - USEPA Subunits	Sample Size	Total PAHs (µg/kg)	Total HMW PAHs (µg/kg)	Total LMW PAHs (µg/kg)	Total Alkylated PAHs (µg/kg)	TPH (mg/kg)	Bis(2-ethylhexyl)phthalate (µg/kg)
Arithmetic	**Phase III**	**0-0.5 feet**	**Baywide**	**254**	**12200**	**10900**	**1350**	**12900**	**342**	**1,120**
Arithmetic	Phase III	0-0.5 feet	1	90	13800	12000	1780	21200	> 553	1,100
Arithmetic	Phase III	0-0.5 feet	2	10	6150	5440	708	4230	< 83.2	283
Arithmetic	Phase III	0-0.5 feet	3	11	19600	18000	1610	11400	349	1,230
Arithmetic	Phase III	0-0.5 feet	4	43	14600	13200	1330	8710	189	1,100
Arithmetic	Phase III	0-0.5 feet	5	50	9080	7950	1160	7060	234	1,380
Arithmetic	Phase III	0-0.5 feet	6	50	10200	9280	889	9450	254	1,040
Geometric	Phase III	0-0.5 feet	1	90	6530	5810	707	6680	> 255	514
Geometric	Phase III	0-0.5 feet	2	10	4710	4160	529	3230	< 61.6	244
Geometric	Phase III	0-0.5 feet	3	11	13900	12600	1180	8720	209	491
Geometric	Phase III	0-0.5 feet	4	43	9990	9080	957	6110	160	538
Geometric	Phase III	0-0.5 feet	5	50	5170	4640	604	3630	146	435
Geometric	Phase III	0-0.5 feet	6	50	5160	4730	447	4070	158	306
Model Significance Testing	**ANOVA[b] Model Significance p-value**				0.062	0.053	0.071	0.166	**.007[e]**	0.055
	Pairwise Differences[c] *** Significant at α = 0.05** **** Significant at α = 0.01**			**4 > 1** **4 > 6** **1 > 2** **1 > 3** **1 > 4** **1 > 5** **1 > 6** **5 > 6**					******	

Mean Statistic[a] (Normalized Data)	Phase	Depth	Spatial Group - USEPA Subunits	Sample Size	Total PAHs (µg/kg-oc)	Total HMW PAHs (µg/kg-oc)	Total LMW PAHs (µg/kg-oc)	Total Alkylated PAHs (µg/kg-oc)	TPH (mg/kg-oc)	Bis(2-ethylhexyl)phthalate (µg/kg-oc)
Arithmetic	Phase III	0-0.5 feet	1	90	529,000	464,000	66,400	713,000	> 23,200	45,200
Arithmetic	Phase III	0-0.5 feet	2	10	271,000	239,000	31,100	192,000	< 5,110	13,100
Arithmetic	Phase III	0-0.5 feet	3	11	1,400,000	1,290,000	102,000	883,000	21,000	54,200
Arithmetic	Phase III	0-0.5 feet	4	43	782,000	711,000	69,100	467,000	14,100	65,300
Arithmetic	Phase III	0-0.5 feet	5	50	635,000	536,000	102,000	401,000	16,700	58,300
Arithmetic	Phase III	0-0.5 feet	6	50	682,000	624,000	57,200	673,000	20,300	58,800
Geometric	Phase III	0-0.5 feet	1	90	335,000	298,000	36,300	343,000	> 13,100	26,400
Geometric	Phase III	0-0.5 feet	2	10	239,000	211,000	26,900	164,000	< 3,130	12,400
Geometric	Phase III	0-0.5 feet	3	11	811,000	736,000	68,900	510,000	12,200	28,700
Geometric	Phase III	0-0.5 feet	4	43	518,000	471,000	49,600	317,000	8,320	27,900
Geometric	Phase III	0-0.5 feet	5	50	294,000	263,000	34,300	206,000	8,310	24,900
Geometric	Phase III	0-0.5 feet	6	50	346,000	317,000	30,000	273,000	10,600	20,600
Model Significance Testing	**p-value for Subunit in ANCOVA[d] Model**				**0.030[e]**	**0.022[e]**	0.099	0.15	**0.002**	0.10
	Pairwise Differences[c] *** Significant at α = 0.05** **** Significant at α = 0.01**			**4 > 1** **4 > 6** **1 > 2** **1 > 3** **1 > 4** **1 > 5** **1 > 6** **5 > 6** **All (1,3,4,5,6) > 2**					******	

Table 4-14
Phase III Surface Sediment – USEPA Subunit Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Spatial Group - USEPA Subunits	Sample Size	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (ng/g)	Methyl Mercury (ng/g)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
Arithmetic	**Phase III**	**0-0.5 feet**	**Baywide**	**254**	**18.3**	**2.06**	**123**	**149**	**166**	**2,350**	**1.1**	**40.9**	**1.02**	**1.81**	**300**
Arithmetic	Phase III	0-0.5 feet	1	90	> 25.8	> 3.74	145	> 237	> 253	> 3,630	1.3	> 47.8	> 1.63	2.39	> 462
Arithmetic	Phase III	0-0.5 feet	2	10	14.2	0.858	77.1	89.2	98.7	1,310	1.55	45	0.662	1.44	204
Arithmetic	Phase III	0-0.5 feet	3	11	10.1	1.42	111	99.3	217	1,680	1.07	34.3	0.605	1.49	208
Arithmetic	Phase III	0-0.5 feet	4	43	13.9	1.51	140	121	132	1,930	1.01	38.4	0.78	1.77	256
Arithmetic	Phase III	0-0.5 feet	5	50	17.3	1.04	104	112	126	1,800	1.02	44.7	0.767	1.76	223
Arithmetic	Phase III	0-0.5 feet	6	50	< 12	< 0.919	< 97.9	< 74.5	< 80.6	< 1,310	0.828	< 27.3	< 0.562	< 1.01	< 161
Geometric	Phase III	0-0.5 feet	1	90	> 18.6	> 1.69	95.5	> 141	> 147	> 1,830	0.801	> 39.9	> 1.01	1.38	> 282
Geometric	Phase III	0-0.5 feet	2	10	13.9	0.771	71.9	82.1	91.8	1,120	1.16	44.8	0.611	1.33	193
Geometric	Phase III	0-0.5 feet	3	11	9.22	0.817	86.2	77.1	101	1,100	0.787	29.5	0.555	1.01	173
Geometric	Phase III	0-0.5 feet	4	43	11.7	1.05	111	99.8	107	1,370	0.775	33.7	0.685	1.37	219
Geometric	Phase III	0-0.5 feet	5	50	13.4	0.801	86.3	86.7	103	1,230	0.715	37.2	0.653	1.31	193
Geometric	Phase III	0-0.5 feet	6	50	< 10.7	< 0.545	< 65	< 49.9	< 53.9	< 762	0.589	< 21.9	< 0.49	< 0.612	< 122
Model Significance Testing	**ANOVA[b] Model Significance p-value**				**0.0001[e]**	**0.0001[e]**	**0.050**	**<.0001[e]**	**<.0001**	**0.003**	0.318	**<.0001**	**<.0001[e]**	**0.0006**	**<.0001**
	Pairwise Differences[c]			**4 > 1**											
	*** Significant at α = 0.05**			**4 > 6**		*	*	**	**			**		**	**
	**** Significant at α = 0.01**			**1 > 2**											
				1 > 3	*										
				1 > 4	**										
				1 > 5		**							*		
				1 > 6	**	**		**	**	**		**	**	**	**
				5 > 6					**			**		**	*

Mean Statistic[a] (Normalized Data)	Phase	Depth	Spatial Group - USEPA Subunits	Sample Size	Arsenic (mg/kg-Al)	Cadmium (mg/kg-Al)	Chromium (mg/kg-Al)	Copper (mg/kg-Al)	Lead (mg/kg-Al)	Mercury (ng/g-Al)	Methyl Mercury (ng/g-Al)	Nickel (mg/kg-Al)	Selenium (mg/kg-Al)	Silver (mg/kg-Al)	Zinc (mg/kg-Al)
Arithmetic	Phase III	0-0.5 feet	1	90	> 1780	> 228	9,470	> 16,100	> 17,400	> 233,000	91.2	> 3,760	> 110	> 153	> 33,100
Arithmetic	Phase III	0-0.5 feet	2	10	788	< 44.5	< 4,050	< 4,690	5,210	67,000	80.8	2,610	< 34.8	75.3	10,900
Arithmetic	Phase III	0-0.5 feet	3	11	858	102	8,960	8,740	28,300	125,000	78.3	3,040	51.9	110	17,200
Arithmetic	Phase III	0-0.5 feet	4	43	1000	105	9,410	8,530	9,600	136,000	70.2	2,710	53.6	118	18,200
Arithmetic	Phase III	0-0.5 feet	5	50	1170	< 73.6	7,270	7,370	8,660	118,000	70.1	2,960	54	111	15,700
Arithmetic	Phase III	0-0.5 feet	6	50	1210	< 79.5	8,390	< 6,590	< 7,210	119,000	78.6	< 2,450	53.2	< 88	< 14,700
Geometric	Phase III	0-0.5 feet	1	90	> 1,510	> 137	7,760	> 11,500	> 11,900	> 148,000	65.1	> 3,240	> 82	> 112	> 22,900
Geometric	Phase III	0-0.5 feet	2	10	775	< 43	< 4,010	< 4,580	5,120	62,400	64.5	2,500	< 34.1	74	10,800
Geometric	Phase III	0-0.5 feet	3	11	828	73.4	7,740	6,930	9,070	98,400	70.7	2,650	49.9	91.2	15,500
Geometric	Phase III	0-0.5 feet	4	43	867	78.4	8,230	7,430	7,980	102,000	57.7	2,500	50.9	102	16,300
Geometric	Phase III	0-0.5 feet	5	50	1,010	< 60.5	6,520	6,550	7,740	93,100	54	2,810	49.3	99.2	14,500
Geometric	Phase III	0-0.5 feet	6	50	1,090	< 55.6	6,630	< 5,090	< 5,500	77,600	60	< 2,230	50	< 62.4	< 12,400
Model Significance Testing	**p-value for Subunit in ANCOVA[d] Model**				**<.0001**	**<.0001**	**0.001**	**<.0001**	**<.0001**	**0.001**	0.72	**<.0001**	**<.0001**	**0.006**	**<.0001**
	Pairwise Differences[c]			**4 > 1**											
	*** Significant at α = 0.05**			**4 > 6**											
	**** Significant at α = 0.01**			**1 > 2**	**	**	**	**	**	*			**		**
				1 > 3	**										
				1 > 4	**	**		**	*			**	**		*
				1 > 5	**	**		**	*	*			**		**
				1 > 6	**	**		**	**	*		**	**	**	**
				5 > 6								*			
				All (1,3,4,5,6) > 2			**								

Table 4-14
Phase III Surface Sediment – USEPA Subunit Comparison

Notes:

[a]Arithmetic means and geometric means for each subunit are shown on both a raw and normalized basis. Organic compounds are normalized by TOC. Metals are normalized by aluminum.

[b]The ANOVA model tests if concentration is dependent upon the subunit. The p-value for the significance of the F statistic is shown. Values that are significant at α = 0.05 are shown in bold. Modeling and post hoc testing was conducted on natural log-transformed data. If Levene's test is significant and the group standard deviations differed by more than a factor of two, the p-value is reported for the Welch ANOVA test which is robust to the equal variance assumption.

[c]Multiple pairwise comparison testing was conducted using the Tukey-Kramer method for unbalanced design (i.e. unequal sample size among groups). Only comparisons that were significant for at least one chemical are listed. In some cases of overall model significance where the p-values are close to the significance threshold (0.05), post hoc testing may not be produce significant comparison results, an outcome that can occur with an unbalanced design.

[d]The ANCOVA model tests if concentration is dependent upon EPA Subunit while controlling for the normalization variable (either TOC or aluminum) which is added as a covariate to the model. The p-value for the significance of the EPA subunit variable in the model is shown. Values that are significant at α = 0.05 are shown in bold. Normalization variables were significant for all ANCOVA models. Modeling and post hoc testing was conducted on natural log-transformed data.

[e]The reported p-value is based on the Welch ANOVA test (see also note b). When the Welch's test is significant but the equal variance ANOVA p-value is insignificant, no post hoc testing was conducted.

The Nelson-Hsu analysis of means test was also conducted for each model and tests whether any individual group mean is greater than the overall (i.e. Bay-wide) mean (α=0.05). The symbol > to the left of a group mean indicates that it is significantly greater than the overall mean. The symbol < to the left of the group mean indicates that it is significantly less than the overall mean. The ANCOVA tests the means after controlling for the normalization variable.

[e]The spatial variable is significant in the ANCOVA model but none of the multiple comparison tests on the least square log means were significant.
1/2 the quantitation limit was substituted for non-detects. Only chemicals with a frequency of detection greater than 70% were included in the analyses.
Analysis includes all Phase III surface sediment data collected 2014-2016 including the Crab/Clam and Sediment Quality Triad sampling programs.
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.
The USEPA Subunits are depicted in Figure 2-8.

Acronyms and Abbreviations:
< = group mean less than overall mean (Nelson-Hsu Test)
> = group mean greater than overall mean (Nelson-Hsu Test)
<.0001 = p-value is less than 0.0001
Al = aluminum
ANCOVA = analysis of covariance
ANOVA = analysis of variance
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/g = nanograms per gram
ng/kg = nanograms per kilogram
oc = organic carbon
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
pg/g = picograms per gram
TCDD = tetrachlorodibenzo-p-dioxin
TOC = total organic carbon
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
TPH = total petroleum hydrocarbons
µg/kg = micrograms per kilogram
USEPA = United States Environmental Protection Agency

Legend for Shading

1	**Lowest Arithmetic or Geometric Mean**
2	
3	
4	
5	
6	**Greatest Arithmetic or Geometric Mean**

Table 4-15
Phase III Surface Sediment – USACE Accumulation Area Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Spatial Group - USACE Accumulation Area	Sample Size	2,3,7,8-TCDD (ng/kg)	Total PCBs (9 Aroclors) (µg/kg)	Total PCBs (209 Congeners) (ng/kg)	Total DDX (2,4' & 4,4') (ND=0) (pg/g)	Total DDX (4,4') (ND=0) (pg/g)	Total Alpha + Gamma Chlordane (pg/g)	Cis-Nonachlor (pg/g)	Dieldrin (pg/g)	Hexachloro-benzene (pg/g)
Arithmetic	**Phase III**	**0-0.5 feet**	**Baywide**	**254**	**87.1**	**239**	**480,000**	**131,000**	**93,100**	**5,070**	**879**	**1740**	**2,870**
Arithmetic	Phase III	0-0.5 feet	No	180	78.1	193	384,000	136,000	93,900	4,340	697	1540	2,980
Arithmetic	Phase III	0-0.5 feet	Yes	74	> 109	> 351	> 712,000	> 119,000	> 91,100	> 6,830	> 1320	> 2230	2,600
Geometric	Phase III	0-0.5 feet	No	180	25.3	105	177,000	29,100	21,800	2,130	327	611	875
Geometric	Phase III	0-0.5 feet	Yes	74	> 45.9	> 197	> 358,000	> 52,600	> 40,200	> 4,690	> 836	> 1230	1,200
			t-Test p-value[b]		**0.007**	**<.0001**	**0.0002**	**0.011**	**0.008**	**<.0001**	**<.0001**	**0.0001**	0.13

Mean Statistic[a] (Normalized Data)	Phase	Depth	Spatial Group - USACE Accumulation Area		2,3,7,8-TCDD (ng/kg-oc)	Total PCBs (9 Aroclors) (µg/kg-oc)	Total PCBs (209 Congeners) (ng/kg-oc)	Total DDX (2,4' & 4,4') (ND=0) (pg/g-oc)	Total DDX (4,4') (ND=0) (pg/g-oc)	Total Alpha + Gamma Chlordane (pg/g-oc)	Cis-Nonachlor (pg/g-oc)	Dieldrin (pg/g-oc)	Hexachloro-benzene (pg/g-oc)
Arithmetic	Phase III	0-0.5 feet	No	180	3,850	11,500	19,700,000	5,680,000	3,950,000	248,000	38,200	78,400	134,000
Arithmetic	Phase III	0-0.5 feet	Yes	74	3,930	> 12,200	> 26,100,000	3,520,000	2,720,000	> 294,000	> 50,600	> 85,300	84,100
Geometric	Phase III	0-0.5 feet	No	180	1,600	6,610	11,100,000	1,830,000	1,380,000	135,000	20,900	38,600	55,300
Geometric	Phase III	0-0.5 feet	Yes	74	1,890	> 8,100	> 14,700,000	2,160,000	1,650,000	> 193,000	> 34,600	> 50,400	49,100
			p-value for Subunit in ANCOVA[c] Model		0.34	**0.016**	**0.036**	0.49	0.43	**0.014**	**0.002**	**0.025**	0.47

Table 4-15
Phase III Surface Sediment – USACE Accumulation Area Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Spatial Group - USACE Accumulation Area	Sample Size	Total PAHs (µg/kg)	Total HMW PAHs (µg/kg)	Total LMW PAHs (µg/kg)	Total Alkylated PAHs (µg/kg)	TPH (mg/kg)	Bis(2-ethylhexyl)phthalate (µg/kg)
Arithmetic	**Phase III**	**0-0.5 feet**	**Baywide**	**254**	**12,200**	**10,900**	**1,350**	**12,900**	**342**	**1120**
Arithmetic	Phase III	0-0.5 feet	No	180	11,200	10,000	1,180	13,300	333	983
Arithmetic	Phase III	0-0.5 feet	Yes	74	14,800	13,000	> 1,790	12,100	363	> 1440
Geometric	Phase III	0-0.5 feet	No	180	6,010	5,430	596	5,010	174	362
Geometric	Phase III	0-0.5 feet	Yes	74	7,960	7,100	> 874	5,700	195	> 705
			t-Test p-value[b]		0.81	0.162	**0.040**	0.57	0.50	**<.0001**

Mean Statistic[a] (Normalized Data)	Phase	Depth	Spatial Group - USACE Accumulation Area		Total PAHs (µg/kg-oc)	Total HMW PAHs (µg/kg-oc)	Total LMW PAHs (µg/kg-oc)	Total Alkylated PAHs (µg/kg-oc)	TPH (mg/kg-oc)	Bis(2-ethylhexyl)phthalate (µg/kg-oc)
Arithmetic	Phase III	0-0.5 feet	No	180	696,000	621,000	75,900	669,000	21,400	51,700
Arithmetic	Phase III	0-0.5 feet	Yes	74	539,000	475,000	63,500	393,000	13,100	> 56,100
Geometric	Phase III	0-0.5 feet	No	180	379,000	342,000	37,500	315,000	11,000	22,800
Geometric	Phase III	0-0.5 feet	Yes	74	327,000	292,000	35,900	234,000	8,030	> 29,000
			p-value for Subunit in ANCOVA[c] Model		0.58	0.54	0.84	0.09	0.42	**0.002**

Table 4-15
Phase III Surface Sediment – USACE Accumulation Area Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Spatial Group - USACE Accumulation Area	Sample Size	Arsenic (mg/kg)		Cadmium (mg/kg)		Chromium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Mercury (ng/g)		Methyl Mercury (ng/g)		Nickel (mg/kg)		Selenium (mg/kg)		Silver (mg/kg)		Zinc (mg/kg)
Arithmetic	**Phase III**	**0-0.5 feet**	**Baywide**	**254**		**18.3**		**2.06**		**123**		**149**		**166**		**2,350**		**1.1**		**40.9**		**1.02**		**1.81**		**300**
Arithmetic	Phase III	0-0.5 feet	No	180		18.4		1.81		116		136		157		2,170		1.07		37.8		1.00		1.59		252
Arithmetic	Phase III	0-0.5 feet	Yes	74		18.1	>	2.68	>	139	>	182	>	188	>	2,790		1.18	>	48.4		1.06	>	2.37	>	415
Geometric	Phase III	0-0.5 feet	No	180		13.6		0.87		81.6		83.6		91.9		1,160		0.711		30.8		0.68		0.989		183
Geometric	Phase III	0-0.5 feet	Yes	74		14.5	>	1.46	>	104	>	125	>	136	>	1,720		0.829	>	42		0.835	>	1.64	>	271
			t-Test p-value[b]			0.56		**0.001**		**0.038**		**0.004**		**0.004**		**0.017**		0.25		**0.0004**		0.057		**0.0008**		**0.0005**

Mean Statistic[a] (Normalized Data)	Phase	Depth	Spatial Group - USACE Accumulation Area		Arsenic (mg/kg-Al)		Cadmium (mg/kg-Al)		Chromium (mg/kg-Al)		Copper (mg/kg-Al)		Lead (mg/kg-Al)		Mercury (ng/g-Al)		Methyl Mercury (ng/g-Al)		Nickel (mg/kg-Al)		Selenium (mg/kg-Al)		Silver (mg/kg-Al)		Zinc (mg/kg-Al)
Arithmetic	Phase III	0-0.5 feet	No	180		1,400		123		8,500		9,970		12,400		155,000		82.1		3,030		75.0		111		19,700
Arithmetic	Phase III	0-0.5 feet	Yes	74		1,170		163		8,770		11,600		12,200		174,000		75.1	>	3,240		67.4		145	>	27,300
Geometric	Phase III	0-0.5 feet	No	180		1,180		75.4		7,070		7,240		7,960		100,000		61.6		2,670		58.7		85.7		15,800
Geometric	Phase III	0-0.5 feet	Yes	74		1,020		103		7,340		8,860		9,590		122,000		58.5	>	2,970		58.6		116	>	19,100
			p-value for Subunit in ANCOVA[c] Model			0.086		0.055		0.93		0.20		0.16		0.44		0.48		**0.039**		0.93		0.066		**0.036**

Table 4-15
Phase III Surface Sediment – USACE Accumulation Area Comparison

Notes:

[a]Arithmetic means and geometric means for each area are shown on both a raw and normalized basis. Organic compounds are normalized by TOC. Metals are normalized by aluminum.

[b]A t-Test was conducted on natural log-transformed data to compare means for each area and significant p-values (α = 0.05) are in bold. For significant tests, the symbol > next to the group mean indicates it is greater than the other.

[c]The ANCOVA model tests if concentration is dependent upon deposition area while controlling for the normalization variable (either TOC or aluminum) which is added as a covariate to the model. The p-value for the significance of the deposition area variable in the model is shown. Values that are significant at α = 0.05 are shown in bold. Normalization variables were significant for all ANCOVA models. Modeling and post t-test was conducted on natural log-transformed data. The symbol > next to the group mean indicates that the least square log mean adjusted for normalization is significantly greater than the other.

1/2 the quantitation limit was substituted for non-detects. Only chemicals with a frequency of detection greater than 70% were included in the analyses.

Analysis includes all Phase III surface sediment data collected 2014-2016 including the Crab/Clam and Sediment Quality Triad sampling programs.

A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

The USACE Accumulation Areas are shown on Figure 4-5.

Acronyms and Abbreviations:

> = group mean is significantly greater (t-Test)
<.0001 = p-value is less than 0.0001
Al = aluminum
ANCOVA = analysis of covariance
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/g = nanograms per gram
ng/kg = nanograms per kilogram
oc = organic carbon
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
pg/g = picograms per gram
TCDD = tetrachlorodibenzo-p-dioxin
TOC = total organic carbon
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
TPH = total petroleum hydrocarbons
USACE = U.S. Army Corps of Engineers
µg/kg = micrograms per kilogram

1 **Lowest Arithmetic or Geometric Mean**
6 **Greatest Arithmetic or Geometric Mean**

Table 4-16
Phase I/II Surface Sediment – Recent Deposition Area Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Recent Deposition?	Sample Size	2,3,7,8-TCDD (ng/kg)	Total PCBs (9 Aroclors) (µg/kg)	Total PCBs (209 Congeners) (ng/kg)	Total DDX (4,4') (ND=0) (pg/g)	Total PAHs (µg/kg)	Total HMW PAHs (µg/kg)	Total LMW PAHs (µg/kg)	TPH (mg/kg)	Bis(2-ethylhexyl)phthalate (µg/kg)	Arsenic (mg/kg)
Arithmetic	Phase I/II	0-0.5 feet	No	45	68.4	1,070	823,000	67,100	26,300	23,400	2,700	1,300	8,460	14.4
Arithmetic	Phase I/II	0-0.5 feet	Yes	62	> 71.9	701	> 708,000	88,600	15,500	13,800	2,150	1,280	5,770	14.7
Geometric	Phase I/II	0-0.5 feet	No	45	32.8	406	339,000	32,300	10,800	9,550	1,300	831	3,040	12.3
Geometric	Phase I/II	0-0.5 feet	Yes	62	> 53.2	512	> 535,000	38,300	10,100	9,440	1,220	928	3,310	12.9
			t-Test p-value[b]		**0.027**	0.25	**0.034**	0.42	0.73	0.95	0.75	0.52	0.71	0.61

Mean Statistic[a] (Normalized Data)	Phase	Depth	Recent Deposition?	Sample Size	2,3,7,8-TCDD (ng/kg-oc)	Total PCBs (9 Aroclors) (µg/kg-oc)	Total PCBs (209 Congeners) (ng/kg-oc)	Total DDX (4,4') (ND=0) (pg/g-oc)	Total PAHs (µg/kg-oc)	Total HMW PAHs (µg/kg-oc)	Total LMW PAHs (µg/kg-oc)	TPH (mg/kg-oc)	Bis(2-ethylhexyl)phthalate (µg/kg-oc)	Arsenic (mg/kg-Al)
Arithmetic	Phase I/II	0-0.5 feet	No	45	2,950	45,900	34,100,000	3,690,000	1,190,000	1,050,000	131,000	56,000	346,000	> 1,220
Arithmetic	Phase I/II	0-0.5 feet	Yes	62	2,760	26,000	24,700,000	2,960,000	543,000	485,000	70,000	43,300	196,000	930
Geometric	Phase I/II	0-0.5 feet	No	45	1,710	22,200	18,100,000	1,750,000	585,000	517,000	70,600	44,500	164,000	> 1,100
Geometric	Phase I/II	0-0.5 feet	Yes	62	2,130	20,900	21,700,000	1,560,000	408,000	382,000	49,300	37,500	135,000	842
			p-value for Subunit in ANCOVA[c] Model		0.13	0.99	0.22	0.96	0.17	0.24	0.12	0.14	0.115	**0.020**

Statistics with Reference to Navigation Channel and Recent Deposition

Mean Statistic[a] (Raw Data)	Phase	Depth	Navigation Channel?	Recent Deposition?	Sample Size	2,3,7,8-TCDD (ng/kg)	Total PCBs (9 Aroclors) (µg/kg)	Total PCBs (209 Congeners) (ng/kg)	Total DDX (4,4') (ND=0) (pg/g)	Total PAHs (µg/kg)	Total HMW PAHs (µg/kg)	Total LMW PAHs (µg/kg)	TPH (mg/kg)	Bis(2-ethylhexyl)phthalate (µg/kg)	Arsenic (mg/kg)
Arithmetic	Phase I/II	0-0.5 feet	No	No	39	68.1	1110	756,000	66,400	28,000	24,900	2,850	1,240	7,230	14.5
Arithmetic	Phase I/II	0-0.5 feet	No	Yes	39	> 83.8	823	> 811,000	78,300	16,500	14,800	2,410	1,550	6,420	16.4
Arithmetic	Phase I/II	0-0.5 feet	Yes	No	6	69.9	800	1,260,000	71,200	15,500	13,900	1,740	1,700	16,500	13.7
Arithmetic	Phase I/II	0-0.5 feet	Yes	Yes	23	51.7	493	534,000	106,000	14,000	12,300	1,720	815	4,690	11.7
Geometric	Phase I/II	0-0.5 feet	No	No	39	30.7	395	310,000	31,000	10,500	9,260	1,260	836	2,760	12.4
Geometric	Phase I/II	0-0.5 feet	No	Yes	39	> 64.1	609	> 640,000	38,900	10,400	10,100	1,230	1,140	3,920	14.3
				t-Test p-value[b]		**0.007**	0.080	**0.006**	0.34	0.98	0.67	0.91	0.11	0.20	0.24
Geometric	Phase I/II	0-0.5 feet	Yes	No	6	50.8	491	604,000	42,000	13,200	11,700	1,560	800	5,680	11.4
Geometric	Phase I/II	0-0.5 feet	Yes	Yes	23	38.8	381	396,000	37,200	9,660	8,400	1,210	657	2,510	10.8
				t-Test p-value[b]		0.48	0.466	0.280	0.834	0.396	0.381	0.475	0.613	0.110	0.819

Statistics with Reference to Geographic Areas with Recent Deposition

Mean Statistic[a] (Raw Data)	Phase	Depth	Geographic Area	Recent Deposition?	Sample Size	2,3,7,8-TCDD (ng/kg)	Total PCBs (9 Aroclors) (µg/kg)	Total PCBs (209 Congeners) (ng/kg)	Total DDX (4,4') (ND=0) (pg/g)	Total PAHs (µg/kg)	Total HMW PAHs (µg/kg)	Total LMW PAHs (µg/kg)	TPH (mg/kg)	Bis(2-ethylhexyl)phthalate (µg/kg)	Arsenic (mg/kg)
Arithmetic	Phase I/II	0-0.5 feet	North	Yes	15	> 94.2	483	505,000	< 23,300	> 22,000	> 19,500	> 2,490	877	4,060	< 9.72
Arithmetic	Phase I/II	0-0.5 feet	Central	Yes	26	58.4	765	667,000	34,200	< 9,650	8,970	< 1,120	1,230	7,210	13.5
Arithmetic	Phase I/II	0-0.5 feet	South	Yes	21	< 72.6	777	904,000	> 203,000	18,300	15,600	3,190	1,640	5,270	> 19.6
Geometric	Phase I/II	0-0.5 feet	North	Yes	15	> 89.2	448	489,000	< 21,800	> 18,500	> 16,500	> 2,010	840	3,460	< 9.57
Geometric	Phase I/II	0-0.5 feet	Central	Yes	26	52.6	551	531,000	30,700	< 7,300	7,300	< 866	900	3,620	12.5
Geometric	Phase I/II	0-0.5 feet	South	Yes	21	< 37.3	514	576,000	> 75,100	9,860	8,600	1,310	1,030	2,900	> 16.7
		p-value for Geographic Area in ANOVA[d] Model				**0.0002[e]**	0.67	0.78	**0.001[e]**	**0.0034**	**0.0034**	**0.0088**	0.66	0.69	**0.0001[e]**
Model Significance Testing	**Pairwise Differences[f]**	**North > South**				**					**				
	*** Significant at α = 0.05**	**North > Central**								**	**	**			
	**** Significant at α = 0.01**	**South > North**							**						**
		South > Central							**						*
		Central>North													

Table 4-16
Phase I/II Surface Sediment – Recent Deposition Area Comparison

Mean Statistic[a] (Raw Data)	Phase	Depth	Recent Deposition?	Sample Size	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (ng/g)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
Arithmetic	Phase I/II	0-0.5 feet	No	45	2.44	127	149	156	3,230	34.6	2.26	256
Arithmetic	Phase I/II	0-0.5 feet	Yes	62	1.98	117	152	155	4,000	> 37.2	> 2.72	272
Geometric	Phase I/II	0-0.5 feet	No	45	1.32	102	109	119	2,030	30.3	1.53	208
Geometric	Phase I/II	0-0.5 feet	Yes	62	1.21	104	128	126	2,020	> 36.2	> 2.32	237
			t-Test p-value[b]		0.71	0.91	0.22	0.65	0.99	**0.025**	**0.005**	0.23

Mean Statistic[a] (Normalized Data)	Phase	Depth	Recent Deposition?	Sample Size	Cadmium (mg/kg-Al)	Chromium (mg/kg-Al)	Copper (mg/kg-Al)	Lead (mg/kg-Al)	Mercury (ng/g-Al)	Nickel (mg/kg-Al)	Silver (mg/kg-Al)	Zinc (mg/kg-Al)
Arithmetic	Phase I/II	0-0.5 feet	No	45	187	> 10,200	12,100	13,900	259,000	2,900	171	21,500
Arithmetic	Phase I/II	0-0.5 feet	Yes	62	117	7,350	9,420	9,450	223,000	2,400	164	16,800
Geometric	Phase I/II	0-0.5 feet	No	45	118	> 9,140	9,730	10,600	182,000	2,720	134	18,600
Geometric	Phase I/II	0-0.5 feet	Yes	62	79.1	6,760	8,390	8,230	132,000	2,360	150	15,500
			p-value for Subunit in ANCOVA[c] Model		0.054	**0.002**	0.21	0.087	0.10	0.11	0.91	0.11

Statistics with Reference to Navigation Channel and Recent Deposition

Mean Statistic[a] (Raw Data)	Phase	Depth	Navigation Channel?	Recent Deposition?	Sample Size	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (ng/g)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
Arithmetic	Phase I/II	0-0.5 feet	No	No	39	2.33	123	142	153	2,850	34.2	1.95	247
Arithmetic	Phase I/II	0-0.5 feet	No	Yes	39	2.37	133	170	183	5,520	39.9	3.04	309
Arithmetic	Phase I/II	0-0.5 feet	Yes	No	6	3.19	155	195	174	> 5,650	37.2	4.53	319
Arithmetic	Phase I/II	0-0.5 feet	Yes	Yes	23	1.34	89.5	120	109	1,500	32.7	2.1	212
Geometric	Phase I/II	0-0.5 feet	No	No	39	1.32	100	108	119	1,890	30.5	1.38	206
Geometric	Phase I/II	0-0.5 feet	No	Yes	39	1.53	120	146	147	2,610	39.2	2.64	269
				t-Test p-value[b]		0.57	0.16	**0.049**	0.17	0.14	**0.004**	**0.0002**	**0.039**
Geometric	Phase I/II	0-0.5 feet	Yes	No	6	1.27	117	114	120	> 3,170	29.2	3.15	221
Geometric	Phase I/II	0-0.5 feet	Yes	Yes	23	0.825	81.5	102	97.8	1,330	31.6	1.8	193
				t-Test p-value[b]		0.386	0.122	0.728	0.440	**0.007**	0.691	0.086	0.597

Statistics with Reference to Geographic Areas with Recent Deposition

Mean Statistic[a] (Raw Data)	Phase	Depth	Geographic Area	Recent Deposition?	Sample Size	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (ng/g)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
Arithmetic	Phase I/II	0-0.5 feet	North	Yes	15	1.16	105	110	112	2,210	31.7	1.94	207
Arithmetic	Phase I/II	0-0.5 feet	Central	Yes	26	1.82	108	134	151	6,180	38.4	3.04	288
Arithmetic	Phase I/II	0-0.5 feet	South	Yes	21	2.76	135	205	191	2,690	39.7	2.96	302
Geometric	Phase I/II	0-0.5 feet	North	Yes	15	0.996	103	105	108	1,970	31.2	1.88	203
Geometric	Phase I/II	0-0.5 feet	Central	Yes	26	1.39	101	119	122	2,010	37.3	2.49	240
Geometric	Phase I/II	0-0.5 feet	South	Yes	21	1.19	107	162	146	2,080	38.7	2.52	262
			p-value for Geographic Area in ANOVA[d] Model			0.296[e]	0.90	0.05[e]	0.25	0.98	**0.015**	0.16	0.26
Model Significance Testing		**Pairwise Differences[f]**	**North > South**										
		*** Significant at α = 0.05**	**North > Central**										
		**** Significant at α = 0.01**	**South > North**					*			*		
			South > Central										
			Central>North								*		

Table 4-16
Phase I/II Surface Sediment – Recent Deposition
Area Comparison

Notes:

[a]Arithmetic means and geometric means for each area are shown on both a raw and normalized basis. Organic compounds are normalized by TOC. Metals are normalized by aluminum. One sample for which aluminum was not detected was excluded from normalized statistics and from the ANCOVA analysis.

[b]A t-Test was conducted on natural log-transformed data to compare means for each area and significant p-values (α = 0.05) are in bold. For significant tests, the symbol > next to the group mean indicates it is greater than the other.

[c]The ANCOVA model tests if concentration is dependent upon short term deposition area while controlling for the normalization variable (either TOC or aluminum) which is added as a covariate to the model. The p-value for the significance of the short-term deposition area variable in the model is shown. Values that are significant at α = 0.05 are shown in bold. Normalization variables were significant for all ANCOVA models. Modeling and post t-test was conducted on natural log-transformed data. The symbol > next to the group mean indicates that the least square log mean adjusted for normalization is significantly greater than the other.

[d]The ANOVA model tests if concentration is dependent upon the geographic area among samples with recent depsoition. The p-value for the significance of the F statisic is shown. Values that are significant at α = 0.05 are shown in bold. Modeling and post hoc testing was conducted on natural log-transformed data. The Nelson-Hsu analysis of means test was conducted and tests whether any individual geographic area mean is greater than the overall (i.e. Bay-wide) mean (α=0.05). The symbol > to the left of a group mean indicates that it is significantly greater than the overall mean. The symbol < to the left of the group mean indicates that it is significantly less than the overall mean. If Levene's test is significant and the group standard deviations differ by more than a factor of two, the p-value is reported for the Welch ANOVA test which is robust to the equal variance assumption.

[e]The reported p-value is based on the Welch ANOVA test (see also note d). When the Welch's test is significant but the equal variance ANOVA p-value is insignificant, no post hoc testing was conducted.

[f]Multiple pairwise comparsion testing was conducted using the Tukey-Kramer method for unbalanced design (i.e. unequal sample size among groups). Only comparisions that were significant for at least one chemical are listed. In some cases of overall model significance where the p-values are close to the significance threshold (0.05), post hoc testing may not be produce significant comparison results, an outcome that can occur with an unbalanced design.

1/2 the quantitation limit was substituted for non-detects. Only chemicals with a frequency of detection greater than 70% were included in the analyses.

Analysis includes all Phase I/II surface sediment data collected within the NBSA boundary.

Sample NB02SED072D-01 had an aluminum result that was non-detect and the sample was removed from all metals analyses.

Areas of recent deposition are defined by samples containing Beryllium-7 (Be-7) at a concentration greater than or equal to 0.5 pCi/g. The Be-7 bearing locations are shown on Figure 3-8.

Acronyms and Abbreviations:

< = group mean less than overall mean (Nelson-Hsu Test)
> = group mean greater than overall mean (Nelson-Hsu Test) or in the case of two groups, group mean is greater for significant t-test.
<.0001 = p-value is less than 0.0001
Al = aluminum
ANCOVA = analysis of covariance
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/g = nanograms per gram
ng/kg = nanograms per kilogram
oc = organic carbon
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
pCi/g = picocuries per gram
pg/g = picograms per gram
TCDD = tetrachlorodibenzo-p-dioxin
TOC = total organic carbon
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
TPH = total petroleum hydrocarbons
µg/kg = micrograms per kilogram

Legend for Shading

1	**Lowest Arithmetic or Geometric Mean**
2	
3	
4	
5	
6	**Greatest Arithmetic or Geometric Mean**

Table 4-17
Phase III Stations with at Least Ten COPC Concentrations within the Top Tenth Percentile

Station	Geographic Area	Geomorphic Unit	USEPA Subunit	Total Number of COPCs in Top 10th Percentile	Dioxin/Furans	PCBs	
					2,3,7,8-TCDD	Total Aroclors	Total PCB Congeners
293	North	Navigation Channel	3	14	X	X	
321	North	Historically Disturbed Subtidal Flats	4	11	X	X	X
327	North	Historically Disturbed Subtidal Flats	4	13	X	X	X
331	North	Subtidal Flats	4	14	X		X
371	North	Subtidal Flats	6	13	X	X	X
383	North	Subtidal Flats	6	16	X		X
384	North	Subtidal Flats	6	15	X	X	X
151	South	Historically Disturbed Subtidal Flats	1	22	X	X	X
154	South	Historically Disturbed Subtidal Flats	1	17	X	X	X
191	South	Historically Disturbed Subtidal Flats	1	15	X		X
212	South	Historically Disturbed Subtidal Flats	1	10		X	X
129	South	Industrial Waterfront	1	28	X		X
134	South	Industrial Waterfront	1	15			
222	South	Industrial Waterfront	1	11		X	X
232	South	Navigation Channel	1	15	X	X	
185	South	Subtidal Flats	1	12	X		X
190	South	Subtidal Flats	1	14			
194	South	Subtidal Flats	1	16			
199	South	Subtidal Flats	1	22	X	X	X
201	South	Subtidal Flats	1	13			
206	South	Subtidal Flats	1	21	X	X	X
207	South	Subtidal Flats	1	13			
208	South	Subtidal Flats	1	13			
213	South	Subtidal Flats	1	19	X		
220	South	Subtidal Flats	1	21	X	X	X
225	South	Subtidal Flats	1	10		X	X
235	South	Subtidal Flats	1	16		X	X
237	South	Transitional Slopes	1	15	X		
239	South	Transitional Slopes	1	17		X	

Table 4-17
Phase III Stations with at Least Ten COPC Concentrations within the Top Tenth Percentile

Station	Geographic Area	Geomorphic Unit	Pesticides								
			Dieldrin	Heptachlor epoxide	Hexachloro-benzene	Total DDx (2,4' and 4,4') (ND-0)	Total DDx (4,4') (ND=0)	Total Alpha + Gamma Chlordane	alpha BHC	beta BHC	cis-Nonachlor
293	North	Navigation Channel	X					X		X	X
321	North	Historically Disturbed Subtidal Flats	X								
327	North	Historically Disturbed Subtidal Flats	X	X	X			X			
331	North	Subtidal Flats	X		X			X			X
371	North	Subtidal Flats	X	.	X				.		.
383	North	Subtidal Flats	X		X					X	
384	North	Subtidal Flats	X		X					X	
151	South	Historically Disturbed Subtidal Flats	X		X	X	X	X	X		X
154	South	Historically Disturbed Subtidal Flats			X	X	X			X	
191	South	Historically Disturbed Subtidal Flats	X	X	X	X	X		X		
212	South	Historically Disturbed Subtidal Flats						X			X
129	South	Industrial Waterfront	X	X	X	X	X	X	X	X	X
134	South	Industrial Waterfront	X	X		X	X				
222	South	Industrial Waterfront						X		X	X
232	South	Navigation Channel	X		X			X			X
185	South	Subtidal Flats			X	X	X		X	X	
190	South	Subtidal Flats			X	X	X		X		
194	South	Subtidal Flats			X	X	X		X		.
199	South	Subtidal Flats			X	X	X		X	X	
201	South	Subtidal Flats			X	X	X				
206	South	Subtidal Flats			X	X	X		X	X	
207	South	Subtidal Flats			X	X	X		X		
208	South	Subtidal Flats				X	X				
213	South	Subtidal Flats			X	X	X		X	X	
220	South	Subtidal Flats	X		X	X	X	X	X	X	X
225	South	Subtidal Flats	X		X	X	X		X	X	
235	South	Subtidal Flats	X			X	X	X		X	X
237	South	Transitional Slopes	X		X	X	X				
239	South	Transitional Slopes	X					X	X	X	X

Table 4-17
Phase III Stations with at Least Ten COPC Concentrations within the Top Tenth Percentile

Station	Geographic Area	Geomorphic Unit	Semivolatile Organics					
			TPH	bis-2-Ethylhexyl phthalate	Total Alkylated PAHs	Total HMW PAHs	Total LMW PAHs	Total PAH
293	North	Navigation Channel	X	X				
321	North	Historically Disturbed Subtidal Flats				X	X	X
327	North	Historically Disturbed Subtidal Flats						
331	North	Subtidal Flats		X				
371	North	Subtidal Flats		X		X	X	X
383	North	Subtidal Flats			X	X	X	X
384	North	Subtidal Flats		X				
151	South	Historically Disturbed Subtidal Flats		X				
154	South	Historically Disturbed Subtidal Flats			X			
191	South	Historically Disturbed Subtidal Flats			X			
212	South	Historically Disturbed Subtidal Flats	X			X	X	X
129	South	Industrial Waterfront			X	X	X	X
134	South	Industrial Waterfront	X	X		X	X	X
222	South	Industrial Waterfront	X	X		X	X	X
232	South	Navigation Channel	X	X				
185	South	Subtidal Flats			X			
190	South	Subtidal Flats			X			
194	South	Subtidal Flats			X		X	X
199	South	Subtidal Flats		X	X			
201	South	Subtidal Flats			X			
206	South	Subtidal Flats		X	X			
207	South	Subtidal Flats			X			
208	South	Subtidal Flats	X		X			
213	South	Subtidal Flats		X	X			
220	South	Subtidal Flats	X	X				
225	South	Subtidal Flats						
235	South	Subtidal Flats	X	X				
237	South	Transitional Slopes			X			
239	South	Transitional Slopes	X	X				

Table 4-17
Phase III Stations with at Least Ten COPC Concentrations within the Top Tenth Percentile

Station	Geographic Area	Geomorphic Unit	Metals										
			Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Methyl mercury	Nickel	Selenium	Silver	Zinc
293	North	Navigation Channel		X	X			X	X			X	
321	North	Historically Disturbed Subtidal Flats		X	X								
327	North	Historically Disturbed Subtidal Flats		X	X			X				X	
331	North	Subtidal Flats		X	X			X				X	X
371	North	Subtidal Flats			X							X	
383	North	Subtidal Flats		X	X	X				X		X	X
384	North	Subtidal Flats			X	X	X			X		X	X
151	South	Historically Disturbed Subtidal Flats	X	X	X	X		X	X	X	X	X	X
154	South	Historically Disturbed Subtidal Flats		X	X	X	X		X		X	X	X
191	South	Historically Disturbed Subtidal Flats		X	X			X				X	
212	South	Historically Disturbed Subtidal Flats		X							X		
129	South	Industrial Waterfront	X	X	X	X	X	X	X	X	X	X	X
134	South	Industrial Waterfront	X			X	X			X	X		X
222	South	Industrial Waterfront											
232	South	Navigation Channel		X	X	X		X				X	X
185	South	Subtidal Flats		X	X								
190	South	Subtidal Flats	X	X	X	X	X	X			X	X	X
194	South	Subtidal Flats	X	X	X	X	X	X			X	X	X
199	South	Subtidal Flats	X	X	X	X	X	X	X	X	X	X	X
201	South	Subtidal Flats	X	X	X	X	X	X			X	X	X
206	South	Subtidal Flats	X	X	X	X	X	X	X		X	X	X
207	South	Subtidal Flats	X	X	X	X	X	X			X	X	
208	South	Subtidal Flats	X	X	X	X	X	X			X	X	X
213	South	Subtidal Flats	X	X	X	X	X	X		X	X	X	X
220	South	Subtidal Flats		X	X	X		X	X				X
225	South	Subtidal Flats	X					X					
235	South	Subtidal Flats		X		X		X			X	X	
237	South	Transitional Slopes	X	X	X	X	X	X			X	X	X
239	South	Transitional Slopes		X	X	X		X		X	X	X	X

Table 4-17
Phase III Stations with at Least Ten COPC Concentrations within the Top Tenth Percentile

Notes:
X indicates a station has a concentration within the top 10th percentile for the COPC.
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Acronyms and Abbreviations:
COPC = constituent of potential concern
HMW = high molecular weight
LMW = low molecular weight
(ND=0) = Only detected isomers were included in the summation
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
TCDD = tetrachlorodibenzo-p-dioxin
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane isomers
TPH = total petroleum hydrocarbons
USEPA = U.S. Environmental Protection Agency

Table 4-18
Comparison of NBSA Surface Sediment Concentrations to Jamaica Bay Reference

Parameter Group	Chemical	Units	Phase III Surface Sediment Concentrations (2014-2016)							Jamaica Bay Surface Sediment Concentrations (2008/2013)									Ratio of Means (NBSA:JB)	Percent of NBSA Results that Exceed 95th Percentile of Reference[a]
			N	Frequency of Detection	Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	N	Frequency of Detection	Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Reporting Limit Range for Non-Detect Values	95th Percentile		
Dioxins/ Furans	2,3,7,8-TCDD	ng/kg	254	100%	87.1	182	42.8	0.12	1,710	13	100%	1.03	0.872	0.66	0.6	3.5	--	3.5	85	88%
PCBs	Total Aroclors[b]	µg/kg	254	94.1%	239	317	140	6.4	2,500	56	7%	--	--	--	2.1	23.2	--	--	--	90%
	Total PCBs congeners	ng/kg	254	100%	480,000	691,000	278,000	2,480	5,030,000	NA										
Pesticides	Dieldrin	pg/g	253	95%	1740	3510	947	39.4	37,400	56	0%	<1840	--	<1,050	--	--	1,000 - 18,000	--	--	--
	Heptachlor epoxide	pg/g	249	33%	113	239	79.4	14.6	2,400	56	0%	<1170	--	<1,000	--	--	530 - 9,200	--	--	--
	Hexachlorobenzene	pg/g	253	100%	2,870	6,250	1,040	13.2	46,200	56	4%	626	617	<1,000	630	2,300	540 - 9,200	--	4.6	24%
	Total DDx (2,4' & 4,4') (ND=0)	pg/g	254	100%	131,000	301,000	34,500	120	2,600,000	56	7%	1,880	4,390	<1,100	4,500	27,000	1,000 - 18,000	--	70	61%
	Total DDx (4,4') (ND=0)	pg/g	254	100%	93,100	205,000	26,000	93	1,800,000	56	7%	1,810	4,310	<1,100	3,000	27,000	1,000 - 18,000	--	51	46%
	Total alpha + gamma chlordane	pg/g	253	96%	5,070	4,800	4,300	39	32,000	56	5%	2,580	10,600	<1,000	860	63,700	530 - 9,200	--	2.0	0%
	alpha-BHC[c]	pg/g	252	68%	118	174	63	6.32	1,260	56	0%	<1170	--	<1,000	--	--	530 - 9,200	--	--	--
	beta-BHC[c]	pg/g	253	58%	117	174	74.8	6.24	1,430											
	cis-Nonachlor	pg/g	248	81%	879	877	781	22.3	4,830	56	4%	774	1,170	<1,000	5,600	6,400	530 - 9,200	--	1.1	0%
Semivolatiles	Total HMW PAHs	µg/kg	254	99%	10,900	12,400	6,980	37	100,000	56	70%	430	1,360	85.5	3.3	9,750	12 - 65	1,580	25	88%
	Total LMW PAHs	µg/kg	254	96%	1,350	2,130	785	5.2	17,000	56	54%	44.4	82.8	27.5	1.1	560	12 - 250	215	30	85%
	Total PAH	µg/kg	254	99%	12,200	14,200	7,700	37	110,000	56	70%	467	1440	85.5	5.1	10,300	12 - 65	1,800	26	88%
	bis(2-Ethylhexyl)phthalate	µg/kg	253	78%	1,120	3,360	400	96	38,000	NA										
	Total Petroleum Hydrocarbons	mg/kg	254	97%	342	435	190	6.45	2,910	NA										
Metals	Arsenic	mg/kg	254	100%	18.3	16.8	13.3	1.18	115	56	100%	6.02	4.6	4.55	0.8	16.9	--	15	3.0	38%
	Cadmium	mg/kg	254	99.2%	2.06	3.28	0.905	0.0592	24.6	56	75%	0.843	1.93	0.4	0.1	14.2	0.025 - 0.29	2.8	2.4	18%
	Chromium	mg/kg	254	100%	123	117	95.8	3.95	777	56	100%	35.6	26.9	28.8	2.3	104	--	86.3	3.5	57%
	Copper	mg/kg	254	100%	149	152	100	1.5	924	56	96%	40.4	64.5	18.4	0.9	390	0.95 - 0.96	120	3.7	39%
	Lead	mg/kg	254	100%	166	220	111	2.18	2,190	56	100%	45.1	51.9	26.7	2.9	290	--	130	3.7	37%
	Mercury	ng/g	254	100%	2,350	2,850	1,480	5.11	22,100	56	100%	328	466	220	10	3,200	--	820	7.2	73%
	Methyl mercury	ng/g	254	99.6%	1.1	1.15	0.833	0.027	11.9	NA										
	Nickel	mg/kg	254	100%	40.9	28.9	37.9	3.83	282	56	93%	12.7	10	10.3	1.7	40	1.9 - 1.9	33.9	3.2	57%
	Selenium	mg/kg	253	98.8%	1.02	1.11	0.704	0.0939	7.58	56	45%	0.69	0.413	<1.7	0.1	1.5	0.025 - 2	1.5	1.5	13%
	Silver	mg/kg	254	99.6%	1.81	1.64	1.46	0.0448	12	56	89%	1.65	1.77	0.91	0.1	5.9	0.025 - 0.48	5.8	1.1	2%
	Zinc	mg/kg	254	100%	300	486	220	8.18	6,810	56	100%	98.3	127	59.5	5.2	670	--	250	3.1	38%

Notes:

[a]NBSA results from Phase III surface sediment samples were compared to the non-parametric 95th percentile of the Jamaica Bay (JB) concentration distribution or the maximum detected value for chemicals with a low frequency of detection.
bTotal Aroclors were reported as 0 when not detected in the Jamaica Bay data set. No reporting limit was reported therefore summary statistics were not estimated.

[c]Statistics reported for Jamaica Bay are for beta, gamma or unspecified BHC compounds combined.
Jamaica Bay data set consists of data collected by the USEPA from 28 stations in the Jamaica Bay estuary in 2008 and 2013. 2,3,7,8-TCDD and other dioxin and furan congeners were only analyzed in 2013 on a subset of 13 samples. Source: https://www.waterqualitydata.us/

For Jamaica Bay data, one-half the reporting limit, as specified in the data source, was substituted for non-detects in the calculation of mean and standard deviation. Where the frequency of detection is 0, the mean is reported as <mean reporting limit. Non-detects were evaluated at the full reporting limit for median estimate. If the median is a non-detect, it is reported as <median reporting limit.

For NBSA Phase III data, one-half the quantitation limit was substituted for non-detects in the calculation of mean and standard deviation. The full quantitation limit was substituted for the median calculation.
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Acronyms and Abbreviations:

< indicates mean or median is less than the reporting limit
-- = statistic not calculated due to detection frequency.
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
N = Number of samples analyzed.
NA = Not analyzed in Jamaica Bay data set.
(ND=0) = Only detected isomers were included in the summation
ng/kg = nanograms per kilogram
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
TCDD = Tetrachlorodibenzo-p-dioxin
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)
µg/kg = micrograms per kilogram
USEPA = United States Environmental Protection Agency

Table 4-19
Summary of Surface Water Concentrations in the NBSA and Comparison to Water Quality Criteria

Group	Chemical	Fraction	Units	NJDEP Saline Surface Water Quality Criteria[a]			Summary Statistics Surface Water Sampling 2011-2013						Number of Exceedances of Aquatic Life Criteria		Mean Exceeds Human Health Criteria?	Number of Exceedances of Human Health Criteria
				Aquatic Life		Human Health	Number of Samples	Frequency of Detection	Mean	Standard Deviation	Minimum Detected	Maximum Detected	Acute	Chronic		
				Acute	Chronic											
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin	Total	pg/L	NA	NA	0.0051	233	36%	1.42	0.99	0.22	7.98	NA	NA	**YES**	84
PCBs	Total PCB Congeners (209)	Total	ng/L	NA	30	0.064	233	100%	6.54	2.96	2.2	20.4	NA	0	**YES**	233
Pesticides	Dieldrin	Total	ng/L	710	1.9	0.054	158	97%	0.33	0.21	0.1	2.1	0	**1**	**YES**	153
	Heptachlor epoxide	Total	ng/L	53	3.6	0.039	158	91%	0.14	0.1	0.03	0.67	0	0	**YES**	140
	Total Alpha + Gamma Chlordane	Total	ng/L	90[b]	4[b]	0.11	158	100%	0.35	0.19	0.05	0.85	0	0	**YES**	153
	4,4'-DDD	Total	ng/L	NA	NA	0.31	158	85%	0.41	0.41	0.17	3.9	NA	NA	**YES**	76
	4,4'-DDE	Total	ng/L	NA	NA	0.22	157	76%	0.43	0.48	0.17	3.9	NA	NA	**YES**	102
	4,4'-DDT	Total	ng/L	130	1	0.22	157	48%	0.14	0.13	0.05	0.64	0	0	NO	7
	Total DDx (4,4') (ND=0)	Total	ng/L	130[c]	1[c]	NA	157	91%	0.85	0.92	0.17	8.1	0	**38**	NA	NA
	Total DDx (2,4' and 4,4') (ND=0)	Total	ng/L	NA	NA	NA	157	92%	1.09	1.29	0.12	11.7	NA	NA	NA	NA
	alpha-BHC	Total	ng/L	NA	NA	4.9	158	88%	0.15	0.37	0.05	4.6	NA	NA	NO	0
	beta-BHC	Total	ng/L	NA	NA	17	158	68%	0.14	0.31	0.03	3.7	NA	NA	NO	0
	Hexachlorobenzene	Total	ng/L	NA	NA	0.29	158	5%	0.17	0.61	0.1	6.8	NA	NA	NO	2
	cis-Nonachlor	Total	ng/L	90[b]	4[b]	0.11	157	54%	0.12	0.13	0.02	0.16	0	0	**YES**	6
PAHs	Acenaphthene	Total	ng/L	NA	NA	990000	157	99%	12.4	10.2	2.69	76.8	NA	NA	NO	0
	Anthracene	Total	ng/L	NA	NA	40000000	157	62%	7.95	6.99	1.08	55.7	NA	NA	NO	0
	Benz(a)anthracene	Total	ng/L	NA	NA	180	157	76%	10.5	15.3	2.16	151	NA	NA	NO	0
	Benzo(a)pyrene	Total	ng/L	NA	NA	18	157	59%	14.1	20.9	3.79	207	NA	NA	NO	0
	Benzo(b)fluoranthene	Total	ng/L	NA	NA	180	157	62%	17.2	22.8	5.08	210	NA	NA	NO	0
	Benzo(k)fluoranthene	Total	ng/L	NA	NA	1800	157	68%	8.95	10.5	1.98	108	NA	NA	NO	0
	Chrysene	Total	ng/L	NA	NA	18000	157	92%	15.9	19.6	3.62	194	NA	NA	NO	0
	Dibenz(a,h)anthracene	Total	ng/L	NA	NA	18	157	63%	5.35	4.81	0.79	31.8	NA	NA	NO	0
	Fluoranthene	Total	ng/L	NA	NA	140000	157	94%	32.7	29.6	10.1	282	NA	NA	NO	0
	Fluorene	Total	ng/L	NA	NA	5300000	157	45%	9.31	5.16	2	56	NA	NA	NO	0
	Indeno(1,2,3-cd)pyrene	Total	ng/L	NA	NA	180	157	73%	9.33	11.0	1.86	112	NA	NA	NO	0
	Pyrene	Total	ng/L	NA	NA	4000000	157	100%	35.9	29	11.2	266	NA	NA	NO	0
	Total HPAHs	Total	ng/L	NA	NA	NA	157	100%	135	177	17.16	1689.8	NA	NA	NA	NA
	Total LPAHs	Total	ng/L	NA	NA	NA	157	100%	58.9	76.22	2.72	660.04	NA	NA	NA	NA
	Total PAHs	Total	ng/L	NA	NA	NA	157	100%	194	221	20.9	1963.7	NA	NA	NA	NA
Semivolatiles	Bis(2-ethylhexyl) phthalate	Total	µg/L	NA	NA	2.2	157	3%	1.96	0.12	1.8	2.7	NA	NA	NO	4
Metals	Arsenic	Dissolved	µg/L	69	36	0.061	158	100%	1.15	0.24	0.67	1.65	0	0	**YES**	158
	Arsenic	Total	µg/L	69	36	0.061	158	100%	1.28	0.28	0.73	2.3	0	0	**YES**	158
	Cadmium	Dissolved	µg/L	40	8.8	16	274	100%	0.05	0.01	0.01	0.1	0	0	NO	0
	Cadmium	Total	µg/L	40	8.8	16	274	100%	0.07	0.02	0.03	0.23	0	0	NO	0
	Chromium	Dissolved	µg/L	NA	NA	750	158	99%	0.37	0.28	0.11	2.7	NA	NA	NO	0
	Chromium	Total	µg/L	NA	NA	750	158	100%	1.17	0.81	0.43	5.61	NA	NA	NO	0
	Chromium, Hexavalent	Dissolved	µg/L	1100	50	NA	119	45%	0.30	0.32	0.04	0.83	0	0	NA	NA
	Copper	Dissolved	µg/L	7.9	5.6	NA	274	100%	1.77	0.47	0.83	4.48	0	0	NA	NA
	Copper	Total	µg/L	7.9	5.6	NA	274	100%	2.92	1.32	1.29	13.1	**4**	**8**	NA	NA
	Lead	Dissolved	µg/L	210	24	NA	274	100%	0.27	0.34	0.04	3.85	0	0	NA	NA
	Lead	Total	µg/L	210	24	NA	274	100%	1.81	1.52	0.53	12	0	0	NA	NA
	Mercury	Dissolved	ng/L	1800	940	51	274	91%	3.25	5.12	0.25	53.5	0	0	NO	1
	Mercury	Total	ng/L	1800	940	51	274	100%	21.4	23.4	0.38	296	0	0	NO	17
	MethylMercury	Dissolved	ng/L	NA	NA	NA	158	31%	0.028	0.011	0.021	0.102	NA	NA	NA	NA
	MethylMercury	Total	ng/L	NA	NA	NA	158	90%	0.052	0.037	0.021	0.294	NA	NA	NA	NA
	Nickel	Dissolved	µg/L	64	22	1700	158	100%	1.14	0.31	0.62	1.92	0	0	NO	0
	Nickel	Total	µg/L	64	22	1700	158	100%	1.45	0.5	0.85	5.05	0	0	NO	0
	Selenium	Dissolved	µg/L	290	71	4200	158	8%	0.95	0.19	0.2	0.6	0	0	NO	0
	Selenium	Total	µg/L	290	71	4200	158	16%	0.91	0.27	0.2	2.1	0	0	NO	0
	Silver	Dissolved	µg/L	1.9	NA	40000	158	59%	0.01	0.01	0	0.06	0	NA	NO	0
	Silver	Total	µg/L	1.9	NA	40000	158	88%	0.03	0.07	0	0.84	0	NA	NO	0
	Zinc	Dissolved	µg/L	90	81	26000	158	100%	6.32	1.88	2.2	13.9	0	0	NO	0
	Zinc	Total	µg/L	90	81	26000	158	100%	8.53	3.18	3.56	28.9	0	0	NO	0

Table 4-19
Summary of Surface Water Concentrations in the NBSA and Comparison to Water Quality Criteria

Notes:
[a]N.J.A.C. 7:9B Surface Water Quality Standards, October 17, 2016
[b]Total Alpha + Gamma Chlordane and cis-Nonachlor are compared to the criteria for chlordane (CAS Number 57-74-9).
[c]Criterion shown is for 4,4'-DDT.
Statistics include all data collected regardless of depth, event, or tidal cycle.
Only detected data are counted as exceedances.
Copper aquatic life criteria are site specific for Newark Bay.
Metals aquatic life criteria are based on dissolved concentrations. Metals human health criteria are based on total recoverable concentrations.
Surface water data were collected by the CPG and non-detects were previously reported (AECOM 2010; 2011) to the reporting limit. Therefore, for consistency with prior reports, non-detect surface water concentrations are reported to the reporting limit rather than the quantitation limit in this RI Report. 1/2 reporting limit substituted for non-detects in summary statistics.

Acronyms and Abbreviations:
CPG = Cooperating Parties Group
NA = No water quality criteria available
(ND=0) = Only detected isomers were included in the summation
NJDEP = New Jersey Department of Environmental Protection
pg/L = picograms per liter
ng/L =nanograms per liter
µg/L = micrograms per liter

References:
AECOM. 2010. Remedial Investigation Water Column Monitoring/Physical Data Collection for the Lower Passaic River, Newark Bay and Wet weather monitoring: Lower Passaic River Restoration Project. Quality Assurance Project Plan. Revision 5.
AECOM. 2011. Quality Assurance Project Plan/Field Sampling Plan Addendum. Remedial Investigation Water Column Monitoring/Small Volume Chemical Data Collection. Lower Passaic River Restoration Project. Revision 2. August, 2011.

Table 4-20
Mean COPC Concentration in the Water Column in the NBSA and Tributaries

Parameter Group	Chemical	Units	Number of Detects / Number of Samples: Mean (Standard Deviation)									
			NBSA[a]							Tributaries		
			All NBSA Stations	NNE	NBN	NNW	NBE	NBS	ARK	Passaic River[b]	Hackensack River (HKN)	Kill Van Kull (KVK)
Dioxins/Furans	2,3,7,8-TCDD	pg/L	84/233: 1.02 (1.02)	15/29: 1.08 (0.699)	25/48: 1.31 (1.22)	18/33: 1.57 (1.4)	13/37: 1.04 (1.29)	7/48: 0.622 (0.299)	6/38: 0.598 (0.264)	273/320: 18.5 (146)	35/48: 1.67 (1.1)	2/38: 0.635 (0.355)
PCBs	Total PCB Congeners (209)	ng/L	233/233: 6.54 (2.96)	29/29: 7.41 (2.95)	48/48: 7.74 (2.71)	33/33: 8.75 (4.22)	37/37: 5.4 (2.11)	48/48: 5.15 (1.88)	38/38: 5.31 (1.63)	320/320: 20.8 (19.3)	48/48: 10.6 (3.44)	38/38: 4.55 (1.47)
Pesticides	Dieldrin	ng/L	153/158: 0.328 (0.216)	20/20: 0.389 (0.214)	32/32: 0.318 (0.152)	21/21: 0.284 (0.0984)	20/25: 0.341 (0.187)	32/32: 0.35 (0.353)	28/28: 0.295 (0.156)	179/200: 0.975 (0.627)	22/30: 0.38 (0.226)	27/28: 0.262 (0.183)
Pesticides	Heptachlor epoxide	ng/L	143/158: 0.137 (0.0986)	20/20: 0.182 (0.11)	31/32: 0.125 (0.0691)	21/21: 0.124 (0.0571)	19/25: 0.155 (0.0982)	26/32: 0.138 (0.145)	26/28: 0.111 (0.0686)	191/200: 0.548 (0.365)	23/30: 0.169 (0.108)	24/28: 0.0935 (0.0644)
Pesticides	Hexachlorobenzene	ng/L	8/158: 0.122 (0.61)	2/20: 0.0756 (0.0537)	0/32: 0.0652 (0.0444)	0/21: 0.0734 (0.0679)	5/25: 0.201 (0.73)	1/32: 0.25 (1.2)	0/28: 0.0411 (0.0222)	46/200: 0.191 (0.295)	7/30: 0.124 (0.102)	0/28: 0.0363 (0.0526)
Pesticides	Total Alpha + Gamma Chlordane	ng/L	158/158: 0.347 (0.186)	20/20: 0.41 (0.186)	32/32: 0.369 (0.162)	21/21: 0.402 (0.202)	25/25: 0.339 (0.187)	32/32: 0.31 (0.197)	28/28: 0.286 (0.17)	198/200: 1.75 (1.68)	30/30: 0.479 (0.229)	24/28: 0.214 (0.216)
Pesticides	Total DDx (2,4' and 4,4') (ND=0)	ng/L	144/158: 1.07 (1.3)	19/20: 0.84 (0.451)	31/32: 0.922 (0.491)	21/21: 1.17 (0.844)	22/25: 0.626 (0.337)	26/32: 0.703 (0.588)	25/28: 2.16 (2.58)	199/200: 2.92 (3.04)	30/30: 1.05 (0.645)	19/28: 0.608 (0.817)
Pesticides	Total DDx (4,4') (ND=0)	ng/L	143/158: 0.841 (0.922)	19/20: 0.672 (0.343)	31/32: 0.746 (0.378)	21/21: 0.959 (0.671)	22/25: 0.496 (0.265)	26/32: 0.596 (0.518)	24/28: 1.57 (1.79)	199/200: 2.34 (2.38)	30/30: 0.842 (0.506)	19/28: 0.527 (0.775)
Pesticides	alpha BHC	ng/L	139/158: 0.15 (0.374)	20/20: 0.106 (0.0392)	32/32: 0.105 (0.0383)	21/21: 0.0982 (0.0356)	14/25: 0.114 (0.0769)	24/32: 0.305 (0.817)	28/28: 0.127 (0.0656)	190/200: 0.0761 (0.046)	23/30: 0.0984 (0.0566)	24/28: 0.135 (0.0938)
Pesticides	beta BHC	ng/L	108/158: 0.12 (0.306)	15/20: 0.086 (0.0688)	28/32: 0.0771 (0.0507)	16/21: 0.0807 (0.0506)	10/25: 0.0828 (0.0675)	18/32: 0.231 (0.665)	21/28: 0.128 (0.0796)	160/200: 0.0837 (0.0511)	17/30: 0.0975 (0.0826)	17/28: 0.117 (0.0884)
Pesticides	cis-Nonachlor	ng/L	84/157: 0.0735 (0.0642)	12/20: 0.0823 (0.0638)	16/32: 0.0793 (0.0648)	14/21: 0.0748 (0.0643)	14/24: 0.0764 (0.0647)	14/32: 0.078 (0.0725)	14/28: 0.0521 (0.0533)	181/200: 0.232 (0.233)	22/30: 0.101 (0.0599)	7/28: 0.077 (0.0786)
PAH-SIM	Total HPAHs	ng/L	157/157: 135 (177)	20/20: 165 (133)	31/31: 162 (119)	21/21: 267 (405)	25/25: 78.2 (25.8)	32/32: 91.1 (48.6)	28/28: 86.5 (68.4)	200/200: 596 (600)	32/32: 279 (263)	28/28: 64 (55)
PAH-SIM	Total LPAHs	ng/L	157/157: 58.9 (76.2)	20/20: 71.9 (62.3)	31/31: 59.1 (51.6)	21/21: 89.5 (67.5)	25/25: 42.6 (55.8)	32/32: 44.2 (50)	28/28: 57.9 (132)	200/200: 144 (95.7)	32/32: 111 (91.5)	28/28: 24.1 (30.6)
PAH-SIM	Total PAHs	ng/L	157/157: 194 (221)	20/20: 237 (178)	31/31: 221 (152)	21/21: 356 (456)	25/25: 121 (71.9)	32/32: 135 (78.6)	28/28: 144 (182)	200/200: 740 (679)	32/32: 390 (343)	28/28: 88.2 (73.7)
Semivolatiles	Bis(2-ethylhexyl) phthalate	µg/L	5/157: 1.02 (0.267)	0/19: <1	1/32: 1.02 (0.254)	0/21: <1	1/25: 1.06 (0.344)	2/32: 1.07 (0.416)	1/28: 0.993 (0.16)	17/166: 1.16 (0.655)	3/32: 1.1 (0.361)	1/28: 0.986 (0.0692)
Metals	Arsenic (Dissolved)	µg/L	158/158: 1.15 (0.241)	20/20: 1.14 (0.256)	32/32: 1.15 (0.274)	21/21: 1.02 (0.122)	25/25: 1.17 (0.264)	32/32: 1.14 (0.216)	28/28: 1.23 (0.243)	192/200: 1.01 (0.414)	32/32: 1.14 (0.339)	28/28: 1.2 (0.221)
Metals	Arsenic	µg/L	158/158: 1.28 (0.28)	20/20: 1.24 (0.259)	32/32: 1.29 (0.264)	21/21: 1.21 (0.267)	25/25: 1.25 (0.302)	32/32: 1.29 (0.27)	28/28: 1.39 (0.304)	196/200: 1.26 (0.477)	32/32: 1.34 (0.356)	28/28: 1.35 (0.274)
Metals	Cadmium (Dissolved)	µg/L	273/274: 0.0543 (0.0144)	34/34: 0.0577 (0.0178)	56/56: 0.0564 (0.0152)	40/40: 0.0566 (0.0141)	42/42: 0.0552 (0.0118)	56/56: 0.0485 (0.0132)	45/46: 0.0536 (0.0134)	272/320: 0.0411 (0.0242)	55/56: 0.0624 (0.025)	46/46: 0.0499 (0.00825)
Metals	Cadmium	µg/L	274/274: 0.0676 (0.0241)	34/34: 0.0686 (0.0159)	56/56: 0.0777 (0.0359)	40/40: 0.0757 (0.0238)	42/42: 0.0619 (0.0167)	56/56: 0.0569 (0.0138)	46/46: 0.0657 (0.0207)	319/320: 0.122 (0.112)	56/56: 0.0893 (0.0273)	46/46: 0.0565 (0.0119)
Metals	Chromium (Dissolved)	µg/L	156/158: 0.371 (0.278)	20/20: 0.443 (0.301)	31/32: 0.486 (0.501)	21/21: 0.383 (0.16)	25/25: 0.344 (0.133)	32/32: 0.298 (0.0972)	27/28: 0.285 (0.138)	194/200: 0.806 (0.652)	32/32: 0.523 (0.227)	28/28: 0.248 (0.104)
Metals	Chromium	µg/L	158/158: 1.17 (0.811)	20/20: 1.26 (0.59)	32/32: 1.43 (0.841)	21/21: 1.62 (1.31)	25/25: 0.847 (0.252)	32/32: 0.97 (0.545)	28/28: 1 (0.825)	198/200: 3.27 (3.13)	32/32: 2.36 (0.895)	28/28: 0.918 (0.743)
Metals	Copper (Dissolved)	µg/L	274/274: 1.77 (0.474)	34/34: 1.86 (0.359)	56/56: 1.85 (0.546)	40/40: 1.72 (0.39)	42/42: 1.81 (0.281)	56/56: 1.66 (0.493)	46/46: 1.72 (0.605)	320/320: 2.52 (1.08)	56/56: 1.95 (0.364)	46/46: 1.57 (0.474)
Metals	Copper	µg/L	274/274: 2.92 (1.32)	34/34: 2.84 (0.668)	56/56: 3.33 (1.75)	40/40: 3.28 (1.32)	42/42: 2.48 (0.667)	56/56: 2.6 (0.888)	46/46: 2.97 (1.71)	320/320: 6.75 (5.69)	56/56: 3.87 (0.974)	46/46: 2.37 (1.05)
Metals	Lead (Dissolved)	µg/L	274/274: 0.268 (0.343)	34/34: 0.304 (0.332)	56/56: 0.393 (0.586)	40/40: 0.299 (0.308)	42/42: 0.223 (0.191)	56/56: 0.191 (0.155)	46/46: 0.198 (0.189)	320/320: 0.858 (1.3)	56/56: 0.288 (0.263)	46/46: 0.194 (0.448)
Metals	Lead	µg/L	274/274: 1.81 (1.52)	34/34: 1.86 (0.87)	56/56: 2.46 (2.19)	40/40: 2.41 (1.68)	42/42: 1.35 (0.834)	56/56: 1.43 (0.94)	46/46: 1.33 (1.37)	320/320: 6.85 (7.46)	56/56: 2.99 (1.15)	46/46: 1.37 (1.45)
Metals	Mercury (Dissolved)	ng/L	248/274: 3.15 (5.13)	32/34: 3.31 (4.31)	53/56: 4.73 (6.28)	37/40: 4.58 (8.95)	38/42: 1.96 (1.87)	52/56: 1.93 (2.7)	36/46: 2.45 (2.8)	319/320: 6.4 (10.7)	56/56: 4.04 (6.07)	36/46: 1.88 (5.11)
Metals	Mercury	ng/L	274/274: 21.4 (23.4)	34/34: 23.5 (14.8)	56/56: 32.3 (41.5)	40/40: 28.2 (19.9)	42/42: 14.6 (10.9)	56/56: 13.3 (7.49)	46/46: 16.8 (14)	320/320: 71 (97.2)	56/56: 55.3 (30)	46/46: 11.7 (10.9)
Metals	Methyl Mercury (Dissolved)	ng/L	49/158: 0.0278 (0.0109)	10/20: 0.0316 (0.018)	10/32: 0.032 (0.0164)	4/21: 0.0258 (0.00383)	10/25: 0.0253 (0.00242)	8/32: 0.0254 (0.00448)	7/28: 0.0266 (0.0078)	151/200: 0.0502 (0.0485)	21/32: 0.0343 (0.0138)	2/28: 0.0249 (0.000901)
Metals	Methyl Mercury	ng/L	142/158: 0.0517 (0.0365)	16/20: 0.0533 (0.0289)	31/32: 0.0652 (0.0385)	20/21: 0.0715 (0.0651)	22/25: 0.0366 (0.0126)	26/32: 0.0419 (0.019)	27/28: 0.0448 (0.0292)	200/200: 0.237 (0.241)	32/32: 0.125 (0.0544)	23/28: 0.0449 (0.0329)
Metals	Nickel (Dissolved)	µg/L	158/158: 1.14 (0.312)	20/20: 1.22 (0.329)	32/32: 1.2 (0.365)	21/21: 1.03 (0.173)	25/25: 1.2 (0.3)	32/32: 1.05 (0.307)	28/28: 1.17 (0.303)	200/200: 1.37 (0.331)	32/32: 1.58 (0.48)	28/28: 0.969 (0.308)
Metals	Nickel	µg/L	158/158: 1.45 (0.497)	20/20: 1.45 (0.377)	32/32: 1.53 (0.424)	21/21: 1.36 (0.451)	25/25: 1.37 (0.367)	32/32: 1.47 (0.766)	28/28: 1.47 (0.403)	200/200: 2.05 (0.889)	32/32: 1.98 (0.589)	28/28: 1.44 (0.645)
Metals	Selenium (Dissolved)	µg/L	12/158: 0.485 (0.0585)	2/20: 0.48 (0.0616)	7/32: 0.459 (0.0979)	1/21: 0.495 (0.0218)	0/25: <0.5	0/32: <0.5	2/28: 0.482 (0.067)	54/200: 0.549 (0.407)	3/32: 0.481 (0.0592)	2/28: 0.486 (0.0525)
Metals	Selenium	µg/L	25/158: 0.484 (0.163)	1/20: 0.49 (0.0447)	8/32: 0.466 (0.0971)	4/21: 0.452 (0.108)	3/25: 0.48 (0.0707)	4/32: 0.497 (0.131)	5/28: 0.514 (0.329)	63/200: 0.539 (0.42)	5/32: 0.472 (0.0729)	4/28: 0.489 (0.0916)
Metals	Silver (Dissolved)	µg/L	93/158: 0.00959 (0.00564)	14/20: 0.00965 (0.00503)	18/32: 0.0109 (0.00993)	11/21: 0.0102 (0.00379)	16/25: 0.00872 (0.00242)	15/32: 0.00934 (0.00314)	19/28: 0.00861 (0.00472)	118/200: 0.0154 (0.0172)	22/32: 0.00928 (0.00361)	21/28: 0.00832 (0.00374)
Metals	Silver	µg/L	139/158: 0.0315 (0.0676)	18/20: 0.0244 (0.0101)	30/32: 0.0556 (0.144)	18/21: 0.0363 (0.0323)	25/25: 0.0168 (0.00735)	24/32: 0.0232 (0.0168)	24/28: 0.028 (0.0222)	196/200: 0.0703 (0.0642)	32/32: 0.0395 (0.013)	26/28: 0.387 (1.9)
Metals	Zinc (Dissolved)	µg/L	158/158: 6.32 (1.88)	20/20: 6.97 (2)	32/32: 6.72 (2.43)	21/21: 6.43 (1.49)	25/25: 6.79 (1.13)	32/32: 5.35 (1.52)	28/28: 5.98 (1.91)	200/200: 7.11 (3.15)	32/32: 9.15 (3.34)	28/28: 4.65 (1.61)
Metals	Zinc	µg/L	158/158: 8.53 (3.18)	20/20: 8.93 (2.35)	32/32: 9.17 (3.13)	21/21: 9.81 (4.15)	25/25: 7.92 (1.5)	32/32: 7.39 (2.2)	28/28: 8.39 (4.43)	200/200: 17.4 (13.5)	32/32: 12.5 (3.65)	28/28: 6.76 (2.67)
Water Quality	Dissolved Organic Carbon	mg/L	274/274: 2.25 (0.546)	34/34: 2.5 (0.617)	56/56: 2.33 (0.583)	40/40: 2.32 (0.465)	42/42: 2.35 (0.483)	56/56: 2.14 (0.519)	46/46: 1.96 (0.459)	319/320: 3.29 (1.29)	56/56: 3.02 (0.846)	46/46: 1.86 (0.48)
Water Quality	Particulate Organic Carbon	mg/L	173/238: 0.957 (0.514)	22/29: 1.01 (0.403)	42/48: 1.21 (0.719)	29/40: 1.05 (0.593)	20/35: 0.744 (0.273)	35/48: 0.884 (0.368)	25/38: 0.786 (0.353)	231/280: 2.34 (1.97)	41/48: 1.36 (0.532)	27/38: 0.978 (0.721)
Water Quality	Suspended Solids	mg/L	274/274: 14.3 (10.2)	34/34: 13.4 (6.68)	56/56: 18.5 (13.1)	40/40: 18.2 (12)	42/42: 9.7 (4.17)	56/56: 14.5 (11.4)	46/46: 10.6 (5)	320/320: 31.4 (30.8)	56/56: 23.7 (11.7)	46/46: 16 (18.3)

Notes:
1/2 reporting limit substituted for non-detects in mean and standard deviation calculation
If all data are non-detect, the mean is reported as < mean reporting limit.
Summary statistics include all data collected regardless of depth, event, or tidal cycle.
[a]NBSA stations are ordered from north to south.
[b]Mean of all Lower Passaic River stations
See Figure 2-10 for station locations

Acronyms and Abbreviations:
< = less than mean reporting limit
alpha BHC = alpha-Hexachlorocyclohexane
beta BHC = beta-Hexachlorocyclohexane
DDx = sum of dichlorodiphenyldichloroethane, dichlorodiphenyldichloroethylene, and dichlorodiphenyltrichloroethane isomers
mg/l =milligrams per liter
NBSA = Newark Bay Study Area
(ND=0) = Only detected isomers were included in the summation.
ng/l =nanograms per liter
PCB = polychlorinated biphenyl
pg/L = picograms per liter
TCDD = tetrachlorodibenzo-p-dioxin
µg/L = micrograms per liter

References:
AECOM. 2010. Remedial Investigation Water Column Monitoring/Physical Data Collection for the Lower Passaic River, Newark Bay and Wet weather monitoring: Lower Passaic River Restoration Project. Quality Assurance Project Plan. Revision 5.
AECOM. 2011. Quality Assurance Project Plan/Field Sampling Plan Addendum. Remedial Investigation Water Column Monitoring/Small Volume Chemical Data Collection. Lower Passaic River Restoration Project. Revision 2. August, 2011.

Table 4-21
Mean COPC Concentration of Water Column Solids in the NBSA and Tributaries

Parameter Group	Chemical	Units	Mean (Standard Deviation)									
			NBSA[a]							Tributaries		
			All NBSA Stations	NNE	NBN	NNW	NBE	NBS	ARK	Passaic River[b]	Hackensack River	Kill Van Kull
Dioxins/Furans	2,3,7,8-TCDD	ng/kg	81.3 (66.9)	88.6 (47.2)	85.7 (67)	89.5 (55.4)	108 (113)	62.9 (47.5)	59.8 (31.6)	370 (2140)	79.6 (40.5)	63.4 (49.4)
PCBs	Total PCB Congeners (209)	ng/kg	554000 (253000)	627000 (260000)	546000 (231000)	553000 (222000)	606000 (228000)	492000 (307000)	536000 (237000)	743000 (353000)	528000 (153000)	416000 (196000)
Pesticides	Dieldrin	pg/g	32900 (24800)	38700 (20500)	28000 (23300)	22200 (12300)	42800 (24100)	34300 (30200)	31700 (27100)	43100 (29400)	20500 (15000)	23000 (20700)
Pesticides	Heptachlor epoxide	pg/g	13900 (11400)	18000 (10200)	11100 (9070)	10000 (6160)	19900 (12800)	13700 (12800)	12200 (12300)	24800 (18700)	9360 (7980)	9150 (9600)
Pesticides	Total Alpha + Gamma Chlordane	pg/g	33000 (22700)	39600 (18900)	29100 (17300)	27000 (10800)	42500 (24300)	30600 (25100)	31400 (29700)	65400 (38600)	24100 (11300)	21000 (26600)
Pesticides	Total DDx (2,4' and 4,4') (ND=0)	pg/g	87600 (95000)	74500 (29900)	65400 (34500)	66600 (15800)	75300 (41600)	59500 (50700)	181000 (186000)	102000 (44900)	48300 (19600)	44600 (62700)
Pesticides	Total DDx (4,4') (ND=0)	pg/g	68500 (66300)	59900 (22400)	53000 (25200)	55500 (14000)	59900 (33200)	49600 (39300)	131000 (128000)	82500 (35600)	39400 (16900)	38800 (57500)
Pesticides	alpha BHC	pg/g	12900 (14700)	11200 (6320)	9260 (6730)	7930 (4860)	14500 (9670)	20100 (28200)	12400 (7850)	4360 (4590)	5270 (3680)	10900 (7440)
Pesticides	beta BHC	pg/g	10100 (13100)	7970 (5930)	6850 (7580)	5590 (3390)	10400 (9050)	14500 (23400)	13400 (11500)	4530 (4290)	4820 (3970)	9290 (8200)
Pesticides	cis-Nonachlor	pg/g	6590 (6220)	7970 (7620)	6050 (5770)	5490 (6550)	8760 (6740)	6780 (6110)	4960 (4650)	8690 (5310)	5000 (3690)	6290 (6760)
PAH-SIM	Total HPAHs	µg/kg	9610 (4920)	13300 (5860)	10200 (3920)	11800 (7420)	9540 (3240)	7690 (3430)	6940 (3100)	20400 (9880)	12200 (5280)	4150 (1900)
PAH-SIM	Total LPAHs	µg/kg	4700 (5800)	6140 (5000)	3970 (4030)	6060 (5090)	4790 (6220)	3530 (4230)	4720 (8900)	6070 (4490)	5040 (3230)	1810 (2780)
PAH-SIM	Total PAHs	µg/kg	14300 (8700)	19400 (8940)	14200 (6370)	17800 (9370)	14300 (8120)	11200 (5830)	11700 (11200)	26400 (13300)	17200 (7300)	5950 (4020)
Metals	Arsenic	mg/kg	18 (31.2)	10.5 (6.69)	15.8 (30)	27.2 (41.5)	20.9 (37.3)	21.2 (40.2)	12.7 (8.56)	10.7 (8.41)	10.1 (5.72)	17.2 (42.1)
Metals	Cadmium	mg/kg	1.33 (2.09)	1.39 (2.14)	1.21 (1.54)	1.23 (1.43)	1.58 (2.92)	1.04 (2.03)	1.65 (2.3)	2.39 (1.37)	1.21 (0.799)	0.761 (1.39)
Metals	Chromium	mg/kg	59.9 (29.2)	71.8 (28.8)	63.8 (29.8)	61.4 (25.9)	64.1 (40.1)	47.6 (17)	56.1 (27.8)	83.7 (35.6)	89.3 (21.9)	41 (10.7)
Metals	Copper	mg/kg	79.2 (48.4)	74.4 (29.4)	75.8 (28)	81.4 (31.2)	74.1 (62.9)	66.6 (42.9)	105 (70.5)	128 (57.4)	83.1 (21.9)	59.1 (49.6)
Metals	Lead	mg/kg	109 (44.8)	121 (46.3)	111 (39.9)	114 (40.8)	117 (53.5)	92.8 (36.2)	103 (49.2)	185 (76.2)	119 (25.4)	80.5 (28)
Metals	Mercury	µg/kg	1290 (662)	1520 (710)	1410 (783)	1420 (732)	1260 (602)	917 (351)	1370 (586)	2000 (2950)	2180 (710)	756 (331)
Metals	Methyl Mercury	µg/kg	3.44 (1.63)	3.86 (1.71)	3.64 (1.76)	3.57 (1.46)	3.38 (1.89)	3.01 (1.42)	3.35 (1.56)	6.8 (4.04)	4.88 (1.85)	3.25 (1.63)
Metals	Nickel	mg/kg	23.9 (18)	20.3 (9.21)	24.2 (14.6)	17.9 (7.6)	27.8 (28)	26.6 (23.9)	24.2 (10.8)	23.7 (12.3)	19.3 (7.53)	28.2 (11.9)
Metals	Silver	mg/kg	2.56 (12)	1.54 (0.672)	6.32 (26.5)	1.7 (0.709)	1.42 (0.885)	1.44 (0.459)	1.95 (1.45)	2.18 (1.67)	1.71 (0.554)	13.8 (65.5)
Metals	Zinc	mg/kg	183 (153)	174 (58.4)	187 (132)	177 (62.8)	239 (312)	148 (58.4)	179 (128)	336 (188)	166 (53.7)	164 (191)

Notes:
Solids concentrations are estimated from water and suspended solids concentrations measured in the small volume chemical water column monitoring program. For organic coumpounds for which only total concentrations were measured, solids concentrations were estimated by dividing the total water concentration by the suspended solids concentration. For metals, for which both total and dissolved concentrations were measured, the dissolved concentration, if detected, was first subtracted from the total concentration before dividing by the suspended solids concentration. Sampling was conducted from 2011 through 2013 as described in the Quality Assurance Project Plan, AECOM (2011). Water concentrations are summarized in Table 4-20. Hexachlorbenzene, Bis(2-ethylhexyl) phthalate, and selenium were excluded due to very low frequency of detection in total water samples (i.e., less than 25%). Summary statistics include all data collected regardless of depth, event, or tidal cycle. 1/2 reporting limit substituted for non-detects in mean and standard deviation calculation.

[a]NBSA stations are ordered from north to south.
[b]Mean of all Lower Passaic River stations
See Figure 2-10 for station locations

Acronyms and Abbreviations:
alpha BHC = alpha-Hexachlorocyclohexane
beta BHC = beta-Hexachlorocyclohexane
DDx = sum of dichlorodiphenyldichloroethane, dichlorodiphenyldichloroethylene, and dichlorodiphenyltrichloroethane isomers
mg/kg = milligram per kilogram
NBSA = Newark Bay Study Area
(ND=0) = Only detected isomers were included in the summation
ng/kg = nanogram per kilogram
PCB = polychlorinated biphenyl
pg/g = picogram per gram
TCDD = tetrachlorodibenzo-p-dioxin
µg/kg = microgram per kilogram

References:
AECOM. 2011. Quality Assurance Project Plan/Field Sampling Plan Addendum. Remedial Investigation Water Column Monitoring/Small Volume Chemical Data Collection. Lower Passaic River Restoration Project. Revision 2. August, 2011.

Table 4-22
Calculated Water and Solid-Phase Concentrations for the High Volume Water Sampling Program

Station		Sample	Sample Volume (L)	Suspended Solids (mg/L)	2,3,7,8-TCDD						Total PCB Congeners					
					Filtered Solids (pg/sample)	Filtrate Sorption Media		Calculated Water Concentration		Calculated[c] Concentration in Water Column Solids (ng/kg)	Filtered Solids (pg/sample)	Filtrate Sorption Media		Calculated Water Concentration		Calculated[c] Concentration in Water Column Solids (ng/kg)
						PUF1 (pg/sample)	PUF2 (pg/sample)	Whole[a] (pg/L)	Dissolved[b] (pg/L)			PUF1 (pg/sample)	PUF2 (pg/sample)	Whole[a] (ng/L)	Dissolved[b] (ng/L)	
NBSA	Northeast (NNE)	N10-CE05-TNNE	400	16.9	1,060	27.7	6.83	2.7	0.086	157	5,970,000	1,560,000	277,000	20	4.59	883,136
	East (NBE)	N08-CE05-TNBE	500	7.3	42.4	6.57	3.52	0.1	0.020	11.6	195,000	508,000	162,000	1.7	1.34	53,425
	South (NBS)	N08-CE05-TNBS	493.5	4.8	43.3	1.36	2.69	0.096	0.008	18.3	663,000	151,000	399,000	2.5	1.11	279,889
		N10-CE05-TNBS	400	10.5	91.2	9.61	2.56	0.26	0.030	21.8	1,040,000	1,320,000	185,000	6.4	3.76	248,804
Lower Passaic River	River Mile 4.2	12I-CE05-T042	200	10.4	735	3.72	10.7	3.7	0.072	354	2,880,000	86,800	381,000	17	2.34	1,387,952
		12I-CE05-T042 (dup)	200	11.2	1,840	4.99	10.6	9.3	0.078	825	2,790,000	124,000	372,000	16	2.48	1,251,121
		13C-CE05-T042	200	29.7	1,380	38.3	10.6	7.1	0.245	233	1,620,000	1,160,000	128,000	15	6.44	273,187
		13C-CE05-T042 (dup)	200	30.6	746	38.9	10	4	0.245	122	2,790,000	1,250,000	576,000	23	9.13	456,628
	River Mile 10.2	12I-CE05-T102	100	28.2	499	8.69	3.76	5.1	0.125	177	1,940,000	227,000	78,600	22	3.06	687,334
		13C-CE05-T102	550	5.35	1,000	134	50.3	2.2	0.335	340	2,520,000	2,470,000	256,000	9.5	4.96	856,415
Kill Van Kull		N08-CE05-TKVK	290	13.1	27.1	< 1.06	1.05	0.097	0.005	7.12	1,360,000	242,000	61,200	5.7	1.05	357,307
		N08-CE05-TKVK (dup)	290	14.0	38.7	0.988	< 0.775	0.14	0.005	9.5	2,120,000	233,000	156,000	8.7	1.34	523,102
		N10-CE05-TKVK	222	20	44.5	1.82	< 0.927	0.21	0.010	10.0	2,850,000	441,000	63,300	15	2.27	641,892
		N10-CE05-TKVK (dup)	222	21.1	66.2	1.85	< 1.22	0.31	0.011	14.2	3,110,000	547,000	105,000	17	2.94	665,511

Notes:
Data were collected during two sampling events in 2012 and 2013 during the HVCWCM program and reported by AECOM (2019).
1/2 reporting limit substituted for non-detect values in calculation of dissolved water concentration.
[a]Calculated as the sum of the mass in filtered solids and sorption media (i.e. PUF1 and PUF2) divided by the sample volume.
[b]Calculated as the sum of the mass in the sorption media (i.e. PUF1 and PUF2) divided by the sample volume.
[c]Calculated as the whole water concentration minus the dissolved fraction and then divided by the suspended solids concentration and appropriate unit conversion factors.

Acronyms and Abbreviations:
< = less than and indicates a non-detect value reported at the reporting limit.
HVCWCM = high volume chemical water column monitoring
L = liter
mg/L =milligrams per liter
NBSA = Newark Bay Study Area
ng/kg = nanogram per kilogram
ng/L =nanograms per liter
PCB = polychlorinated biphenyl
pg = picograms
pg/L = picograms per liter
PUF = Polyurethane Foam
TCDD = tetrachlorodibenzo-p-dioxin

Reference:
AECOM. 2019. High Volume Chemical Water Column Monitoring Sampling Program Characterization Summary. Lower Passaic River Study Area RI/FS. May 2019.

Table 4-23
Porewater Summary Statistics

Chemical Group	Analyte Group	Analyte	Units	Number of Samples	Frequency of Detection	Mean	Standard Deviation	Median	Minimum Detected	Maximum Detected	Minimum Non-Detect	Maximum Non-Detect
Organic Compounds[a]	PCDD/PCDF	2,3,7,8-TCDD	pg/L	30	30/30 (100%)	0.761	1.65	0.423	0.119	9.35	--	--
	PCBs	Total PCBs (209 Congeners)	ng/L	30	30/30 (100%)	15.3	27.1	6.73	3.99	152	--	--
	Pesticides	Alpha-BHC	ng/mL	30	5/30 (16.7%)	0.0000128	0.0000315	<0.00000204	0.0000218	0.000134	0.00000182	0.00000204
	Pesticides	Beta-BHC	ng/mL	30	0/30 (0%)	<0.00000277	0.00000072	<0.00000331	--	--	0.00000184	0.00000331
	Pesticides	Cis-Nonachlor	ng/mL	30	29/30 (96.7%)	0.0000164	0.0000063	0.0000162	0.00000989	0.0000369	0.0000000278	0.0000000278
	Pesticides	Dieldrin	ng/mL	30	30/30 (100%)	0.000248	0.000158	0.000198	0.000127	0.000868	--	--
	Pesticides	Heptachlor Epoxide	ng/mL	30	13/30 (43.3%)	0.00000765	0.0000102	<0.000000142	0.00000906	0.0000364	0.000000142	0.000000146
	Pesticides	Hexachlorobenzene	ng/mL	30	30/30 (100%)	0.000704	0.00163	0.000236	0.0000383	0.00778	--	--
	Pesticides	Total Alpha + Gamma Chlordane	ng/mL	30	30/30 (100%)	0.000291	0.0000872	0.00029	0.00014	0.00047	--	--
	Pesticides	Total DDx (2,4' & 4,4') (ND=0)	ng/mL	30	30/30 (100%)	0.00224	0.00292	0.0013	0.00062	0.015	--	--
	Pesticides	Total DDx (4,4') (ND=0)	ng/mL	30	30/30 (100%)	0.00165	0.00199	0.00098	0.00047	0.01	--	--
	PAHs	Total HMW PAHs	ng/L	30	30/30 (100%)	252	242	155	59	930	--	--
	PAHs	Total LMW PAHs	ng/L	30	15/30 (50%)	676	882	580	14	3,200	436	678
	PAHs	Total PAHs	ng/L	30	30/30 (100%)	800	1,170	175	59	4,100	--	--
Metals		Aluminum	mg/L	29	4/29 (13.8%)	0.159	0.307	<0.13	0.203	1.51	0.13	0.13
		Arsenic	mg/L	29	9/29 (31%)	0.0123	0.0176	<0.0054	0.0183	0.0748	0.0054	0.0054
		Cadmium	mg/L	29	0/29 (0%)	<0.00188	0.000543	<0.0023	--	--	0.0012	0.0023
		Chromium	mg/L	29	26/29 (89.7%)	0.00619	0.00291	0.0058	0.0036	0.0148	0.0035	0.0035
		Copper	mg/L	29	5/29 (17.2%)	0.00191	0.00292	<0.002	0.0021	0.0155	0.002	0.002
		Lead	mg/L	29	6/29 (20.7%)	0.00106	0.00189	<0.00065	0.00097	0.0076	0.00065	0.00065
		Mercury	ng/L	30	29/30 (96.7%)	139	62.2	130	52.9	348	1.65	1.65
		Methyl Mercury	ng/L	30	30/30 (100%)	137	71.6	114	33.1	368	--	--
		Nickel	mg/L	29	0/29 (0%)	<0.0047	0	<0.0047	--	--	0.0047	0.0047
		Selenium	mg/L	29	10/29 (34.5%)	0.00183	0.000828	<0.0025	0.0025	0.0034	0.0025	0.0025
		Silver	mg/L	29	0/29 (0%)	<0.00055	0	<0.00055	--	--	0.00055	0.00055
		Zinc	mg/L	29	3/29 (10.3%)	0.0398	0.0767	<0.037	0.0967	0.402	0.037	0.037

Notes:
[a]Porewater concentrations for organic compounds are calculated based on the concentrations within extracts from passive samplers and the chemical specific polymer-water partition coefficients (K_{PS}). Uncertainty in the porewater concentrations arises from the fact that the source of the K_{PS} values are regression relationships derived in experimental studies. Estimated values of K_{PS} are expected to be accurate within 0.3 log units or a factor of 2 (USEPA/SERDP/ESTCP 2017). Therefore, porewater concentrations could be as much as two times greater or lower than the calculated values presented for organic compounds. PCDD/PCDF concentrations may also be biased low because they were not corrected for equilibrium.
Non-detects are reported to the reporting limit.
Non-detects included at the 1/2 quantitation limit for mean and standard deviation estimates.
Non-detects evaluated at full quantitation limit for median estimate.
If all sample results are non-detect, non-detects evaluated at full quantitation limit.
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Table 4-23
Porewater Summary Statistics

Acronyms and Abbreviations:

< = indicates the median is a non-detect or that the mean was calculated using all non-detects reported at the quantitati
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/L = milligrams per liter
(ND=0) = Only detected isomers were included in the summation
ng/L = nanograms per liter
ng/mL = nanograms per milliliter
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
PCDD = polychlorinated dibenzo-p-dioxin
PCDF = polychlorinated dibenzofuran
pg/L = picograms per liter
TCDD = tetrachlorodibenzo-p-dioxin
Total DDx = sum of dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyltrichloroethane (DDT)

Reference

USEPA/SERDP/ESTCP. 2017. Laboratory, Field, and Analytical Procedures for Using Passive Sampling in the Evaluation of Contaminated Sediments: User's Manual. EPA/600/R-16/357. Office of Research and Development, Washington, DC. https://www.epa.gov/superfund/superfund-contaminated-sediments-guidance-documents-fact-sheets-and-policies.

Table 4-25
Whole Body Softshell Clam Samples – By BERA Assessment Zone

Analyte Group	Analyte	Units	NBSA BERA Assessment Zone	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	North	8	8	100%	6.19	3.08	5.16	3.63	13.4	--	--	2,490
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Southeast	4	4	100%	4.96	3.13	3.76	2.75	9.59	--	--	1,350
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Southwest	6	6	100%	3.98	2.01	3.73	1.69	7.08	--	--	1,380
PCBs	Total PCBs (9)	µg/kg	North	8	8	100%	44.1	25.5	36.5	19	91	--	--	15,000
PCBs	Total PCBs (9)	µg/kg	Southeast	4	4	100%	56.8	20.4	59	34	75	--	--	16,800
PCBs	Total PCBs (9)	µg/kg	Southwest	6	6	100%	108	108	71.5	31	320	--	--	39,000
PCBs	Total PCBs congener (209 specified)	ng/kg	North	8	8	100%	70,500	41,400	54,900	33,000	144,000	--	--	26,000,000
PCBs	Total PCBs congener (209 specified)	ng/kg	Southeast	4	4	100%	61,700	20,800	59,200	43,400	85,000	--	--	18,000,000
PCBs	Total PCBs congener (209 specified)	ng/kg	Southwest	6	6	100%	170,000	137,000	143,000	55,300	431,000	--	--	57,800,000
Pesticides	alpha-BHC	ng/kg	North	8	4	50%	28.2	33.4	22.4	5.32	9.06	35.7	189	8,380
Pesticides	alpha-BHC	ng/kg	Southeast	4	4	100%	8.07	0.932	8.42	6.73	8.71	--	--	2,500
Pesticides	alpha-BHC	ng/kg	Southwest	6	4	67%	21.7	22.1	13.6	7.03	13.8	38.8	132	6,360
Pesticides	beta-BHC	ng/kg	North	8	1	13%	23.7	17.1	<35.3	16.3	16.3	33.1	132	8,480
Pesticides	beta-BHC	ng/kg	Southeast	4	0	0%	<38.8	--	<39.1	--	--	37.4	39.6	<118,440
Pesticides	beta-BHC	ng/kg	Southwest	6	1	17%	34.5	23.8	<38.7	20	20	35.7	132	9,640
Pesticides	cis-Nonachlor	ng/kg	North	8	8	100%	358	118	330	215	515	--	--	138,000
Pesticides	cis-Nonachlor	ng/kg	Southeast	4	4	100%	355	58.4	347	296	429	--	--	107,000
Pesticides	cis-Nonachlor	ng/kg	Southwest	6	6	100%	430	175	415	249	731	--	--	147,000
Pesticides	Dieldrin	ng/kg	North	8	8	100%	482	116	472	342	648	--	--	191,000
Pesticides	Dieldrin	ng/kg	Southeast	4	4	100%	561	151	549	393	753	--	--	164,000
Pesticides	Dieldrin	ng/kg	Southwest	6	6	100%	646	211	600	417	897	--	--	219,000
Pesticides	Heptachlor epoxide	ng/kg	North	8	8	100%	76.5	16.6	75.2	51.6	103	--	--	30,400
Pesticides	Heptachlor epoxide	ng/kg	Southeast	4	4	100%	74.8	10.8	76.9	61.7	83.7	--	--	22,900
Pesticides	Heptachlor epoxide	ng/kg	Southwest	6	6	100%	81.5	23.5	77.2	62.3	127	--	--	27,000
Pesticides	Hexachlorobenzene	ng/kg	North	8	8	100%	202	42.6	207	120	270	--	--	85,600
Pesticides	Hexachlorobenzene	ng/kg	Southeast	4	4	100%	183	55.5	164	141	265	--	--	53,000
Pesticides	Hexachlorobenzene	ng/kg	Southwest	6	6	100%	309	153	258	193	606	--	--	99,300
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	ng/kg	North	8	8	100%	7,630	3,210	6,250	5,200	14,000	--	--	2,860,000
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	ng/kg	Southeast	4	4	100%	8,300	3,150	8,100	5,000	12,000	--	--	2,410,000
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	ng/kg	Southwest	6	6	100%	36,500	11,800	35,000	19,000	54,000	--	--	12,300,000
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	ng/kg	North	8	8	100%	5,840	2,530	4,800	3,900	11,000	--	--	2,180,000
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	ng/kg	Southeast	4	4	100%	6,230	2,310	6,100	3,800	8,900	--	--	1,810,000
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	ng/kg	Southwest	6	6	100%	26,700	8,730	25,000	15,000	41,000	--	--	8,880,000
Pesticides	Total alpha + gamma chlordane	ng/kg	North	8	8	100%	1,800	529	1,750	1,100	2,700	--	--	717,000
Pesticides	Total alpha + gamma chlordane	ng/kg	Southeast	4	4	100%	1,830	299	1,800	1,500	2,200	--	--	553,000
Pesticides	Total alpha + gamma chlordane	ng/kg	Southwest	6	6	100%	2,170	797	2,050	1,400	3,600	--	--	748,000

Table 4-25
Whole Body Softshell Clam Samples – By BERA Assessment Zone

Analyte Group	Analyte	Units	NBSA BERA Assessment Zone	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
PAHs	Total Alkylated PAHs	µg/kg	North	8	8	100%	269	103	244	166	440	--	--	109,000
PAHs	Total Alkylated PAHs	µg/kg	Southeast	4	4	100%	226	121	177	145	406	--	--	62,900
PAHs	Total Alkylated PAHs	µg/kg	Southwest	6	6	100%	421	183	406	231	761	--	--	146,000
PAHs	Total HMW PAHs	µg/kg	North	8	8	100%	348	96.3	345	220	500	--	--	154,000
PAHs	Total HMW PAHs	µg/kg	Southeast	4	4	100%	213	37.7	210	170	260	--	--	65,000
PAHs	Total HMW PAHs	µg/kg	Southwest	6	6	100%	385	166	390	190	580	--	--	137,000
PAHs	Total LMW PAHs	µg/kg	North	8	8	100%	30.1	15.8	27	13	59	--	--	13,500
PAHs	Total LMW PAHs	µg/kg	Southeast	4	4	100%	20.9	11.1	19.5	9.6	35	--	--	5,860
PAHs	Total LMW PAHs	µg/kg	Southwest	6	6	100%	65.7	60	56	13	170	--	--	21,600
PAHs	Total PAH	µg/kg	North	8	8	100%	375	110	370	230	550	--	--	166,000
PAHs	Total PAH	µg/kg	Southeast	4	4	100%	230	40.8	230	180	280	--	--	69,900
PAHs	Total PAH	µg/kg	Southwest	6	6	100%	450	217	445	200	720	--	--	158,000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	North	8	1	13%	331	13.2	<665	300	300	660	680	136,000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Southeast	4	0	0%	<668	--	<670	--	--	660	670	<202,000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Southwest	6	0	0%	<674	--	<675	--	--	660	680	<234,000
Lipids	Lipids	%	North	8	7	88%	0.296	0.133	0.29	0.19	0.48	0.1	0.1	NR
Lipids	Lipids	%	Southeast	4	4	100%	0.345	0.0968	0.3	0.29	0.49	--	--	NR
Lipids	Lipids	%	Southwest	6	5	83%	0.45	0.304	0.44	0.3	0.97	0.1	0.1	NR
Metals	Arsenic	mg/kg	North	8	8	100%	5.42	1.73	4.89	3.73	8.67	--	--	NR
Metals	Arsenic	mg/kg	Southeast	4	4	100%	2.16	0.585	2.17	1.43	2.86	--	--	NR
Metals	Arsenic	mg/kg	Southwest	6	6	100%	5.29	4.39	3.44	1.59	12.4	--	--	NR
Metals	Cadmium	mg/kg	North	8	8	100%	0.203	0.0354	0.206	0.138	0.243	--	--	NR
Metals	Cadmium	mg/kg	Southeast	4	4	100%	0.21	0.0419	0.208	0.162	0.264	--	--	NR
Metals	Cadmium	mg/kg	Southwest	6	5	83%	0.189	0.108	0.162	0.13	0.345	0.1	0.1	NR
Metals	Chromium	mg/kg	North	8	8	100%	3.62	1.19	4.06	2.13	5.18	--	--	NR
Metals	Chromium	mg/kg	Southeast	4	4	100%	4.06	2.79	3.49	1.78	7.47	--	--	NR
Metals	Chromium	mg/kg	Southwest	6	5	83%	2.63	2.28	1.73	1.18	5.81	0.4	0.4	NR
Metals	Copper	mg/kg	North	8	8	100%	8.54	1.82	8.25	6.29	11.1	--	--	NR
Metals	Copper	mg/kg	Southeast	4	4	100%	9.65	2.81	8.59	7.62	13.8	--	--	NR
Metals	Copper	mg/kg	Southwest	6	6	100%	14.1	8.44	11.1	6.94	30.2	--	--	NR
Metals	Lead	mg/kg	North	8	8	100%	16	7.23	15.9	4.98	27.1	--	--	NR
Metals	Lead	mg/kg	Southeast	4	4	100%	8.45	2.57	8.96	4.89	11	--	--	NR
Metals	Lead	mg/kg	Southwest	6	5	83%	22.2	36.3	6.11	4.61	94.8	0.2	0.2	NR
Metals	Mercury	µg/kg	North	8	8	100%	121	112	80.8	50.5	391	--	--	NR
Metals	Mercury	µg/kg	Southeast	4	4	100%	73.4	19.6	68.7	55.3	101	--	--	NR
Metals	Mercury	µg/kg	Southwest	6	6	100%	102	56.2	86.2	62.3	213	--	--	NR
Metals	Methyl mercury	µg/kg	North	8	8	100%	36.9	12.9	34.6	21.6	60.9	--	--	NR
Metals	Methyl mercury	µg/kg	Southeast	4	4	100%	36.1	13.2	40	18	46.6	--	--	NR
Metals	Methyl mercury	µg/kg	Southwest	6	6	100%	32.9	19	28.7	14.7	63.2	--	--	NR
Metals	Nickel	mg/kg	North	8	8	100%	2.47	0.877	2.19	1.35	4.19	--	--	NR
Metals	Nickel	mg/kg	Southeast	4	4	100%	2.03	0.407	1.95	1.64	2.56	--	--	NR
Metals	Nickel	mg/kg	Southwest	6	5	83%	1.81	1.65	1.46	1.03	4.99	0.4	0.4	NR

Table 4-25
Whole Body Softshell Clam Samples – By BERA Assessment Zone

Analyte Group	Analyte	Units	NBSA BERA Assessment Zone	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Metals	Selenium	mg/kg	North	8	8	100%	0.968	0.108	0.909	0.869	1.12	--	--	NR
Metals	Selenium	mg/kg	Southeast	4	4	100%	0.803	0.0557	0.794	0.744	0.878	--	--	NR
Metals	Selenium	mg/kg	Southwest	6	6	100%	0.896	0.0622	0.911	0.797	0.969	--	--	NR
Metals	Silver	mg/kg	North	8	8	100%	0.388	0.0983	0.369	0.244	0.549	--	--	NR
Metals	Silver	mg/kg	Southeast	4	4	100%	0.515	0.247	0.5	0.245	0.816	--	--	NR
Metals	Silver	mg/kg	Southwest	6	6	100%	0.249	0.121	0.199	0.142	0.433	--	--	NR
Metals	Zinc	mg/kg	North	8	8	100%	28.7	2.82	29.2	24.8	32.4	--	--	NR
Metals	Zinc	mg/kg	Southeast	4	4	100%	27.8	4.06	28.9	21.9	31.3	--	--	NR
Metals	Zinc	mg/kg	Southwest	6	6	100%	52.7	44.1	41	22.4	140	--	--	NR

Notes:
Non-detects included at the 1/2 quantitation limit for mean and standard deviation estimates.
Non-detects evaluated at full quantitation limit for median estimate. If the median is a non-detect, it is indicated by the "less than" symbol (<).
When all data are reported as non-detect, the calculated mean and standard deviation are calculated using the full quantitation limit; a “less than” symbol (<) was assigned to the mean to indicate all values are below the quantitation limit
Lipid-normalized results are calculated as the wet weight concentration divided by the fraction lipids.
BERA assessment zones are depicted on Figure 4-35
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Acronyms and Abbreviations:
< = indicates the median is a non-detect or that the mean was calculated using all non-detects reported at the quantitation limit
-- = Not reported due to frequency of detection
% = percent
BERA = Baseline Ecological Risk Assessment
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligram per kilogram
NBSA = Newark Bay Study Area
(ND=0) = Only detected isomers were included in the summation.
ng/kg = nanogram per kilogram
NR = not reported for metals or lipids
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
µg/kg = microgram per kilogram

Table 4-26
Whole Body Blue Crab Samples

Analyte Group	Analyte	Units	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	37	37	100%	22.5	9.14	22.6	4.6	44.9	--	--	1,270
PCBs	Total PCBs (9)	µg/kg	37	29	78%	65.3	31.9	64.3	38.8	188	33	170	6,030
PCBs	Total PCBs congener (209 specified)	ng/kg	37	37	100%	335,000	104,000	319,000	169,000	597,000	--	--	15,400,000
Pesticides	alpha-BHC	ng/kg	35	35	100%	32.5	13.7	29.8	17.2	76.1	--	--	5,380
Pesticides	beta-BHC	ng/kg	37	37	100%	74.2	30.5	65.8	17.3	178	--	--	8,080
Pesticides	cis-Nonachlor	ng/kg	37	37	100%	4,520	2,030	4,190	2,040	13,000	--	--	273,000
Pesticides	Dieldrin	ng/kg	36	36	100%	5,220	2,270	4,860	1,850	11,100	--	--	452,000
Pesticides	Heptachlor epoxide	ng/kg	37	37	100%	2,990	1,510	2,510	1,400	8,430	--	--	131,000
Pesticides	Hexachlorobenzene	ng/kg	37	37	100%	955	397	876	480	2,090	--	--	77,800
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	ng/kg	37	37	100%	104,000	46,300	98,800	45,400	264,000	--	--	7,820,000
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	ng/kg	37	37	100%	103,000	46,200	97,600	45,400	264,000	--	--	7,800,000
Pesticides	Total alpha + gamma chlordane	ng/kg	37	37	100%	1940	954	1730	305	3810	--	--	152,000
PAHs	Total Alkylated PAHs	µg/kg	37	32	86%	14.8	19.8	10.4	3.13	119	6.6	32	2,880
PAHs	Total HMW PAHs	µg/kg	37	34	92%	31.1	43.3	18.9	4.35	196	6.6	32	3,150
PAHs	Total LMW PAHs	µg/kg	37	35	95%	25.7	61.8	12	3.78	382	6.7	32	12,800
PAHs	Total PAH	µg/kg	37	35	95%	53	77.6	28.6	4.32	384	6.7	32	14,000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	36	0	0%	<1,852	--	<680	--	--	660	3,400	<44,800
Lipids	Lipids	%	37	37	100%	1.9	0.528	1.74	0.911	3.23	--	--	NR
Metals	Arsenic	mg/kg	37	37	100%	2.5	0.532	2.46	1.5	3.81	--	--	NR
Metals	Cadmium	mg/kg	37	37	100%	0.315	0.142	0.262	0.148	0.668	--	--	NR
Metals	Chromium	mg/kg	37	37	100%	0.263	0.0971	0.237	0.177	0.711	--	--	NR
Metals	Copper	mg/kg	37	37	100%	28.9	6.52	28.5	18.7	47.9	--	--	NR
Metals	Lead	mg/kg	37	37	100%	0.665	0.783	0.458	0.224	5.04	--	--	NR
Metals	Mercury	µg/kg	37	37	100%	116	28.2	111	39.7	180	--	--	NR
Metals	Methyl mercury	µg/kg	34	34	100%	124	40	121	29.7	207	--	--	NR
Metals	Nickel	mg/kg	37	36	97%	0.312	0.157	0.281	0.195	1.11	0.392	0.392	NR
Metals	Selenium	mg/kg	37	37	100%	1.07	0.156	1.06	0.697	1.37	--	--	NR
Metals	Silver	mg/kg	37	37	100%	0.785	0.217	0.784	0.266	1.41	--	--	NR
Metals	Zinc	mg/kg	37	37	100%	40.4	6.6	41.1	28.8	53	--	--	NR

Notes:
Non-detects included at the 1/2 quantitation limit for mean and standard deviation estimates.
Non-detects evaluated at full quantitation limit for median estimate. If the median is a non-detect, it is indicated by the "less than" symbol (<).
When all data are reported as non-detect, the calculated mean and standard deviation are calculated using the full quantitation limit; a “less than” symbol (<) was assigned to the mean to indicate all values are
Lipid-normalized results are calculated as the wet weight concentration divided by the fraction lipids.
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Acronyms and Abbreviations:
< = indicates the median is a non-detect or that the mean was calculated using all non-detects reported at the quantitation limit
-- = Not reported due to frequency of detection
% = percent
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligram per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/kg = nanogram per kilogram
NR = not reported for metals or lipids
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
µg/kg = microgram per kilogram

Table 4-27
Whole Body Blue Crab Spatial Comparison

Analyte Group	Analyte	NBSA BERA Assessment Zone	Frequency of Detection	Arithmetic Mean	Geometric Mean	Units	p-value ANOVA[a]	Tukey-Kramer Pairwise Difference[a]	p-value ANCOVA[b]
Dioxins/ Furans	2,3,7,8-TCDD	North	12/12 (100%)	31	30.3	ng/kg	**<0.0001**	A	**<0.0001**
		Southeast	13/13 (100%)	22.5	21.6	ng/kg		B	
		Southwest	12/12 (100%)	14	13.1	ng/kg		C	
PCBs	Total PCB congeners	North	12/12 (100%)	440,000	432,000	ng/kg	**<0.0001**	A	**<0.0001**
		Southeast	13/13 (100%)	310,000	302,000	ng/kg		B	
		Southwest	12/12 (100%)	256,000	251,000	ng/kg		B	
Pesticides	alpha-BHC	North	11/11 (100%)	30.4	29.2	ng/kg	0.877	--	0.682
		Southeast	13/13 (100%)	31.8	30.7	ng/kg		--	
		Southwest	12/12 (100%)	35.4	31.5	ng/kg		--	
	beta-BHC	North	12/12 (100%)	94.7	89.4	ng/kg	**0.009**	A	**0.025**
		Southeast	13/13 (100%)	69.2	66.6	ng/kg		AB	
		Southwest	12/12 (100%)	59.1	53.7	ng/kg		B	
	cis-Nonachlor	North	12/12 (100%)	6,290	5,920	ng/kg	**<0.0001**	A	**<0.0001[c]**
		Southeast	13/13 (100%)	4,200	4,150	ng/kg		B	
		Southwest	12/12 (100%)	3,100	3,030	ng/kg		C	
	Dieldrin	North	11/11 (100%)	6,890	6,350	ng/kg	**0.001**	A	**0.003[c]**
		Southeast	13/13 (100%)	5,400	5,190	ng/kg		A	
		Southwest	12/12 (100%)	3,490	3,280	ng/kg		B	
	Heptachlor epoxide	North	12/12 (100%)	4,340	4,040	ng/kg	**<0.0001**	A	**<0.0001[c]**
		Southeast	13/13 (100%)	2,600	2,530	ng/kg		B	
		Southwest	12/12 (100%)	2,080	2,030	ng/kg		B	
	Hexachlorobenzene	North	12/12 (100%)	1,370	1,340	ng/kg	**<0.0001**	A	**<0.0001**
		Southeast	13/13 (100%)	829	808	ng/kg		B	
		Southwest	12/12 (100%)	672	644	ng/kg		B	
	Total Chlordane (alpha + gamma)	North	12/12 (100%)	2,390	2,190	ng/kg	**0.018**	A	**0.038[c]**
		Southeast	13/13 (100%)	2,010	1,840	ng/kg		AB	
		Southwest	12/12 (100%)	1,400	1,180	ng/kg		B	
	Total DDx (2,4' & 4,4') (ND=0)	North	12/12 (100%)	94,500	87,700	ng/kg	**0.044**	AB	**0.021[c]**
		Southeast	13/13 (100%)	85,700	82,900	ng/kg		B	
		Southwest	12/12 (100%)	132,000	121,000	ng/kg		A	
PAHs	Total Alkylated PAHs	North	11/12 (92%)	16.7	13.3	µg/kg	0.277	--	0.244
		Southeast	11/13 (85%)	18.3	8.75	µg/kg		--	
		Southwest	10/12 (83%)	9.01	7.78	µg/kg		--	
	Total HMW PAHs	North	11/12 (92%)	44.4	29.7	µg/kg	**0.035**	A	0.086
		Southeast	13/13 (100%)	36.1	18.6	µg/kg		AB	
		Southwest	10/12 (83%)	12.5	10.8	µg/kg		B	
	Total LMW PAHs	North	11/12 (92%)	23.6	18.4	µg/kg	0.200	--	0.104
		Southeast	13/13 (100%)	41.7	13.2	µg/kg		--	
		Southwest	11/12 (92%)	10.6	9.32	µg/kg		--	
	Total PAH	North	11/12 (92%)	66.2	45.5	µg/kg	**0.027**	A	**0.037[c]**
		Southeast	13/13 (100%)	74	32.8	µg/kg		AB	
		Southwest	11/12 (92%)	17	14.9	µg/kg		B	
Metals	Arsenic	North	12/12 (100%)	2.05	2.02	mg/kg	**<0.0001**	B	**NA**
		Southeast	13/13 (100%)	2.52	2.49	mg/kg		A	
		Southwest	12/12 (100%)	2.92	2.89	mg/kg		A	
	Cadmium	North	12/12 (100%)	0.259	0.239	mg/kg	0.193	--	**NA**
		Southeast	13/13 (100%)	0.345	0.32	mg/kg		--	
		Southwest	12/12 (100%)	0.338	0.306	mg/kg		--	
	Chromium	North	12/12 (100%)	0.312	0.295	mg/kg	0.050	--	**NA**
		Southeast	13/13 (100%)	0.237	0.232	mg/kg		--	
		Southwest	12/12 (100%)	0.241	0.232	mg/kg		--	

Table 4-27
Whole Body Blue Crab Spatial Comparison

Analyte Group	Analyte	NBSA BERA Assessment Zone	Frequency of Detection	Arithmetic Mean	Geometric Mean	Units	p-value ANOVA[a]	Tukey-Kramer Pairwise Difference[a]	p-value ANCOVA[b]
Metals (cont.)	Copper	North	12/12 (100%)	29.8	29.2	mg/kg	0.585	--	**NA**
		Southeast	13/13 (100%)	27.4	26.8	mg/kg		--	
		Southwest	12/12 (100%)	29.6	28.9	mg/kg		--	
	Lead	North	12/12 (100%)	0.643	0.587	mg/kg	0.319	--	**NA**
		Southeast	13/13 (100%)	0.477	0.434	mg/kg		--	
		Southwest	12/12 (100%)	0.89	0.582	mg/kg		--	
	Mercury	North	12/12 (100%)	137	135	µg/kg	**<0.0001**	A	**NA**
		Southeast	13/13 (100%)	121	120	µg/kg		A	
		Southwest	12/12 (100%)	90.7	88	µg/kg		B	
	Methyl mercury	North	11/11 (100%)	131	127	µg/kg	0.601	--	**NA**
		Southeast	11/11 (100%)	125	117	µg/kg		--	
		Southwest	12/12 (100%)	116	108	µg/kg		--	
	Nickel	North	12/12 (100%)	0.376	0.334	mg/kg	0.160	--	**NA**
		Southeast	12/13 (92%)	0.27	0.259	mg/kg		--	
		Southwest	12/12 (100%)	0.292	0.286	mg/kg		--	
	Selenium	North	12/12 (100%)	0.977	0.966	mg/kg	**0.022**	B	**NA**
		Southeast	13/13 (100%)	1.15	1.14	mg/kg		A	
		Southwest	12/12 (100%)	1.07	1.07	mg/kg		AB	
	Silver	North	12/12 (100%)	0.868	0.847	mg/kg	0.091	--	**NA**
		Southeast	13/13 (100%)	0.794	0.773	mg/kg		--	
		Southwest	12/12 (100%)	0.691	0.652	mg/kg		--	
	Zinc	North	12/12 (100%)	42.1	41.4	mg/kg	0.540	--	**NA**
		Southeast	13/13 (100%)	38.9	38.4	mg/kg		--	
		Southwest	12/12 (100%)	40.2	39.9	mg/kg		--	

Notes:

[a]The ANOVA model tests if concentration is dependent upon assessment zone. The p-value for the significance of the F statisic is shown. Values that are significant at α = 0.05 are shaded and bolded. Modeling and post hoc testing (Tukey-Kramer method for unbalanced design) was conducted on natural log-transformed data. Letters (A, B, etc.) are assigned by concentration with letter A representing the highest mean concentration. BERA assessment zones that do not share a letter are significantly different (α = 0.05). Those that share a letter are not significantly different.

[b]The ANCOVA model tests if concentration is dependent upon assessment zone while controlling for lipid content which is added as a covariate to the model. The p-value for the significance of the assessment zone in the model is shown. Values that are significant at α = 0.05 are shown in bold. Modeling and post hoc testing was conducted on natural log-transformed data. Where significant, the ANCOVA model resulted in the same conclusions for the Tukey-Kramer pairwise differences as the ANOVA model. The ANCOVA model was not conducted for metals concentrations.

[c]The lipid covariate was not marginally significant (α= 0.05) when added to the model, an indication that the assessment zone explains the majority of the variance in concentrations.
Non-detects included at the 1/2 quantitation limit.
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.
BERA assessment zones are depicted in Figure 4-35.

Acronyms and Abbreviations:

< = less than
-- Not statistically significant at alpha = 0.05.
% = percent
ANOVA = analysis of variance
ANCOVA = analysis of covariance
BERA = Baseline Ecological Risk Assessment
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
ng/kg = nanograms per kilogram
(ND=0) = Only detected isomers were included in the summation
NA = Not applicable
NBSA = Newark Bay Study Area
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
TCDD = tetrachlorodibenzo-p-dioxin
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
µg/kg = micrograms per kilogram

Table 4-28
Sport Fish Samples – By Species and Tissue Type

Analyte Group	Analyte	Units	Species	Tissue Type	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	American Eel	Fillet	18	17	94%	7.06	4.2	6.23	2.48	14.7	0.95	0.95	115
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	American Eel	Whole Body	18	18	100%	5.57	3.95	4.65	1.69	16.3	--	--	145
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Bluefish	Fillet	18	18	100%	0.963	0.87	0.623	0.08	3.19	--	--	121
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Striped Bass	Fillet	18	18	100%	3	6.2	0.643	0.23	24.5	--	--	116
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Summer Flounder	Fillet	18	17	94%	4.38	2.66	4.15	1.26	10.4	0.98	0.98	755
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Summer Flounder	Whole Body	8	8	100%	5.49	5.37	3.02	1.58	16.4	--	--	661
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	White Perch	Fillet	18	18	100%	13.2	7.12	12.6	1.44	31.8	--	--	1040
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	White Perch	Liver	11	11	100%	48.4	32	44	9.07	108	--	--	852
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	White Perch	Whole Body	27	27	100%	48.5	47.8	39.3	3.66	203	--	--	2,090
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Winter Flounder	Whole Body	10	10	100%	5.44	2.5	4.75	2	10.4	--	--	514
PCBs	Total PCBs (9)	µg/kg	American Eel	Fillet	18	16	89%	361	274	320	69	1,000	170	170	6,280
PCBs	Total PCBs (9)	µg/kg	American Eel	Whole Body	15	15	100%	461	355	340	51	1,400	--	--	11,400
PCBs	Total PCBs (9)	µg/kg	Bluefish	Fillet	18	18	100%	82.2	84.8	42.5	13	320	--	--	15,700
PCBs	Total PCBs (9)	µg/kg	Striped Bass	Fillet	18	18	100%	366	490	193	55	1,800	--	--	14,500
PCBs	Total PCBs (9)	µg/kg	Summer Flounder	Fillet	18	18	100%	157	177	80	17	740	--	--	20,500
PCBs	Total PCBs (9)	µg/kg	Summer Flounder	Whole Body	8	8	100%	89.5	64.1	82	23	190	--	--	9,910
PCBs	Total PCBs (9)	µg/kg	White Perch	Fillet	18	18	100%	684	337	678	250	1,300	--	--	52,500
PCBs	Total PCBs (9)	µg/kg	White Perch	Liver	4	4	100%	1,150	173	1,150	1,000	1,300	--	--	22,700
PCBs	Total PCBs (9)	µg/kg	White Perch	Whole Body	26	26	100%	1,820	976	1,850	470	5,300	--	--	79,600
PCBs	Total PCBs (9)	µg/kg	Winter Flounder	Whole Body	10	10	100%	105	81.6	89	21	205	--	--	12,100
PCBs	Total PCBs congener (209 specified)	ng/kg	American Eel	Fillet	18	18	100%	624,000	314,000	594,000	197,000	1,150,000	--	--	13,200,000
PCBs	Total PCBs congener (209 specified)	ng/kg	American Eel	Whole Body	18	18	100%	603,000	315,000	618,000	101,000	1,500,000	--	--	17,400,000
PCBs	Total PCBs congener (209 specified)	ng/kg	Bluefish	Fillet	18	18	100%	105,000	52,600	92,300	42,300	258,000	--	--	19,200,000
PCBs	Total PCBs congener (209 specified)	ng/kg	Striped Bass	Fillet	18	18	100%	346,000	411,000	197,000	93,200	1,730,000	--	--	13,200,000
PCBs	Total PCBs congener (209 specified)	ng/kg	Summer Flounder	Fillet	18	18	100%	118,000	111,000	92,800	23,900	495,000	--	--	16,400,000
PCBs	Total PCBs congener (209 specified)	ng/kg	Summer Flounder	Whole Body	8	8	100%	287,000	176,000	209,000	111,000	600,000	--	--	41,000,000
PCBs	Total PCBs congener (209 specified)	ng/kg	White Perch	Fillet	18	18	100%	456,000	142,000	445,000	217,000	700,000	--	--	32,700,000
PCBs	Total PCBs congener (209 specified)	ng/kg	White Perch	Liver	11	11	100%	1,750,000	581,000	1,700,000	1,010,000	2,910,000	--	--	29,200,000
PCBs	Total PCBs congener (209 specified)	ng/kg	White Perch	Whole Body	27	27	100%	1,370,000	715,000	1,110,000	569,000	3,530,000	--	--	59,000,000
PCBs	Total PCBs congener (209 specified)	ng/kg	Winter Flounder	Whole Body	10	10	100%	144,000	18,700	150,000	114,000	173,000	--	--	15,000,000
Pesticides	alpha-BHC	ng/kg	American Eel	Fillet	17	17	100%	90.7	63.2	86.2	28.1	270	--	--	1,530
Pesticides	alpha-BHC	ng/kg	American Eel	Whole Body	17	16	94%	66.6	41.3	56.2	21.7	158	31.7	31.7	1,700
Pesticides	alpha-BHC	ng/kg	Bluefish	Fillet	18	17	94%	23.5	13.2	22.2	7.45	64.1	38.8	38.8	3,630
Pesticides	alpha-BHC	ng/kg	Striped Bass	Fillet	18	18	100%	45.9	27.7	46.8	8.89	103	--	--	1,610
Pesticides	alpha-BHC	ng/kg	Summer Flounder	Fillet	18	16	89%	17.7	13.1	15.8	5.47	65	38.1	39.6	3,030
Pesticides	alpha-BHC	ng/kg	Summer Flounder	Whole Body	8	7	88%	15.4	7.25	18.1	6.22	26.6	34.5	34.5	1,730
Pesticides	alpha-BHC	ng/kg	White Perch	Fillet	18	15	83%	43.5	40.2	39.2	22.5	196	38.8	39.2	3,010
Pesticides	alpha-BHC	ng/kg	White Perch	Liver	10	9	90%	169	115	201	46.5	357	38.5	38.5	2,700
Pesticides	alpha-BHC	ng/kg	White Perch	Whole Body	26	25	96%	129	117	95.1	19.7	439	35.7	35.7	4,110
Pesticides	alpha-BHC	ng/kg	Winter Flounder	Whole Body	10	10	100%	23.1	9.79	21.2	13	43	--	--	2,550
Pesticides	beta-BHC	ng/kg	American Eel	Fillet	18	18	100%	91.7	42.3	80.5	13.6	153	--	--	1,910
Pesticides	beta-BHC	ng/kg	American Eel	Whole Body	18	17	94%	72.8	51.5	54.3	25.7	178	27.6	27.6	1,950
Pesticides	beta-BHC	ng/kg	Bluefish	Fillet	18	18	100%	23.3	12.7	20.2	8.97	57.2	--	--	2,760
Pesticides	beta-BHC	ng/kg	Striped Bass	Fillet	18	17	94%	32.4	17	33.8	5.91	61.6	39.6	39.6	1,270
Pesticides	beta-BHC	ng/kg	Summer Flounder	Fillet	18	12	67%	15.5	5.35	18	5.42	23.2	38.1	39.6	3,330
Pesticides	beta-BHC	ng/kg	Summer Flounder	Whole Body	8	6	75%	14.7	6.04	15.9	5.75	22.3	37	40	2,050
Pesticides	beta-BHC	ng/kg	White Perch	Fillet	18	17	94%	32.7	10.6	34	13.7	53.4	39.2	39.2	2,390
Pesticides	beta-BHC	ng/kg	White Perch	Liver	11	11	100%	105	38.8	118	50.9	163	--	--	1,670
Pesticides	beta-BHC	ng/kg	White Perch	Whole Body	27	24	89%	58.5	44.2	46.6	16.1	184	28.6	38.5	2,080
Pesticides	beta-BHC	ng/kg	Winter Flounder	Whole Body	10	10	100%	11.6	1.94	12	7.29	14.4	--	--	1,200

Table 4-28
Sport Fish Samples – By Species and Tissue Type

Analyte Group	Analyte	Units	Species	Tissue Type	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Pesticides	cis-Nonachlor	ng/kg	American Eel	Fillet	18	18	100%	8,930	4,530	8,270	2,710	17,600	--	--	188,000
Pesticides	cis-Nonachlor	ng/kg	American Eel	Whole Body	18	18	100%	8,870	2,470	8,860	2,480	12,900	--	--	292,000
Pesticides	cis-Nonachlor	ng/kg	Bluefish	Fillet	18	18	100%	911	737	703	192	3,440	--	--	183,000
Pesticides	cis-Nonachlor	ng/kg	Striped Bass	Fillet	18	18	100%	3,970	6,810	1,880	735	28,800	--	--	142,000
Pesticides	cis-Nonachlor	ng/kg	Summer Flounder	Fillet	18	18	100%	852	659	715	91.5	2,450	--	--	127,000
Pesticides	cis-Nonachlor	ng/kg	Summer Flounder	Whole Body	8	8	100%	920	448	905	155	1,590	--	--	124,000
Pesticides	cis-Nonachlor	ng/kg	White Perch	Fillet	18	18	100%	6,550	2,340	6,490	2,410	11,800	--	--	490,000
Pesticides	cis-Nonachlor	ng/kg	White Perch	Liver	11	11	100%	12,600	4,640	13,700	7,260	19,800	--	--	207,000
Pesticides	cis-Nonachlor	ng/kg	White Perch	Whole Body	27	27	100%	14,200	5,020	13,900	8,230	28,700	--	--	616,000
Pesticides	cis-Nonachlor	ng/kg	Winter Flounder	Whole Body	10	10	100%	1,530	249	1,520	1,170	2,010	--	--	163,000
Pesticides	Dieldrin	ng/kg	American Eel	Fillet	18	18	100%	11,700	6,330	10,300	1,290	21,700	--	--	234,000
Pesticides	Dieldrin	ng/kg	American Eel	Whole Body	18	18	100%	9,760	4,850	9,050	2,890	20,900	--	--	301,000
Pesticides	Dieldrin	ng/kg	Bluefish	Fillet	18	18	100%	1,840	2,610	997	393	11,700	--	--	196,000
Pesticides	Dieldrin	ng/kg	Striped Bass	Fillet	18	18	100%	3,960	6,680	1,700	501	28,000	--	--	143,000
Pesticides	Dieldrin	ng/kg	Summer Flounder	Fillet	18	18	100%	1,160	624	1,120	264	2,530	--	--	186,000
Pesticides	Dieldrin	ng/kg	Summer Flounder	Whole Body	8	8	100%	723	298	726	253	1,180	--	--	96,300
Pesticides	Dieldrin	ng/kg	White Perch	Fillet	18	18	100%	6,280	2,050	6,030	2,700	11,700	--	--	467,000
Pesticides	Dieldrin	ng/kg	White Perch	Liver	11	11	100%	17,100	5,220	20,700	8,200	21,700	--	--	276,000
Pesticides	Dieldrin	ng/kg	White Perch	Whole Body	27	27	100%	14,300	6,740	13,400	5,590	28,300	--	--	595,000
Pesticides	Dieldrin	ng/kg	Winter Flounder	Whole Body	10	10	100%	2,120	549	2,020	1,210	3,040	--	--	222,000
Pesticides	Heptachlor epoxide	ng/kg	American Eel	Fillet	18	18	100%	3,040	1,740	2,520	474	6,340	--	--	58,400
Pesticides	Heptachlor epoxide	ng/kg	American Eel	Whole Body	18	18	100%	2,150	1,180	1,740	605	4,380	--	--	61,400
Pesticides	Heptachlor epoxide	ng/kg	Bluefish	Fillet	18	18	100%	492	699	271	89.8	3,140	--	--	50,500
Pesticides	Heptachlor epoxide	ng/kg	Striped Bass	Fillet	18	18	100%	764	1,050	322	132	4,310	--	--	30,800
Pesticides	Heptachlor epoxide	ng/kg	Summer Flounder	Fillet	18	18	100%	279	152	291	58.5	551	--	--	45,900
Pesticides	Heptachlor epoxide	ng/kg	Summer Flounder	Whole Body	8	8	100%	153	68	133	80	292	--	--	20,300
Pesticides	Heptachlor epoxide	ng/kg	White Perch	Fillet	18	18	100%	1,670	929	1,460	540	4,700	--	--	119,000
Pesticides	Heptachlor epoxide	ng/kg	White Perch	Liver	11	11	100%	3,730	1,410	3,890	1,850	5,720	--	--	60,200
Pesticides	Heptachlor epoxide	ng/kg	White Perch	Whole Body	27	27	100%	3,590	2,050	3,440	1,010	8,750	--	--	140,000
Pesticides	Heptachlor epoxide	ng/kg	Winter Flounder	Whole Body	10	10	100%	549	134	568	269	716	--	--	57,200
Pesticides	Hexachlorobenzene	ng/kg	American Eel	Fillet	18	18	100%	3,360	1,750	2,970	771	6,590	--	--	78,200
Pesticides	Hexachlorobenzene	ng/kg	American Eel	Whole Body	18	18	100%	3,090	1,250	3,060	1,270	5,970	--	--	101,000
Pesticides	Hexachlorobenzene	ng/kg	Bluefish	Fillet	18	18	100%	433	253	365	127	1,120	--	--	57,000
Pesticides	Hexachlorobenzene	ng/kg	Striped Bass	Fillet	18	18	100%	720	628	657	178	2,630	--	--	26,900
Pesticides	Hexachlorobenzene	ng/kg	Summer Flounder	Fillet	18	18	100%	402	212	408	101	812	--	--	66,400
Pesticides	Hexachlorobenzene	ng/kg	Summer Flounder	Whole Body	8	8	100%	249	105	212	101	424	--	--	33,100
Pesticides	Hexachlorobenzene	ng/kg	White Perch	Fillet	18	18	100%	1,080	427	1,070	502	2,220	--	--	81,100
Pesticides	Hexachlorobenzene	ng/kg	White Perch	Liver	11	11	100%	2,470	628	2,380	1,580	3,520	--	--	41,700
Pesticides	Hexachlorobenzene	ng/kg	White Perch	Whole Body	27	27	100%	2,240	1,320	1,950	900	6,210	--	--	96,600
Pesticides	Hexachlorobenzene	ng/kg	Winter Flounder	Whole Body	10	10	100%	856	371	669	413	1,360	--	--	82,800
Pesticides	Total alpha + gamma chlordane	ng/kg	American Eel	Fillet	18	18	100%	14,600	7,970	13,000	2,400	27,000	--	--	273,000
Pesticides	Total alpha + gamma chlordane	ng/kg	American Eel	Whole Body	18	18	100%	13,500	7,250	16,000	1,600	25,000	--	--	370,000
Pesticides	Total alpha + gamma chlordane	ng/kg	Bluefish	Fillet	18	18	100%	3,590	4,520	2,400	560	20,000	--	--	473,000
Pesticides	Total alpha + gamma chlordane	ng/kg	Striped Bass	Fillet	18	18	100%	11,700	28,500	2,850	1,000	123,000	--	--	405,000
Pesticides	Total alpha + gamma chlordane	ng/kg	Summer Flounder	Fillet	18	18	100%	2,180	1,420	2,100	360	5,800	--	--	338,000
Pesticides	Total alpha + gamma chlordane	ng/kg	Summer Flounder	Whole Body	8	8	100%	1,790	781	1,900	300	2,700	--	--	252,000
Pesticides	Total alpha + gamma chlordane	ng/kg	White Perch	Fillet	18	18	100%	22,800	13,000	20,300	7,100	67,000	--	--	1,720,000
Pesticides	Total alpha + gamma chlordane	ng/kg	White Perch	Liver	11	11	100%	34,000	15,600	37,000	12,000	69,000	--	--	562,000
Pesticides	Total alpha + gamma chlordane	ng/kg	White Perch	Whole Body	27	27	100%	52,100	26,800	48,000	10,000	110,000	--	--	2,170,000
Pesticides	Total alpha + gamma chlordane	ng/kg	Winter Flounder	Whole Body	10	10	100%	6,400	962	6,700	5,000	7,900	--	--	665,000

Table 4-28
Sport Fish Samples – By Species and Tissue Type

Analyte Group	Analyte	Units	Species	Tissue Type	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Pesticides	Total DDx (2,4 & 4,4) Total Fraction (ND=0)	ng/kg	American Eel	Fillet	18	18	100%	326,000	231,000	275,000	63,000	990,000	--	--	8,850,000
Pesticides	Total DDx (2,4 & 4,4) Total Fraction (ND=0)	ng/kg	Bluefish	Fillet	18	18	100%	24,500	34,800	16,000	4,600	160,000	--	--	10,500,000
Pesticides	Total DDx (2,4 & 4,4) Total Fraction (ND=0)	ng/kg	Striped Bass	Fillet	18	18	100%	104,000	231,000	31,500	14,000	1,000,000	--	--	3,430,000
Pesticides	Total DDx (2,4 & 4,4) Total Fraction (ND=0)	ng/kg	Summer Flounder	Fillet	18	18	100%	31,600	34,600	14,000	1,900	130,000	--	--	4,090,000
Pesticides	Total DDx (2,4 & 4,4) Total Fraction (ND=0)	ng/kg	White Perch	Fillet	18	18	100%	261,000	183,000	190,000	42,000	710,000	--	--	20,000,000
Pesticides	Total DDx (2,4 & 4,4) Total Fraction (ND=0)	ng/kg	White Perch	Liver	11	11	100%	464,000	234,000	400,000	180,000	1,000,000	--	--	7,410,000
Pesticides	Total DDx (2,4 & 4,4) Total Fraction (ND=0)	ng/kg	American Eel	Whole Body	18	18	100%	256,000	123,000	225,000	85,000	610,000	--	--	9,120,000
Pesticides	Total DDx (2,4 & 4,4) Total Fraction (ND=0)	ng/kg	Summer Flounder	Whole Body	8	8	100%	24,300	12,100	27,300	4,700	39,000	--	--	3,420,000
Pesticides	Total DDx (2,4 & 4,4) Total Fraction (ND=0)	ng/kg	White Perch	Whole Body	27	27	100%	417,000	251,000	380,000	100,000	1,100,000	--	--	16,900,000
Pesticides	Total DDx (2,4 & 4,4) Total Fraction (ND=0)	ng/kg	Winter Flounder	Whole Body	10	10	100%	32,800	10,600	31,500	21,000	45,000	--	--	3,390,000
Pesticides	Total DDx (4,4) Total Fraction (ND=0)	ng/kg	American Eel	Fillet	18	18	100%	323,000	228,000	275,000	62,000	980,000	--	--	8,780,000
Pesticides	Total DDx (4,4) Total Fraction (ND=0)	ng/kg	Bluefish	Fillet	18	18	100%	23,400	34,900	15,000	4,400	160,000	--	--	10,400,000
Pesticides	Total DDx (4,4) Total Fraction (ND=0)	ng/kg	Striped Bass	Fillet	18	18	100%	92,800	204,000	28,000	12,000	880,000	--	--	3,070,000
Pesticides	Total DDx (4,4) Total Fraction (ND=0)	ng/kg	Summer Flounder	Fillet	18	18	100%	28,400	30,500	12,000	1,600	110,000	--	--	3,720,000
Pesticides	Total DDx (4,4) Total Fraction (ND=0)	ng/kg	White Perch	Fillet	18	18	100%	214,000	147,000	160,000	38,000	615,000	--	--	16,600,000
Pesticides	Total DDx (4,4) Total Fraction (ND=0)	ng/kg	White Perch	Liver	11	11	100%	369,000	178,000	330,000	160,000	800,000	--	--	5,930,000
Pesticides	Total DDx (4,4) Total Fraction (ND=0)	ng/kg	American Eel	Whole Body	18	18	100%	253,000	123,000	225,000	83,000	610,000	--	--	9,000,000
Pesticides	Total DDx (4,4) Total Fraction (ND=0)	ng/kg	Summer Flounder	Whole Body	8	8	100%	22,500	11,000	25,300	4,100	36,000	--	--	3,160,000
Pesticides	Total DDx (4,4) Total Fraction (ND=0)	ng/kg	White Perch	Whole Body	27	27	100%	336,000	188,000	330,000	92,000	825,000	--	--	13,700,000
Pesticides	Total DDx (4,4) Total Fraction (ND=0)	ng/kg	Winter Flounder	Whole Body	10	10	100%	30,700	9,710	29,300	20,000	43,000	--	--	3,170,000
PAHs	Total Alkylated PAHs	µg/kg	American Eel	Fillet	18	4	22%	22.6	53.6	<13	12.6	236	6.7	33	722
PAHs	Total Alkylated PAHs	µg/kg	American Eel	Whole Body	18	6	33%	13.2	11.4	<13	8.15	52.3	6.7	33	520
PAHs	Total Alkylated PAHs	µg/kg	Bluefish	Fillet	18	4	22%	9.81	13.9	<13	5.8	65.5	13	13	1390
PAHs	Total Alkylated PAHs	µg/kg	Striped Bass	Fillet	18	4	22%	9.23	6.45	<13	6.3	27	13	13	455
PAHs	Total Alkylated PAHs	µg/kg	Summer Flounder	Fillet	18	2	11%	10.7	13	<13	31.4	57.1	13	13	1790
PAHs	Total Alkylated PAHs	µg/kg	Summer Flounder	Whole Body	8	0	0%	<24.4	--	<32	--	--	6.7	33	<3,800
PAHs	Total Alkylated PAHs	µg/kg	White Perch	Fillet	18	0	0%	<33	--	<33	--	--	32	33	<2,460
PAHs	Total Alkylated PAHs	µg/kg	White Perch	Liver	11	8	73%	28.2	18.2	33	15	74	33	33	435
PAHs	Total Alkylated PAHs	µg/kg	White Perch	Whole Body	27	17	63%	40.1	39.1	33	13.8	192	33	33	1,410
PAHs	Total Alkylated PAHs	µg/kg	Winter Flounder	Whole Body	10	0	0%	<23	--	<23	--	--	13	33	<2,320
PAHs	Total HMW PAHs	µg/kg	American Eel	Fillet	18	5	28%	8.49	4.97	<13	6.3	19	6.7	33	212
PAHs	Total HMW PAHs	µg/kg	American Eel	Whole Body	18	7	39%	9.09	5.62	<13	2.8	20	6.7	33	348
PAHs	Total HMW PAHs	µg/kg	Bluefish	Fillet	18	2	11%	7.94	4.76	<13	13	26	13	13	1240
PAHs	Total HMW PAHs	µg/kg	Striped Bass	Fillet	18	0	0%	<13	--	<13	--	--	13	13	<662
PAHs	Total HMW PAHs	µg/kg	Summer Flounder	Fillet	18	1	6%	7.03	2.24	<13	16	16	13	13	1490
PAHs	Total HMW PAHs	µg/kg	Summer Flounder	Whole Body	8	0	0%	<24.4	--	<32	--	--	6.7	33	<3,800
PAHs	Total HMW PAHs	µg/kg	White Perch	Fillet	18	0	0%	<33	--	<33	--	--	32	33	<2,460
PAHs	Total HMW PAHs	µg/kg	White Perch	Liver	11	8	73%	12.6	4.92	14	5.5	20	13	33	215
PAHs	Total HMW PAHs	µg/kg	White Perch	Whole Body	27	7	26%	14.5	5.3	<33	8.3	32	13	33	698
PAHs	Total HMW PAHs	µg/kg	Winter Flounder	Whole Body	10	0	0%	<23	--	<23	--	--	13	33	<2,320
PAHs	Total LMW PAHs	µg/kg	American Eel	Fillet	18	13	72%	25.4	24.8	22	4.2	86	13	33	539
PAHs	Total LMW PAHs	µg/kg	American Eel	Whole Body	18	17	94%	28	31.8	14	6.1	96	33	33	1,300
PAHs	Total LMW PAHs	µg/kg	Bluefish	Fillet	18	5	28%	23.3	61.7	<13	12	270	13	13	2600
PAHs	Total LMW PAHs	µg/kg	Striped Bass	Fillet	18	4	22%	8.42	5.88	<13	5.5	26	13	13	421
PAHs	Total LMW PAHs	µg/kg	Summer Flounder	Fillet	18	3	17%	23.5	49.8	<13	5.8	170	13	13	2940
PAHs	Total LMW PAHs	µg/kg	Summer Flounder	Whole Body	8	1	13%	12.5	5.22	<32	5.7	5.7	13	33	1,930
PAHs	Total LMW PAHs	µg/kg	White Perch	Fillet	18	0	0%	<33	--	<33	--	--	32	33	<2,460
PAHs	Total LMW PAHs	µg/kg	White Perch	Liver	11	8	73%	33	21.8	33	14	83	33	33	508
PAHs	Total LMW PAHs	µg/kg	White Perch	Whole Body	27	20	74%	76.2	115	47	6.1	610	13	33	2,760
PAHs	Total LMW PAHs	µg/kg	Winter Flounder	Whole Body	10	0	0%	<23	--	<23	--	--	13	33	<2,320

Table 4-28
Sport Fish Samples – By Species and Tissue Type

Analyte Group	Analyte	Units	Species	Tissue Type	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
PAHs	Total PAH	µg/kg	American Eel	Fillet	18	13	72%	28.1	27.5	24.5	4.2	94	13	33	562
PAHs	Total PAH	µg/kg	American Eel	Whole Body	18	17	94%	31.8	36.3	15.5	6.1	110	33	33	1,440
PAHs	Total PAH	µg/kg	Bluefish	Fillet	18	6	33%	24.9	63.9	<13	12	280	13	13	2730
PAHs	Total PAH	µg/kg	Striped Bass	Fillet	18	4	22%	8.42	5.88	<13	5.5	26	13	13	421
PAHs	Total PAH	µg/kg	Summer Flounder	Fillet	18	3	17%	24.6	53.3	<13	5.8	190	13	13	3000
PAHs	Total PAH	µg/kg	Summer Flounder	Whole Body	8	1	13%	12.5	5.22	<32	5.7	5.7	13	33	1,930
PAHs	Total PAH	µg/kg	White Perch	Fillet	18	0	0%	<33	--	<33	--	--	32	33	<2,460
PAHs	Total PAH	µg/kg	White Perch	Liver	11	10	91%	39	27.5	33	14	100	33	33	594
PAHs	Total PAH	µg/kg	White Perch	Whole Body	27	20	74%	80.5	122	47	6.1	640	13	33	2,900
PAHs	Total PAH	µg/kg	Winter Flounder	Whole Body	10	0	0%	<23	--	<23	--	--	13	33	<2,320
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	American Eel	Whole Body	18	0	0%	<3,360	--	<3,400	--	--	3,300	3,400	<124,800
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Summer Flounder	Whole Body	8	0	0%	<3,380	--	<3,400	--	--	3,300	3,400	<478,000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	White Perch	Whole Body	27	0	0%	<3,380	--	<3,400	--	--	3,300	3,400	<169,400
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Winter Flounder	Whole Body	10	0	0%	<3,380	--	<3,400	--	--	3,300	3,400	<358,000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	American Eel	Fillet	18	0	0%	<3,380	--	<3,400	--	--	3,300	3,400	<90,600
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Bluefish	Fillet	18	0	0%	<3,360	--	<3,400	--	--	3,300	3,400	<580,000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Striped Bass	Fillet	18	0	0%	<3,380	--	<3,400	--	--	3,300	3,400	<171,200
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Summer Flounder	Fillet	18	0	0%	<3,380	--	<3,400	--	--	3,300	3,400	<762,000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	White Perch	Fillet	18	0	0%	<2,020	--	<1,990	--	--	660	3,400	<166,600
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	White Perch	Liver	11	0	0%	<3,040	--	<3,400	--	--	670	5,100	<48,800
Lipids	Lipids	%	American Eel	Fillet	18	18	100%	7.02	5.33	5.95	0.95	20.4	--	--	NR
Lipids	Lipids	%	American Eel	Whole Body	18	18	100%	4.6	3.95	3.08	1.3	13.4	--	--	NR
Lipids	Lipids	%	Bluefish	Fillet	18	18	100%	1.5	2.2	1.04	0.1	10	--	--	NR
Lipids	Lipids	%	Striped Bass	Fillet	18	18	100%	2.97	1.47	3.43	0.59	5.3	--	--	NR
Lipids	Lipids	%	Summer Flounder	Fillet	18	18	100%	1.71	3	0.735	0.1	10	--	--	NR
Lipids	Lipids	%	Summer Flounder	Whole Body	8	8	100%	0.918	0.461	0.91	0.39	1.55	--	--	NR
Lipids	Lipids	%	White Perch	Fillet	18	18	100%	1.75	1.21	1.55	0.6	6.05	--	--	NR
Lipids	Lipids	%	White Perch	Liver	11	11	100%	6.14	1.15	5.8	4.2	8.2	--	--	NR
Lipids	Lipids	%	White Perch	Whole Body	27	27	100%	2.63	1.34	2.5	0.77	6.8	--	--	NR
Lipids	Lipids	%	Winter Flounder	Whole Body	10	10	100%	1.07	0.363	1.15	0.57	1.6	--	--	NR
Metals	Arsenic	mg/kg	American Eel	Fillet	18	18	100%	1.02	0.41	0.878	0.6	1.96	--	--	NR
Metals	Arsenic	mg/kg	American Eel	Whole Body	18	18	100%	0.808	0.279	0.699	0.42	1.5	--	--	NR
Metals	Arsenic	mg/kg	Bluefish	Fillet	18	18	100%	0.586	0.28	0.519	0.26	1.27	--	--	NR
Metals	Arsenic	mg/kg	Striped Bass	Fillet	18	18	100%	1.16	0.28	1.15	0.41	1.6	--	--	NR
Metals	Arsenic	mg/kg	Summer Flounder	Fillet	18	18	100%	1.52	0.65	1.38	0.6	3.6	--	--	NR
Metals	Arsenic	mg/kg	Summer Flounder	Whole Body	8	8	100%	1.5	0.615	1.6	0.517	2.26	--	--	NR
Metals	Arsenic	mg/kg	White Perch	Fillet	18	18	100%	0.671	0.24	0.674	0.3	1.19	--	--	NR
Metals	Arsenic	mg/kg	White Perch	Liver	10	10	100%	3.07	4.67	1.51	1.05	16.3	--	--	NR
Metals	Arsenic	mg/kg	White Perch	Whole Body	27	27	100%	0.499	0.135	0.453	0.326	0.885	--	--	NR
Metals	Arsenic	mg/kg	Winter Flounder	Whole Body	10	10	100%	1.86	0.362	1.85	1.35	2.71	--	--	NR
Metals	Cadmium	mg/kg	American Eel	Fillet	18	0	0%	<0.09	--	<0.0976	--	--	0.07	0.1	NR
Metals	Cadmium	mg/kg	American Eel	Whole Body	18	0	0%	<0.0982	--	<0.098	--	--	0.0962	0.1	NR
Metals	Cadmium	mg/kg	Bluefish	Fillet	18	0	0%	<0.0874	--	<0.093	--	--	0.07	0.1	NR
Metals	Cadmium	mg/kg	Striped Bass	Fillet	18	0	0%	<0.0922	--	<0.0971	--	--	0.07	0.1	NR
Metals	Cadmium	mg/kg	Summer Flounder	Fillet	18	0	0%	<0.0944	--	<0.0971	--	--	0.07	0.1	NR
Metals	Cadmium	mg/kg	Summer Flounder	Whole Body	8	1	13%	0.05	0.00386	<0.0971	0.0593	0.0593	0.0952	0.099	NR
Metals	Cadmium	mg/kg	White Perch	Fillet	18	0	0%	<0.0898	--	<0.0893	--	--	0.08	0.1	NR
Metals	Cadmium	mg/kg	White Perch	Liver	10	6	60%	0.481	0.72	0.223	0.12	0.25	0.59	5	NR
Metals	Cadmium	mg/kg	White Perch	Whole Body	27	0	0%	<0.0976	--	<0.0971	--	--	0.0952	0.1	NR
Metals	Cadmium	mg/kg	Winter Flounder	Whole Body	10	0	0%	<0.097	--	<0.0971	--	--	0.0952	0.099	NR

Table 4-28
Sport Fish Samples – By Species and Tissue Type

Analyte Group	Analyte	Units	Species	Tissue Type	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Metals	Chromium	mg/kg	American Eel	Fillet	18	1	6%	0.304	0.53	<0.39	2.42	2.42	0.27	0.4	NR
Metals	Chromium	mg/kg	American Eel	Whole Body	18	5	28%	0.193	0.0461	<0.388	0.105	0.348	0.385	0.4	NR
Metals	Chromium	mg/kg	Bluefish	Fillet	18	2	11%	0.168	0.03	<0.356	0.11	0.17	0.27	0.4	NR
Metals	Chromium	mg/kg	Striped Bass	Fillet	18	5	28%	0.18	0.03	<0.36	0.13	0.23	0.27	0.4	NR
Metals	Chromium	mg/kg	Summer Flounder	Fillet	18	4	22%	0.237	0.25	<0.385	0.11	1.23	0.29	0.4	NR
Metals	Chromium	mg/kg	Summer Flounder	Whole Body	8	4	50%	0.179	0.0391	0.312	0.115	0.242	0.381	0.396	NR
Metals	Chromium	mg/kg	White Perch	Fillet	18	13	72%	0.147	0.05	0.143	0.1	0.28	0.32	0.39	NR
Metals	Chromium	mg/kg	White Perch	Liver	10	5	50%	1.18	1.59	0.715	0.1	5.23	0.37	4	NR
Metals	Chromium	mg/kg	White Perch	Whole Body	27	19	70%	0.342	0.41	0.364	0.0997	2.13	0.385	0.4	NR
Metals	Chromium	mg/kg	Winter Flounder	Whole Body	10	10	100%	0.387	0.143	0.375	0.188	0.638	--	--	NR
Metals	Copper	mg/kg	American Eel	Fillet	18	11	61%	0.221	0.04	0.266	0.19	0.32	0.28	0.4	NR
Metals	Copper	mg/kg	American Eel	Whole Body	18	18	100%	0.873	0.526	0.752	0.61	2.94	--	--	NR
Metals	Copper	mg/kg	Bluefish	Fillet	18	18	100%	0.744	0.11	0.721	0.58	1.06	--	--	NR
Metals	Copper	mg/kg	Striped Bass	Fillet	18	18	100%	0.507	0.14	0.489	0.31	0.78	--	--	NR
Metals	Copper	mg/kg	Summer Flounder	Fillet	18	18	100%	0.186	0.06	0.176	0.13	0.39	--	--	NR
Metals	Copper	mg/kg	Summer Flounder	Whole Body	8	7	88%	0.674	0.239	0.707	0.47	0.909	0.392	0.392	NR
Metals	Copper	mg/kg	White Perch	Fillet	18	18	100%	0.607	0.06	0.605	0.54	0.8	--	--	NR
Metals	Copper	mg/kg	White Perch	Liver	10	10	100%	1,940	2,130	1,300	542	7,800	--	--	NR
Metals	Copper	mg/kg	White Perch	Whole Body	27	27	100%	15.6	13.1	9.27	2.26	50	--	--	NR
Metals	Copper	mg/kg	Winter Flounder	Whole Body	10	10	100%	1.13	0.337	1.07	0.683	1.73	--	--	NR
Metals	Lead	mg/kg	American Eel	Fillet	18	5	28%	0.0724	0.03	<0.168	0.03	0.03	0.14	0.2	NR
Metals	Lead	mg/kg	American Eel	Whole Body	18	17	94%	0.231	0.146	0.167	0.0502	0.482	0.196	0.196	NR
Metals	Lead	mg/kg	Bluefish	Fillet	18	2	11%	0.0809	0.02	<0.183	0.02	0.04	0.14	0.2	NR
Metals	Lead	mg/kg	Striped Bass	Fillet	18	1	6%	0.0888	0.02	<0.193	0.04	0.04	0.14	0.2	NR
Metals	Lead	mg/kg	Summer Flounder	Fillet	18	0	0%	<0.1888	--	<0.194	--	--	0.15	0.2	NR
Metals	Lead	mg/kg	Summer Flounder	Whole Body	8	6	75%	0.063	0.0228	0.0554	0.0381	0.0687	0.192	0.196	NR
Metals	Lead	mg/kg	White Perch	Fillet	18	14	78%	0.0546	0.03	0.0447	0.03	0.1	0.17	0.19	NR
Metals	Lead	mg/kg	White Perch	Liver	10	6	60%	0.818	1.51	0.15	0.09	0.16	1.05	10	NR
Metals	Lead	mg/kg	White Perch	Whole Body	27	25	93%	0.18	0.0676	0.19	0.0609	0.285	0.19	0.198	NR
Metals	Lead	mg/kg	Winter Flounder	Whole Body	10	10	100%	0.621	0.372	0.485	0.364	1.56	--	--	NR
Metals	Mercury	µg/kg	American Eel	Fillet	18	18	100%	356	155	318	172	638	--	--	NR
Metals	Mercury	µg/kg	American Eel	Whole Body	18	18	100%	182	83.9	174	43.3	347	--	--	NR
Metals	Mercury	µg/kg	Bluefish	Fillet	18	18	100%	294	79.1	294	101	396	--	--	NR
Metals	Mercury	µg/kg	Striped Bass	Fillet	18	18	100%	250	78.4	237	104	485	--	--	NR
Metals	Mercury	µg/kg	Summer Flounder	Fillet	18	18	100%	150	66.8	125	67.1	348	--	--	NR
Metals	Mercury	µg/kg	Summer Flounder	Whole Body	8	8	100%	88.2	26.2	83.6	52.9	131	--	--	NR
Metals	Mercury	µg/kg	White Perch	Fillet	18	18	100%	269	85.2	255	133	430	--	--	NR
Metals	Mercury	µg/kg	White Perch	Liver	10	10	100%	201	41.5	194	141	282	--	--	NR
Metals	Mercury	µg/kg	White Perch	Whole Body	27	27	100%	127	53.7	113	63.9	287	--	--	NR
Metals	Mercury	µg/kg	Winter Flounder	Whole Body	10	10	100%	49	49.1	35.1	24.9	187	--	--	NR
Metals	Methyl mercury	µg/kg	American Eel	Fillet	18	18	100%	388	173	332	170	764	--	--	NR
Metals	Methyl mercury	µg/kg	American Eel	Whole Body	18	18	100%	203	85.4	183	77.8	400	--	--	NR
Metals	Methyl mercury	µg/kg	Bluefish	Fillet	18	18	100%	348	97	367	122	467	--	--	NR
Metals	Methyl mercury	µg/kg	Striped Bass	Fillet	16	16	100%	294	101	276	129	576	--	--	NR
Metals	Methyl mercury	µg/kg	Summer Flounder	Fillet	18	18	100%	180	79.2	158	65.9	400	--	--	NR
Metals	Methyl mercury	µg/kg	Summer Flounder	Whole Body	8	8	100%	95.1	27.3	99.5	39	127	--	--	NR
Metals	Methyl mercury	µg/kg	White Perch	Fillet	16	16	100%	352	139	342	153	657	--	--	NR
Metals	Methyl mercury	µg/kg	White Perch	Liver	10	10	100%	89.2	22.8	83.2	64.1	132	--	--	NR
Metals	Methyl mercury	µg/kg	White Perch	Whole Body	27	27	100%	148	64.4	130	83.4	338	--	--	NR
Metals	Methyl mercury	µg/kg	Winter Flounder	Whole Body	9	9	100%	31	9.35	28.8	21.3	51.6	--	--	NR

Table 4-28
Sport Fish Samples – By Species and Tissue Type

Analyte Group	Analyte	Units	Species	Tissue Type	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Metals	Nickel	mg/kg	American Eel	Fillet	18	1	6%	0.18	0.03	<0.387	0.2	0.2	0.27	0.4	NR
Metals	Nickel	mg/kg	American Eel	Whole Body	18	7	39%	0.332	0.28	<0.396	0.206	1.29	0.385	0.4	NR
Metals	Nickel	mg/kg	Bluefish	Fillet	18	0	0%	<0.35	--	<0.372	--	--	0.27	0.4	NR
Metals	Nickel	mg/kg	Striped Bass	Fillet	18	0	0%	<0.37	--	<0.388	--	--	0.27	0.4	NR
Metals	Nickel	mg/kg	Summer Flounder	Fillet	18	1	6%	0.203	0.07	<0.388	0.46	0.46	0.29	0.4	NR
Metals	Nickel	mg/kg	Summer Flounder	Whole Body	8	2	25%	0.248	0.142	<0.392	0.212	0.598	0.381	0.396	NR
Metals	Nickel	mg/kg	White Perch	Fillet	18	0	0%	<0.36	--	<0.357	--	--	0.31	0.4	NR
Metals	Nickel	mg/kg	White Perch	Liver	10	2	20%	1.73	2.99	<1.5	0.18	0.22	0.38	20	NR
Metals	Nickel	mg/kg	White Perch	Whole Body	27	2	7%	0.225	0.11	<0.392	0.512	0.685	0.381	0.4	NR
Metals	Nickel	mg/kg	Winter Flounder	Whole Body	10	8	80%	0.221	0.042	0.229	0.187	0.32	0.381	0.385	NR
Metals	Selenium	mg/kg	American Eel	Fillet	18	18	100%	0.465	0.12	0.445	0.34	0.85	--	--	NR
Metals	Selenium	mg/kg	American Eel	Whole Body	18	18	100%	0.811	0.41	0.632	0.467	1.83	--	--	NR
Metals	Selenium	mg/kg	Bluefish	Fillet	18	18	100%	0.505	0.08	0.489	0.33	0.68	--	--	NR
Metals	Selenium	mg/kg	Striped Bass	Fillet	18	18	100%	0.359	0.05	0.354	0.27	0.44	--	--	NR
Metals	Selenium	mg/kg	Summer Flounder	Fillet	18	18	100%	0.599	0.11	0.576	0.43	0.82	--	--	NR
Metals	Selenium	mg/kg	Summer Flounder	Whole Body	8	8	100%	0.461	0.0696	0.445	0.402	0.61	--	--	NR
Metals	Selenium	mg/kg	White Perch	Fillet	18	18	100%	0.61	0.1	0.6	0.48	0.81	--	--	NR
Metals	Selenium	mg/kg	White Perch	Liver	10	10	100%	51.8	55.4	36.5	15.6	204	--	--	NR
Metals	Selenium	mg/kg	White Perch	Whole Body	27	27	100%	1.18	0.403	0.943	0.754	2.04	--	--	NR
Metals	Selenium	mg/kg	Winter Flounder	Whole Body	10	10	100%	0.576	0.102	0.573	0.423	0.701	--	--	NR
Metals	Silver	mg/kg	American Eel	Fillet	18	0	0%	<0.09	--	<0.0976	--	--	0.07	0.1	NR
Metals	Silver	mg/kg	American Eel	Whole Body	18	13	72%	0.034	0.013	0.0267	0.02	0.0475	0.0971	0.1	NR
Metals	Silver	mg/kg	Bluefish	Fillet	18	0	0%	<0.0874	--	<0.093	--	--	0.07	0.1	NR
Metals	Silver	mg/kg	Striped Bass	Fillet	18	0	0%	<0.0922	--	<0.0971	--	--	0.07	0.1	NR
Metals	Silver	mg/kg	Summer Flounder	Fillet	18	0	0%	<0.0944	--	<0.0971	--	--	0.07	0.1	NR
Metals	Silver	mg/kg	Summer Flounder	Whole Body	8	1	13%	0.0452	0.00941	<0.0971	0.022	0.022	0.0952	0.099	NR
Metals	Silver	mg/kg	White Perch	Fillet	18	0	0%	<0.0898	--	<0.0893	--	--	0.08	0.1	NR
Metals	Silver	mg/kg	White Perch	Liver	10	10	100%	43.6	42.7	28.8	12	159	--	--	NR
Metals	Silver	mg/kg	White Perch	Whole Body	27	27	100%	0.287	0.224	0.179	0.0591	0.889	--	--	NR
Metals	Silver	mg/kg	Winter Flounder	Whole Body	10	3	30%	0.0407	0.0123	<0.0957	0.022	0.0235	0.0952	0.099	NR
Metals	Zinc	mg/kg	American Eel	Fillet	18	18	100%	26.4	7.18	25.2	15.3	43.1	--	--	NR
Metals	Zinc	mg/kg	American Eel	Whole Body	18	18	100%	31.4	4.71	31.4	25.1	40.5	--	--	NR
Metals	Zinc	mg/kg	Bluefish	Fillet	18	18	100%	16.5	2.23	16.6	13.1	21.4	--	--	NR
Metals	Zinc	mg/kg	Striped Bass	Fillet	18	18	100%	6.72	1.35	6.51	4.76	10.7	--	--	NR
Metals	Zinc	mg/kg	Summer Flounder	Fillet	18	18	100%	6.39	1.1	6.68	4.47	7.93	--	--	NR
Metals	Zinc	mg/kg	Summer Flounder	Whole Body	8	8	100%	18.1	5.31	18.8	10.6	27.1	--	--	NR
Metals	Zinc	mg/kg	White Perch	Fillet	18	18	100%	11.2	3.11	11	6.87	18.7	--	--	NR
Metals	Zinc	mg/kg	White Perch	Liver	10	10	100%	113	105	83.9	48.8	405	--	--	NR
Metals	Zinc	mg/kg	White Perch	Whole Body	27	27	100%	26.2	6.2	26.2	16.6	41.8	--	--	NR
Metals	Zinc	mg/kg	Winter Flounder	Whole Body	10	10	100%	24.9	5.41	25.4	18.1	31	--	--	NR

Table 4-28
Sport Fish Samples – By Species and Tissue Type

Notes:
Non-detects included at the 1/2 quantitation limit for mean and standard deviation estimates.
Non-detects evaluated at full quantitation limit for median estimate. If the median is a non-detect, it is indicated by the "less than" symbol (<).
When all data are reported as non-detect, the calculated mean and standard deviation are calculated using the full quantitation limit; a “less than” symbol (<) was assigned to the mean to indicate all values are below the quantitation limit.
Lipid-normalized results are calculated as the wet weight concentration divided by the fraction lipids.
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Acronyms and Abbreviations:
< = indicates the median is a non-detect or that the mean was calculated using all non-detects reported at the quantitation limit
-- = Not reported due to frequency of detection
% = percent
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligram per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/kg = nanogram per kilogram
NR = not reported for metals or lipids
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
µg/kg = microgram per kilogram

Table 4-29
Whole Body American Eel Spatial Comparison

Analyte Group	Analyte	NBSA BERA Assessment Zone	Frequency of Detection	Arithmetic Mean	Geometric Mean	Units	p-value ANOVA[a]	Tukey-Kramer Pairwise Difference[a]	p-value ANCOVA[b]	Tukey-Kramer Pairwise Difference[b]
Dioxins/ Furans	2,3,7,8-TCDD	North	6/6 (100%)	7.45	6.68	ng/kg	0.211	--	**0.0005**	A
		Southeast	6/6 (100%)	4.2	3.58	ng/kg		--		B
		Southwest	6/6 (100%)	5.06	3.8	ng/kg		--		B
PCBs	Total PCB congeners	North	6/6 (100%)	617,000	614,000	ng/kg	0.699	--	0.322	--
		Southeast	6/6 (100%)	490,000	454,000	ng/kg		--		--
		Southwest	6/6 (100%)	704,000	517,000	ng/kg		--		--
Pesticides	alpha-BHC	North	6/6 (100%)	54.6	51.6	ng/kg	0.710[d]	--	0.557	--
		Southeast	6/6 (100%)	76.8	66	ng/kg		--		--
		Southwest	4/5 (80%)	68.6	49	ng/kg		--		--
	beta-BHC	North	5/6 (83%)	69	53.7	ng/kg	0.916	--	0.600	--
		Southeast	6/6 (100%)	63.7	56.2	ng/kg		--		--
		Southwest	6/6 (100%)	85.6	64	ng/kg		--		--
	cis-Nonachlor	North	6/6 (100%)	9,890	9,660	ng/kg	0.273	--	0.235	--
		Southeast	6/6 (100%)	9,040	8,950	ng/kg		--		--
		Southwest	6/6 (100%)	7,690	6,920	ng/kg		--		--
	Dieldrin	North	6/6 (100%)	9,170	8,220	ng/kg	0.958	--	0.941	--
		Southeast	6/6 (100%)	9,310	9,010	ng/kg		--		--
		Southwest	6/6 (100%)	10,800	8,750	ng/kg		--		--
	Heptachlor epoxide	North	6/6 (100%)	2,670	2,480	ng/kg	0.326	--	**0.048**	A
		Southeast	6/6 (100%)	1,730	1,620	ng/kg		--		B
		Southwest	6/6 (100%)	2,070	1,610	ng/kg		--		AB
	Hexachlorobenzene	North	6/6 (100%)	3,670	3,560	ng/kg	0.072	--	**0.012**	A
		Southeast	6/6 (100%)	2,210	2,120	ng/kg		--		B
		Southwest	6/6 (100%)	3,370	3,080	ng/kg		--		AB
	Total Chlordane (alpha + gamma)	North	6/6 (100%)	16,300	15,900	ng/kg	0.143[d]	--	**0.003**	A
		Southeast	6/6 (100%)	15,300	13,700	ng/kg		--		A
		Southwest	6/6 (100%)	8,980	5,810	ng/kg		--		B
	Total DDx (2,4' & 4,4') (ND=0)	North	6/6 (100%)	182,000	180,000	ng/kg	**0.003**	B	**0.001**	B
		Southeast	6/6 (100%)	203,000	188,000	ng/kg		B		B
		Southwest	6/6 (100%)	383,000	368,000	ng/kg		A		A

Table 4-29
Whole Body American Eel Spatial Comparison

Analyte Group	Analyte	NBSA BERA Assessment Zone	Frequency of Detection	Arithmetic Mean	Geometric Mean	Units	p-value ANOVA[a]	Tukey-Kramer Pairwise Difference[a]	p-value ANCOVA[b]	Tukey-Kramer Pairwise Difference[b]
PAHs	Total LMW PAHs	North	6/6 (100%)	18	16.2	µg/kg	**0.005**[d]	AB	**0.005**[c]	AB
		Southeast	6/6 (100%)	7.62	7.52	µg/kg		B		B
		Southwest	5/6 (83%)	58.2	40.3	µg/kg		A		A
	Total PAH	North	6/6 (100%)	19.9	17.4	µg/kg	**0.004**[d]	AB	**0.002**[c]	AB
		Southeast	6/6 (100%)	8.28	7.96	µg/kg		B		B
		Southwest	5/6 (83%)	67.3	48.5	µg/kg		A		A
Metals	Arsenic	North	6/6 (100%)	0.784	0.734	mg/kg	0.218	--	**NA**	**NA**
		Southeast	6/6 (100%)	0.953	0.923	mg/kg		--		
		Southwest	6/6 (100%)	0.689	0.668	mg/kg		--		
	Copper	North	6/6 (100%)	0.75	0.741	mg/kg	0.408	--	**NA**	**NA**
		Southeast	6/6 (100%)	0.748	0.743	mg/kg		--		
		Southwest	6/6 (100%)	1.12	0.944	mg/kg		--		
	Lead	North	5/6 (83%)	0.246	0.205	mg/kg	0.813	--	**NA**	**NA**
		Southeast	6/6 (100%)	0.182	0.163	mg/kg		--		
		Southwest	6/6 (100%)	0.265	0.204	mg/kg		--		
	Mercury	North	6/6 (100%)	223	187	µg/kg	0.741	--	**NA**	**NA**
		Southeast	6/6 (100%)	153	148	µg/kg		--		
		Southwest	6/6 (100%)	170	152	µg/kg		--		
	Methyl mercury	North	6/6 (100%)	268	252	µg/kg	0.079	--	**NA**	**NA**
		Southeast	6/6 (100%)	155	151	µg/kg		--		
		Southwest	6/6 (100%)	185	171	µg/kg		--		
	Selenium	North	6/6 (100%)	0.613	0.611	mg/kg	**0.003**[d]	B	**NA**	**NA**
		Southeast	6/6 (100%)	1.26	1.21	mg/kg		A		
		Southwest	6/6 (100%)	0.557	0.55	mg/kg		B		
	Zinc	North	6/6 (100%)	31	30.7	mg/kg	0.984	--	**NA**	**NA**
		Southeast	6/6 (100%)	31.5	31.2	mg/kg		--		
		Southwest	6/6 (100%)	31.6	31.1	mg/kg		--		

Table 4-29
Whole Body American Eel Spatial Comparison

Notes:

[a]The ANOVA model tests if concentration is dependent upon assessment zone. The p-value for the significance of the F statisic is shown. Values that are significant at α = 0.05 are shaded and bolded. Modeling and post hoc testing (Tukey-Kramer method for unbalanced design) was conducted on natural log-transformed data. Letters (A, B, etc.) are assigned by concentration with letter A representing the highest mean concentration. BERA assessment zones that do not share a letter are significantly different (α = 0.05). Those that share a letter are not significantly different. If Levene's test is significant and the group standard deviations differ by more than a factor of two, the p-value is reported for the Welch ANOVA test which is robust to the equal variance assumption.

[b]The ANCOVA model tests if concentration is dependent upon assessment zone while controlling for lipid content which is added as a covariate to the model. The p-value for the significance of the assessment zone in the model is shown. Values that are significant at α = 0.05 are shown in bold. Modeling and post hoc testing was conducted on natural log-transformed data. The ANCOVA model was not conducted for metals concentrations.

[c]The lipid covariate was not marginally significant (α= 0.05) when added to the model, an indication that the assessment zone explains the majority of the variance in concentrations.

[d]The reported p-value is based on the Welch ANOVA test (see also note a).

Non-detects included at the 1/2 quantitation limit.
The following analytes were not evaluated due to low frequency of detection: Total Alkylated PAHs, Total HMW PAHs, bis(2-Ethylhexyl)phthalate, cadmium, chromium, nickel, and silver.

A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.
BERA assessment zones are depicted in Figure 4-35.

Acronyms and Abbreviations:

-- Not statistically significant at alpha = 0.05.
% = percent
ANOVA = analysis of variance
ANCOVA = analysis of covariance
BERA = Baseline Ecological Risk Assessment
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
ng/kg = nanograms per kilogram
(ND=0) = Only detected isomers were included in the summation
NA = Not applicable
NBSA = Newark Bay Study Area
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
TCDD = tetrachlorodibenzo-p-dioxin
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
µg/kg = micrograms per kilogram

Table 4-30
Whole Body Flounder Spatial Comparison

Analyte Group	Analyte	NBSA BERA Assessment Zone	Frequency of Detection	Arithmetic Mean	Geometric Mean	Units	p-value ANOVA[a]	Tukey-Kramer Pairwise Difference[a]	p-value ANCOVA[bc]
Dioxins/ Furans	2,3,7,8-TCDD	North	6/6 (100%)	8.75	8.01	ng/kg	**0.004**	A	**0.006[c]**
		Southeast	6/6 (100%)	4.9	4.14	ng/kg		AB	
		Southwest	6/6 (100%)	2.73	2.62	ng/kg		B	
PCBs	Total PCB congeners	North	6/6 (100%)	282,000	233,000	ng/kg	0.298	--	0.259
		Southeast	6/6 (100%)	154,000	151,000	ng/kg		--	
		Southwest	6/6 (100%)	187,000	170,000	ng/kg		--	
Pesticides	alpha-BHC	North	6/6 (100%)	17.7	16.1	ng/kg	0.888	--	0.587
		Southeast	6/6 (100%)	20.1	18.3	ng/kg		--	
		Southwest	5/6 (83%)	21.3	18.4	ng/kg		--	
	beta-BHC	North	5/6 (83%)	13.4	13.2	ng/kg	0.855	--	0.888
		Southeast	5/6 (83%)	12.5	12	ng/kg		--	
		Southwest	6/6 (100%)	13	11.7	ng/kg		--	
	cis-Nonachlor	North	6/6 (100%)	1,490	1,450	ng/kg	0.191	--	0.219
		Southeast	6/6 (100%)	1,280	1,230	ng/kg		--	
		Southwest	6/6 (100%)	998	794	ng/kg		--	
	Dieldrin	North	6/6 (100%)	1,850	1,680	ng/kg	0.265	--	0.334
		Southeast	6/6 (100%)	1,420	1,300	ng/kg		--	
		Southwest	6/6 (100%)	1,220	874	ng/kg		--	
	Heptachlor epoxide	North	6/6 (100%)	458	393	ng/kg	0.492	--	0.605
		Southeast	6/6 (100%)	355	285	ng/kg		--	
		Southwest	6/6 (100%)	306	230	ng/kg		--	
	Hexachlorobenzene	North	6/6 (100%)	948	772	ng/kg	0.081	--	0.119
		Southeast	6/6 (100%)	461	406	ng/kg		--	
		Southwest	6/6 (100%)	351	298	ng/kg		--	
	Total Chlordane (alpha + gamma)	North	6/6 (100%)	5,120	4,380	ng/kg	0.229	--	0.268
		Southeast	6/6 (100%)	4,810	4,280	ng/kg		--	
		Southwest	6/6 (100%)	3,120	2,040	ng/kg		--	
	Total DDx (2,4' & 4,4') (ND=0)	North	6/6 (100%)	31,200	29,900	ng/kg	0.510	--	0.547
		Southeast	6/6 (100%)	29,500	28,000	ng/kg		--	
		Southwest	6/6 (100%)	26,400	20,700	ng/kg		--	
Metals	Arsenic	North	6/6 (100%)	1.4	1.27	mg/kg	0.139	--	**NA**
		Southeast	6/6 (100%)	1.74	1.67	mg/kg		--	
		Southwest	6/6 (100%)	1.96	1.95	mg/kg		--	
	Chromium	North	5/6 (83%)	0.38	0.34	mg/kg	0.233	--	**NA**
		Southeast	4/6 (67%)	0.28	0.26	mg/kg		--	
		Southwest	5/6 (83%)	0.22	0.21	mg/kg		--	
	Copper	North	6/6 (100%)	1.15	1.06	mg/kg	0.192	--	**NA**
		Southeast	6/6 (100%)	0.92	0.9	mg/kg		--	
		Southwest	5/6 (83%)	0.71	0.64	mg/kg		--	
	Lead	North	6/6 (100%)	0.64	0.33	mg/kg	0.385	--	**NA**
		Southeast	6/6 (100%)	0.31	0.22	mg/kg		--	
		Southwest	4/6 (67%)	0.17	0.12	mg/kg		--	
	Mercury	North	6/6 (100%)	60.4	51.4	µg/kg	0.933	--	**NA**
		Southeast	6/6 (100%)	71.2	55.2	µg/kg		--	
		Southwest	6/6 (100%)	67.7	59.2	µg/kg		--	
	Methyl mercury	North	5/5 (100%)	65.6	52.8	µg/kg	0.353	--	**NA**
		Southeast	6/6 (100%)	43.7	37.4	µg/kg		--	
		Southwest	6/6 (100%)	74.9	65.1	µg/kg		--	
	Selenium	North	6/6 (100%)	0.57	0.56	mg/kg	0.145	--	**NA**
		Southeast	6/6 (100%)	0.55	0.54	mg/kg		--	
		Southwest	6/6 (100%)	0.46	0.45	mg/kg		--	
	Zinc	North	6/6 (100%)	23.6	22.2	mg/kg	0.437	--	**NA**
		Southeast	6/6 (100%)	23.1	22.7	mg/kg		--	
		Southwest	6/6 (100%)	18.9	18.3	mg/kg		--	

Table 4-30
Whole Body Flounder Spatial Comparison

Notes:

Flounder included both winter and summer flounder.

[a]The ANOVA model tests if concentration is dependent upon assessment zone. The p-value for the significance of the F statisic is shown. Values that are significant at α = 0.05 are shaded and bolded. Modeling and post hoc testing (Tukey-Kramer method for unbalanced design) was conducted on natural log-transformed data. Letters (A, B, etc.) are assigned by concentration with letter A representing the highest mean concentration. BERA assessment zones that do not share a letter are significantly different (α = 0.05). Those that share a letter are not significantly different.

[b]The ANCOVA model tests if concentration is dependent upon assessment zone while controlling for lipid content which is added as a covariate to the model. The p-value for the significance of the assessment zone in the model is shown. Values that are significant at α = 0.05 are shown in bold. Modeling and post hoc testing was conducted on natural log-transformed data. The ANCOVA model was not conducted for metals concentrations. Where significant, the ANCOVA model resulted in the same conclusions for the Tukey-Kramer pairwise differences as the ANOVA model.

[c]The lipid covariate was not marginally significant (α= 0.05) when added to the model, an indication that the assessment zone explains the majority of the variance in concentrations.

Non-detects included at the 1/2 quantitation limit.
The following analytes were not evaluated due to low frequency of detection: Total Alkylated PAHs, Total HMW PAHs, Total LMW PAHs, Total PAHs, bis(2-Ethylhexyl)phthalate, cadmium, nickel, and silver.

A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.
BERA assessment zones are depicted in Figure 4-35.

Acronyms and Abbreviations:

-- Not statistically significant at alpha = 0.05.
% = percent
ANOVA = analysis of variance
ANCOVA = analysis of covariance
BERA = Baseline Ecological Risk Assessment
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
ng/kg = nanograms per kilogram
(ND=0) = Only detected isomers were included in the summation
NA = Not applicable
NBSA = Newark Bay Study Area
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
TCDD = tetrachlorodibenzo-p-dioxin
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
µg/kg = micrograms per kilogram

Table 4-31
Whole Body White Perch Spatial Comparison

Analyte Group	Analyte	NBSA BERA Assessment Zone	Frequency of Detection	Arithmetic Mean	Geometric Mean	Units	p-value ANOVA[a]	Tukey-Kramer Pairwise Difference[a]	p-value ANCOVA[b]	Tukey-Kramer Pairwise Difference[b]
Dioxins/ Furans	2,3,7,8-TCDD	North	9/9 (100%)	85.2	68	ng/kg	**0.0002**	A	**0.00004**	A
		Southeast	9/9 (100%)	43.2	36.4	ng/kg		A		A
		Southwest	9/9 (100%)	17	10.4	ng/kg		B		B
PCBs	Total PCB congeners	North	9/9 (100%)	1,690,000	1,510,000	ng/kg	0.263	--	**0.023**	A
		Southeast	9/9 (100%)	1,140,000	1,080,000	ng/kg		--		A
		Southwest	9/9 (100%)	1,280,000	1,150,000	ng/kg		--		B
Pesticides	alpha-BHC	North	8/9 (89%)	121	68.2	ng/kg	**0.0004[d]**	B	**0.033**	B
		Southeast	8/8 (100%)	51.4	44.1	ng/kg		B		AB
		Southwest	9/9 (100%)	205	185	ng/kg		A		A
	beta-BHC	North	7/9 (78%)	62.6	43.7	ng/kg	**0.022**	AB	0.561	--
		Southeast	9/9 (100%)	31.2	27.7	ng/kg		B		--
		Southwest	8/9 (89%)	81.8	72.4	ng/kg		A		--
	cis-Nonachlor	North	9/9 (100%)	16,700	15,700	ng/kg	0.066	--	**0.025**	A
		Southeast	9/9 (100%)	11,400	11,000	ng/kg		--		AB
		Southwest	9/9 (100%)	14,500	14,100	ng/kg		--		B
	Dieldrin	North	9/9 (100%)	13,700	13,000	ng/kg	**0.001**	AB	0.139	--
		Southeast	9/9 (100%)	9,520	8,800	ng/kg		B		--
		Southwest	9/9 (100%)	19,700	18,500	ng/kg		A		--
	Heptachlor epoxide	North	9/9 (100%)	3,780	3,220	ng/kg	0.247	--	0.089	--
		Southeast	9/9 (100%)	2,970	2,380	ng/kg		--		--
		Southwest	9/9 (100%)	4,030	3,760	ng/kg		--		--
	Hexachlorobenzene	North	9/9 (100%)	2,960	2,640	ng/kg	0.064	--	**0.0005**	A
		Southeast	9/9 (100%)	2,070	1,860	ng/kg		--		A
		Southwest	9/9 (100%)	1,700	1,530	ng/kg		--		B
	Total Chlordane (alpha + gamma)	North	9/9 (100%)	66,300	60,100	ng/kg	0.197	--	**0.006**	A
		Southeast	9/9 (100%)	44,700	37,900	ng/kg		--		A
		Southwest	9/9 (100%)	45,400	39,800	ng/kg		--		B
	Total DDx (2,4' & 4,4') (ND=0)	North	9/9 (100%)	376,000	353,000	ng/kg	**0.002**	AB	0.160	--
		Southeast	9/9 (100%)	250,000	219,000	ng/kg		B		--
		Southwest	9/9 (100%)	627,000	557,000	ng/kg		A		--

Table 4-31
Whole Body White Perch Spatial Comparison

Analyte Group	Analyte	NBSA BERA Assessment Zone	Frequency of Detection	Arithmetic Mean	Geometric Mean	Units	p-value ANOVA[a]	Tukey-Kramer Pairwise Difference[a]	p-value ANCOVA[b]	Tukey-Kramer Pairwise Difference[b]
PAHs	Total LMW PAHs	North	9/9 (100%)	161	122	µg/kg	**<.0001**	A	**<.0001[c]**	A
		Southeast	3/9 (33%)	15.5	14.2	µg/kg		C		B
		Southwest	8/9 (89%)	52.4	43	µg/kg		B		B
	Total PAH	North	9/9 (100%)	168	127	µg/kg	**<.0001**	A	**<.0001[c]**	A
		Southeast	3/9 (33%)	15.5	14.2	µg/kg		C		B
		Southwest	8/9 (89%)	57.6	45.4	µg/kg		B		B
Metals	Arsenic	North	9/9 (100%)	0.412	0.409	mg/kg	**0.001**	B	**NA**	**NA**
		Southeast	9/9 (100%)	0.465	0.456	mg/kg		B		
		Southwest	9/9 (100%)	0.62	0.605	mg/kg		A		
	Chromium	North	7/9 (78%)	0.486	0.31	mg/kg	0.267	--	**NA**	**NA**
		Southeast	7/9 (78%)	0.315	0.264	mg/kg		--		
		Southwest	5/9 (56%)	0.225	0.181	mg/kg		--		
	Copper	North	9/9 (100%)	11.4	7.66	mg/kg	**0.001**	B	**NA**	**NA**
		Southeast	9/9 (100%)	7.9	6.38	mg/kg		B		
		Southwest	9/9 (100%)	27.4	25.5	mg/kg		A		
	Lead	North	8/9 (89%)	0.209	0.2	mg/kg	**0.001**	A	**NA**	**NA**
		Southeast	8/9 (89%)	0.214	0.206	mg/kg		A		
		Southwest	9/9 (100%)	0.117	0.111	µg/kg		B		
	Mercury	North	9/9 (100%)	124	113	µg/kg	0.714	--	**NA**	**NA**
		Southeast	9/9 (100%)	121	115	µg/kg		--		
		Southwest	9/9 (100%)	136	129	µg/kg		--		
	Methyl mercury	North	9/9 (100%)	178	162	µg/kg	0.233	--	**NA**	**NA**
		Southeast	9/9 (100%)	141	135	µg/kg		--		
		Southwest	9/9 (100%)	126	120	µg/kg		--		
	Selenium	North	9/9 (100%)	1.04	1	mg/kg	**0.0001**	B	**NA**	**NA**
		Southeast	9/9 (100%)	0.93	0.906	mg/kg		B		
		Southwest	9/9 (100%)	1.58	1.56	mg/kg		A		
	Silver	North	9/9 (100%)	0.209	0.157	mg/kg	**0.001**	B	**NA**	**NA**
		Southeast	9/9 (100%)	0.171	0.146	mg/kg		B		
		Southwest	9/9 (100%)	0.483	0.44	mg/kg		A		
	Zinc	North	9/9 (100%)	27.9	27.4	mg/kg	**0.0002**	A	**NA**	**NA**
		Southeast	9/9 (100%)	30.1	29.7	mg/kg		A		
		Southwest	9/9 (100%)	20.6	20.3	mg/kg		B		

Table 4-31
Whole Body White Perch Spatial Comparison

Notes:

[a]The ANOVA model tests if concentration is dependent upon assessment zone. The p-value for the significance of the F statisic is shown. Values that are significant at α = 0.05 are shaded and bolded. Modeling and post hoc testing (Tukey-Kramer method for unbalanced design) was conducted on natural log-transformed data. Letters (A, B, etc.) are assigned by concentration with letter A representing the highest mean concentration. BERA assessment zones that do not share a letter are significantly different (α = 0.05). Those that share a letter are not significantly different. If Levene's test is significant and the group standard deviations differ by more than a factor of two, the p-value is reported for the Welch ANOVA test which is robust to the equal variance assumption.

[b]The ANCOVA model tests if concentration is dependent upon assessment zone while controlling for lipid content which is added as a covariate to the model. The p-value for the significance of the assessment zone in the model is shown. Values that are significant at α = 0.05 are shown in bold. Modeling and post hoc testing was conducted on natural log-transformed data. The ANCOVA model was not conducted for metals concentrations.

[c]The lipid covariate was not marginally significant (α= 0.05) when added to the model, an indication that the assessment zone explains the majority of the variance in concentrations.

[d]The reported p-value is based on the Welch ANOVA test (see also note a).
Non-detects included at the 1/2 quantitation limit.
The following analytes were not evaluated due to low frequency of detection: Total Alkylated PAHs, Total HMW PAHs, bis(2-Ethylhexyl)phthalate, cadmium, and nickel.

A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.
BERA assessment zones are depicted in Figure 4-35.

Acronyms and Abbreviations:

< = less than
-- Not statistically significant at alpha = 0.05.
% = percent
ANOVA = analysis of variance
ANCOVA = analysis of covariance
BERA = Baseline Ecological Risk Assessment
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
ng/kg = nanograms per kilogram
(ND=0) = Only detected isomers were included in the summation
NA = Not applicable
NBSA = Newark Bay Study Area
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
TCDD = tetrachlorodibenzo-p-dioxin
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
µg/kg = micrograms per kilogram

Table 4-32
Whole Body Forage Fish Samples

Analyte Group	Analyte	Units	Species	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Atlantic Menhaden	2	2	100%	4.33	0.58	4.33	3.92	4.74	--	--	143
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Atlantic Silverside	7	7	100%	8.04	2.93	7.16	5.91	14.5	--	--	562
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Mummichog	4	4	100%	9.85	4.7	8.51	5.99	16.4	--	--	369
Dioxins/Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	ng/kg	Striped Killifish	13	13	100%	23.9	11.9	20.3	3.62	39.5	--	--	662
PCBs	Total PCBs (9)	µg/kg	Atlantic Menhaden	2	2	100%	400	99	400	330	470	--	--	11,200
PCBs	Total PCBs (9)	µg/kg	Atlantic Silverside	7	6	86%	442	349	330	190	1100	170	170	29,500
PCBs	Total PCBs (9)	µg/kg	Mummichog	4	4	100%	666	623	370	325	1600	--	--	20,300
PCBs	Total PCBs (9)	µg/kg	Striped Killifish	13	13	100%	1,300	727	1,300	480	2,900	--	--	35,500
PCBs	Total PCBs congener (209 specified)	ng/kg	Atlantic Menhaden	2	2	100%	533,000	120,000	533,000	448,000	617,000	--	--	15,000,000
PCBs	Total PCBs congener (209 specified)	ng/kg	Atlantic Silverside	7	7	100%	684,000	278,000	544,000	483,000	1,150,000	--	--	46,200,000
PCBs	Total PCBs congener (209 specified)	ng/kg	Mummichog	4	4	100%	1,180,000	1,460,000	545,000	275,000	3,370,000	--	--	34,100,000
PCBs	Total PCBs congener (209 specified)	ng/kg	Striped Killifish	13	13	100%	1,230,000	536,000	1,190,000	660,000	2,540,000	--	--	33,800,000
Pesticides	alpha-BHC	ng/kg	Atlantic Menhaden	2	2	100%	76.7	47.1	76.7	43.4	110	--	--	1,760
Pesticides	alpha-BHC	ng/kg	Atlantic Silverside	7	6	86%	18.6	5.31	18.2	13.8	25.9	29	29	1,290
Pesticides	alpha-BHC	ng/kg	Mummichog	4	1	25%	22	12.6	<34	40.5	40.5	27.2	38.8	720
Pesticides	alpha-BHC	ng/kg	Striped Killifish	13	9	69%	71.3	88	35.5	34.9	183	33.3	650	2,130
Pesticides	beta-BHC	ng/kg	Atlantic Menhaden	2	2	100%	107	57.8	107	66.2	148	--	--	2,570
Pesticides	beta-BHC	ng/kg	Atlantic Silverside	7	5	71%	26.1	18.1	21.4	14.9	27.7	40	132	1,930
Pesticides	beta-BHC	ng/kg	Mummichog	4	3	75%	39	17.8	44.6	28.9	57.4	38.8	38.8	1,330
Pesticides	beta-BHC	ng/kg	Striped Killifish	13	13	100%	138	232	64.4	41.1	885	--	--	4,260
Pesticides	cis-Nonachlor	ng/kg	Atlantic Menhaden	2	2	100%	3,840	1,510	3,840	2,770	4,900	--	--	99,500
Pesticides	cis-Nonachlor	ng/kg	Atlantic Silverside	7	7	100%	2,940	876	2,750	2,040	4,640	--	--	207,000
Pesticides	cis-Nonachlor	ng/kg	Mummichog	4	4	100%	2,610	1,060	2,430	1,610	3,990	--	--	93,000
Pesticides	cis-Nonachlor	ng/kg	Striped Killifish	13	13	100%	6,580	2,170	7,050	3,150	9,780	--	--	178,000
Pesticides	Dieldrin	ng/kg	Atlantic Menhaden	2	2	100%	6,110	3,460	6,110	3,660	8,550	--	--	144,000
Pesticides	Dieldrin	ng/kg	Atlantic Silverside	7	7	100%	2,000	487	1,880	1,310	2,780	--	--	140,000
Pesticides	Dieldrin	ng/kg	Mummichog	4	4	100%	5,280	2,070	4,720	3,540	8,170	--	--	190,000
Pesticides	Dieldrin	ng/kg	Striped Killifish	13	13	100%	8,700	2,080	8,930	5,120	11,500	--	--	240,000
Pesticides	Heptachlor epoxide	ng/kg	Atlantic Menhaden	2	2	100%	1,120	456	1,120	796	1,440	--	--	28,800
Pesticides	Heptachlor epoxide	ng/kg	Atlantic Silverside	7	7	100%	288	119	234	186	519	--	--	20,200
Pesticides	Heptachlor epoxide	ng/kg	Mummichog	4	4	100%	652	287	699	295	914	--	--	22,600
Pesticides	Heptachlor epoxide	ng/kg	Striped Killifish	13	13	100%	1,310	570	1360	563	2,500	--	--	35,200
Pesticides	Hexachlorobenzene	ng/kg	Atlantic Menhaden	2	2	100%	958	569	958	556	1,360	--	--	22,300
Pesticides	Hexachlorobenzene	ng/kg	Atlantic Silverside	7	7	100%	455	161	418	292	752	--	--	31,700
Pesticides	Hexachlorobenzene	ng/kg	Mummichog	4	4	100%	51.2	44.3	33.6	20.6	117	--	--	1,910
Pesticides	Hexachlorobenzene	ng/kg	Striped Killifish	13	13	100%	43.3	51.8	23.8	12.6	203	--	--	1,200
Pesticides	Total alpha + gamma chlordane	ng/kg	Atlantic Menhaden	2	2	100%	12,200	5,440	12,200	8,300	16,000	--	--	306,000
Pesticides	Total alpha + gamma chlordane	ng/kg	Atlantic Silverside	7	7	100%	3,060	1,020	2,800	2,000	4,800	--	--	213,000
Pesticides	Total alpha + gamma chlordane	ng/kg	Mummichog	4	4	100%	5,190	2,150	5,000	3,050	7,700	--	--	183,000
Pesticides	Total alpha + gamma chlordane	ng/kg	Striped Killifish	13	13	100%	17,000	8,820	13,000	6,800	33,000	--	--	474,000
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	ng/kg	Atlantic Menhaden	2	2	100%	223,000	124,000	223,000	135,000	310,000	--	--	5,290,000
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	ng/kg	Atlantic Silverside	7	7	100%	147,000	77,300	97,000	74,000	260,000	--	--	10,100,000
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	ng/kg	Mummichog	4	4	100%	226,000	175,000	235,000	42,500	390,000	--	--	7,490,000
Pesticides	Total DDx (2,4' & 4,4') Total Fraction (ND=0)	ng/kg	Striped Killifish	13	13	100%	250,000	118,000	210,000	150,000	510,000	--	--	7,000,000
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	ng/kg	Atlantic Menhaden	2	2	100%	170,000	84,900	170,000	110,000	230,000	--	--	4,170,000
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	ng/kg	Atlantic Silverside	7	7	100%	134,000	67,600	92,000	68,000	230,000	--	--	9,170,000

Table 4-32
Whole Body Forage Fish Samples

Analyte Group	Analyte	Units	Species	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	ng/kg	Mummichog	4	4	100%	218,000	167,000	230,000	41,500	370,000	--	--	7,260,000
Pesticides	Total DDx (4,4') Total Fraction (ND=0)	ng/kg	Striped Killifish	13	13	100%	218,000	97,200	190,000	130,000	440,000	--	--	6,080,000
PAHs	Total Alkylated PAHs	µg/kg	Atlantic Menhaden	2	2	100%	9.85	6.01	9.85	5.6	14.1	--	--	387
PAHs	Total Alkylated PAHs	µg/kg	Atlantic Silverside	7	0	0%	<14.12	--	<6.6	--	--	6.5	33	<918
PAHs	Total Alkylated PAHs	µg/kg	Mummichog	4	2	50%	9.19	8.85	7.4	8.2	22	6.5	6.6	281
PAHs	Total Alkylated PAHs	µg/kg	Striped Killifish	13	7	54%	9.24	6.43	7.7	4.6	20.9	6.6	32	245
PAHs	Total HMW PAHs	µg/kg	Atlantic Menhaden	2	2	100%	18	18.4	18	5	31	--	--	806
PAHs	Total HMW PAHs	µg/kg	Atlantic Silverside	7	3	43%	9.76	7.55	<6.6	2.9	20	6.5	33	669
PAHs	Total HMW PAHs	µg/kg	Mummichog	4	2	50%	9.24	6.89	10.2	3.4	13.8	6.6	33	302
PAHs	Total HMW PAHs	µg/kg	Striped Killifish	13	9	69%	24.4	28.4	7.1	2.7	87	6.6	32	690
PAHs	Total LMW PAHs	µg/kg	Atlantic Menhaden	2	2	100%	31.3	7.42	31.3	26	36.5	--	--	1,070
PAHs	Total LMW PAHs	µg/kg	Atlantic Silverside	7	1	14%	7.17	6.38	<6.6	4	4	6.5	33	466
PAHs	Total LMW PAHs	µg/kg	Mummichog	4	3	75%	9.75	7.85	9.85	2.8	16.6	33	33	322
PAHs	Total LMW PAHs	µg/kg	Striped Killifish	13	11	85%	21	27	8.7	3.5	85	6.6	32	585
PAHs	Total PAH	µg/kg	Atlantic Menhaden	2	2	100%	49.3	25.8	49.3	31	67.5	--	--	1,880
PAHs	Total PAH	µg/kg	Atlantic Silverside	7	4	57%	9.87	7.44	6.6	2.9	20	6.6	33	676
PAHs	Total PAH	µg/kg	Mummichog	4	3	75%	14.1	12.4	18.5	2.8	30.5	33	33	493
PAHs	Total PAH	µg/kg	Striped Killifish	13	11	85%	43.1	54.1	20	4.7	170	6.6	32	1210
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Atlantic Menhaden	2	0	0%	<3400	--	<3400	--	--	3400	3400	<106000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Atlantic Silverside	7	0	0%	<2960	--	<3300	--	--	670	3400	<202000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Mummichog	4	0	0%	<3360	--	<3350	--	--	3300	3400	<120000
Semivolatiles	bis(2-Ethylhexyl)phthalate	µg/kg	Striped Killifish	13	0	0%	<2940	--	<3300	--	--	660	3400	<79400
Lipids	Lipids	%	Atlantic Menhaden	2	2	100%	5.05	4.31	5.05	2	8.1	--	--	NR
Lipids	Lipids	%	Atlantic Silverside	7	7	100%	1.46	0.207	1.4	1.2	1.7	--	--	NR
Lipids	Lipids	%	Mummichog	4	4	100%	2.91	0.792	2.53	2.5	4.1	--	--	NR
Lipids	Lipids	%	Striped Killifish	13	13	100%	3.74	0.676	3.6	2.9	4.9	--	--	NR
Metals	Arsenic	mg/kg	Atlantic Menhaden	2	2	100%	0.907	0.428	0.907	0.605	1.21	--	--	NR
Metals	Arsenic	mg/kg	Atlantic Silverside	7	7	100%	0.564	0.176	0.597	0.33	0.846	--	--	NR
Metals	Arsenic	mg/kg	Mummichog	4	4	100%	0.597	0.0912	0.592	0.49	0.713	--	--	NR
Metals	Arsenic	mg/kg	Striped Killifish	13	13	100%	0.996	0.465	0.904	0.535	2.36	--	--	NR
Metals	Cadmium	mg/kg	Atlantic Menhaden	2	0	0%	<0.0976	--	<0.0976	--	--	0.0971	0.098	NR
Metals	Cadmium	mg/kg	Atlantic Silverside	7	0	0%	<0.0984	--	<0.099	--	--	0.0962	0.1	NR
Metals	Cadmium	mg/kg	Mummichog	4	0	0%	<0.098	--	<0.098	--	--	0.0962	0.1	NR
Metals	Cadmium	mg/kg	Striped Killifish	13	0	0%	<0.0986	--	<0.099	--	--	0.0962	0.1	NR
Metals	Chromium	mg/kg	Atlantic Menhaden	2	2	100%	0.245	0.136	0.245	0.148	0.341	--	--	NR
Metals	Chromium	mg/kg	Atlantic Silverside	7	4	57%	0.203	0.0529	0.297	0.115	0.297	0.385	0.4	NR
Metals	Chromium	mg/kg	Mummichog	4	3	75%	0.441	0.41	0.4	0.13	1.03	0.392	0.392	NR
Metals	Chromium	mg/kg	Striped Killifish	13	12	92%	0.458	0.264	0.407	0.306	1.24	0.4	0.4	NR
Metals	Copper	mg/kg	Atlantic Menhaden	2	2	100%	0.905	0.276	0.905	0.709	1.1	--	--	NR
Metals	Copper	mg/kg	Atlantic Silverside	7	6	86%	0.806	0.325	0.804	0.651	1.21	0.396	0.396	NR
Metals	Copper	mg/kg	Mummichog	4	4	100%	4.54	0.51	4.71	3.81	4.95	--	--	NR
Metals	Copper	mg/kg	Striped Killifish	13	13	100%	3.58	3.34	2.98	1.7	14.5	--	--	NR
Metals	Lead	mg/kg	Atlantic Menhaden	2	2	100%	0.383	0.198	0.383	0.243	0.524	--	--	NR
Metals	Lead	mg/kg	Atlantic Silverside	7	7	100%	0.277	0.121	0.279	0.124	0.426	--	--	NR
Metals	Lead	mg/kg	Mummichog	4	4	100%	0.816	0.662	0.585	0.306	1.79	--	--	NR
Metals	Lead	mg/kg	Striped Killifish	13	12	92%	0.546	0.292	0.485	0.29	1.06	0.2	0.2	NR

Table 4-32
Whole Body Forage Fish Samples

Analyte Group	Analyte	Units	Species	Number of Samples	Number of Detects	Frequency of Detection	Arithmetic Mean	Standard Deviation	Median	Minimum Detect	Maximum Detect	Minimum Non-detect	Maximum Non-detect	Lipid-Normalized Mean
Metals	Mercury	µg/kg	Atlantic Menhaden	2	2	100%	53.7	7.81	53.7	48.2	59.2	--	--	NR
Metals	Mercury	µg/kg	Atlantic Silverside	7	7	100%	65.1	11.9	68.3	53	85.1	--	--	NR
Metals	Mercury	µg/kg	Mummichog	4	4	100%	42.9	17.1	37.1	29.7	67.6	--	--	NR
Metals	Mercury	µg/kg	Striped Killifish	13	13	100%	39.3	21.4	32.3	16.6	98.2	--	--	NR
Metals	Methyl mercury	µg/kg	Atlantic Menhaden	2	2	100%	83.1	26.8	83.1	64.2	102	--	--	NR
Metals	Methyl mercury	µg/kg	Atlantic Silverside	7	7	100%	111	40.4	110	62.7	176	--	--	NR
Metals	Methyl mercury	µg/kg	Mummichog	4	4	100%	50.8	6.45	47.9	47.1	60.5	--	--	NR
Metals	Methyl mercury	µg/kg	Striped Killifish	13	13	100%	42.7	28.6	39.2	11.3	128	--	--	NR
Metals	Nickel	mg/kg	Atlantic Menhaden	2	0	0%	<0.39	--	<0.39	--	--	0.388	0.392	NR
Metals	Nickel	mg/kg	Atlantic Silverside	7	0	0%	<0.394	--	<0.396	--	--	0.385	0.4	NR
Metals	Nickel	mg/kg	Mummichog	4	1	25%	0.254	0.114	<0.396	0.425	0.425	0.392	0.4	NR
Metals	Nickel	mg/kg	Striped Killifish	13	6	46%	0.384	0.248	<0.4	0.42	0.921	0.385	0.4	NR
Metals	Selenium	mg/kg	Atlantic Menhaden	2	2	100%	0.466	0.017	0.466	0.454	0.478	--	--	NR
Metals	Selenium	mg/kg	Atlantic Silverside	7	7	100%	0.503	0.0737	0.49	0.413	0.645	--	--	NR
Metals	Selenium	mg/kg	Mummichog	4	4	100%	0.541	0.104	0.569	0.392	0.633	--	--	NR
Metals	Selenium	mg/kg	Striped Killifish	13	13	100%	0.738	0.102	0.732	0.575	0.975	--	--	NR
Metals	Silver	mg/kg	Atlantic Menhaden	2	0	0%	<0.0976	--	<0.0976	--	--	0.0971	0.098	NR
Metals	Silver	mg/kg	Atlantic Silverside	7	1	14%	0.0453	0.0105	<0.099	0.0216	0.0216	0.0962	0.1	NR
Metals	Silver	mg/kg	Mummichog	4	4	100%	0.0583	0.0118	0.0575	0.0475	0.0709	--	--	NR
Metals	Silver	mg/kg	Striped Killifish	13	13	100%	0.0786	0.0877	0.0584	0.0233	0.364	--	--	NR
Metals	Zinc	mg/kg	Atlantic Menhaden	2	2	100%	15.8	3.64	15.8	13.2	18.4	--	--	NR
Metals	Zinc	mg/kg	Atlantic Silverside	7	7	100%	40	3.9	39.3	34.9	46.7	--	--	NR
Metals	Zinc	mg/kg	Mummichog	4	4	100%	66.6	6.04	67.5	58.8	72.7	--	--	NR
Metals	Zinc	mg/kg	Striped Killifish	13	13	100%	37.8	6.7	37.3	23.5	50.9	--	--	NR

Notes:
Non-detects included at the 1/2 quantitation limit for mean and standard deviation estimates.
Non-detects evaluated at full quantitation limit for median estimate. If the median is a non-detect, it is indicated by the "less than" symbol (<).
When all data are reported as non-detect, the calculated mean and standard deviation are calculated using the full quantitation limit; a “less than” symbol (<) was assigned to the mean to indicate all values are below the quantitation
Lipid-normalized results are calculated as the wet weight concentration divided by the fraction lipids.
A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.

Acronyms and Abbreviations:
< = indicates the median is a non-detect or that the mean was calculated using all non-detects reported at the quantitation limit
-- = Not reported due to frequency of detection
% = percent
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligram per kilogram
(ND=0) = Only detected isomers were included in the summation
ng/kg = nanogram per kilogram
NR = not reported for metals or lipids
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
µg/kg = microgram per kilogram

Table 4-33
Whole Body *Fundulus* spp. Spatial Comparison

Analyte Group	Analyte	NBSA BERA Assessment Zone	Frequency of Detection	Arithmetic Mean	Geometric Mean	Units	p-value ANOVA[a]	Tukey-Kramer Pairwise Difference[a]	p-value ANCOVA[b]	Tukey-Kramer Pairwise Difference[b]
Dioxins/ Furans	2,3,7,8-TCDD	North	8/8 (100%)	29.5	27	ng/kg	**0.0086**	A	**0.007[c]**	A
		Southeast	3/3 (100%)	16	16	ng/kg		AB		AB
		Southwest	6/6 (100%)	11	9.31	ng/kg		B		B
PCBs	Total PCB congeners	North	8/8 (100%)	1,200,000	986,000	ng/kg	0.428	--	**0.019**	A
		Southeast	3/3 (100%)	724,000	719,000	ng/kg		--		B
		Southwest	6/6 (100%)	1,480,000	1,280,000	ng/kg		--		A
Pesticides	beta-BHC	North	7/8 (88%)	54.7	50.8	ng/kg	0.227	--	0.225	--
		Southeast	3/3 (100%)	50.6	49.7	ng/kg		--		--
		Southwest	6/6 (100%)	227	108	ng/kg		--		--
	cis-Nonachlor	North	8/8 (100%)	6,780	6,030	ng/kg	0.080	--	**0.049**	A
		Southeast	3/3 (100%)	6,840	6,590	ng/kg		--		AB
		Southwest	6/6 (100%)	3,530	3,380	ng/kg		--		B
	Dieldrin	North	8/8 (100%)	9,140	8,670	ng/kg	**0.030**	A	**0.036[c]**	A
		Southeast	3/3 (100%)	9,070	9,070	ng/kg		AB		AB
		Southwest	6/6 (100%)	5,660	5,570	ng/kg		B		B
	Heptachlor epoxide	North	8/8 (100%)	1,250	1,180	ng/kg	0.206	--	0.146	--
		Southeast	3/3 (100%)	1,350	1,290	ng/kg		--		--
		Southwest	6/6 (100%)	925	735	ng/kg		--		--
	Hexachlorobenzene	North	8/8 (100%)	40	31	ng/kg	0.868	--	0.9109	--
		Southeast	3/3 (100%)	36	28	ng/kg		--		--
		Southwest	6/6 (100%)	56	37	ng/kg		--		--
	Total Chlordane (alpha + gamma)	North	8/8 (100%)	15,200	12,100	ng/kg	0.830	--	0.858	--
		Southeast	3/3 (100%)	16,900	13,500	ng/kg		--		--
		Southwest	6/6 (100%)	11,700	10,100	ng/kg		--		--
	Total DDx (2,4' & 4,4') (ND=0)	North	8/8 (100%)	164,000	148,000	ng/kg	**0.004**	B	**0.0011[c]**	B
		Southeast	3/3 (100%)	173,000	171,000	ng/kg		AB		B
		Southwest	6/6 (100%)	387,000	376,000	ng/kg		A		A

Table 4-33
Whole Body *Fundulus* spp. Spatial Comparison

Analyte Group	Analyte	NBSA BERA Assessment Zone	Frequency of Detection	Arithmetic Mean	Geometric Mean	Units	p-value ANOVA[a]	Tukey-Kramer Pairwise Difference[a]	p-value ANCOVA[b]	Tukey-Kramer Pairwise Difference[b]
PAHs	Total LMW PAHs	North	8/8 (100%)	18.1	10.1	µg/kg	0.439	--	0.132	--
		Southeast	2/3 (67%)	6.93	5.45	µg/kg		--		--
		Southwest	4/6 (67%)	24.5	14.6	µg/kg		--		--
	Total PAH	North	8/8 (100%)	40.6	21.6	µg/kg	0.426	--	0.184	--
		Southeast	2/3 (67%)	9.83	7.42	µg/kg		--		--
		Southwest	4/6 (67%)	43.7	21.1	µg/kg		--		--
Metals	Arsenic	North	8/8 (100%)	0.92	0.82	mg/kg	0.713	--	NA	NA
		Southeast	3/3 (100%)	0.73	0.73	mg/kg		--		
		Southwest	6/6 (100%)	0.97	0.92	mg/kg		--		
	Chromium	North	7/8 (88%)	0.57	0.48	mg/kg	0.368	--	NA	NA
		Southeast	3/3 (100%)	0.34	0.34	mg/kg		--		
		Southwest	5/6 (83%)	0.35	0.32	mg/kg		--		
	Copper	North	8/8 (100%)	4.75	3.84	mg/kg	0.398	--	NA	NA
		Southeast	3/3 (100%)	2.5	2.43	mg/kg		--		
		Southwest	6/6 (100%)	3.19	3.05	mg/kg		--		
	Lead	North	7/8 (88%)	0.65	0.49	mg/kg	0.655	--	NA	NA
		Southeast	3/3 (100%)	0.4	0.39	mg/kg		--		
		Southwest	6/6 (100%)	0.66	0.6	µg/kg		--		
	Mercury	North	8/8 (100%)	51.8	47.6	µg/kg	**0.039**	A	NA	NA
		Southeast	3/3 (100%)	29.5	29.4	µg/kg		AB		
		Southwest	6/6 (100%)	30	29	µg/kg		B		
	Methyl mercury	North	8/8 (100%)	54.1	49	µg/kg	0.216	--	NA	NA
		Southeast	3/3 (100%)	39	38.8	µg/kg		--		
		Southwest	6/6 (100%)	34.7	28.8	µg/kg		--		
	Selenium	North	8/8 (100%)	0.68	0.67	mg/kg	0.6578	--	NA	NA
		Southeast	3/3 (100%)	0.63	0.63	mg/kg		--		
		Southwest	6/6 (100%)	0.73	0.72	mg/kg		--		
	Silver	North	8/8 (100%)	0.1	0.08	mg/kg	0.123	--	NA	NA
		Southeast	3/3 (100%)	0.04	0.04	mg/kg		--		
		Southwest	6/6 (100%)	0.05	0.05	mg/kg		--		
	Zinc	North	8/8 (100%)	45.1	43.3	mg/kg	0.1271	--	NA	NA
		Southeast	3/3 (100%)	32.3	31.6	mg/kg		--		
		Southwest	6/6 (100%)	50.1	48.6	mg/kg		--		

Table 4-33
Whole Body *Fundulus* spp. Spatial Comparison

Notes:

Fundulus includes mummichog and striped killifish.

[a]The ANOVA model tests if concentration is dependent upon assessment zone. The p-value for the significance of the F statistic is shown. Values that are significant at α = 0.05 are shaded and bolded. Modeling and post hoc testing (Tukey-Kramer method for unbalanced design) was conducted on natural log-transformed data. Letters (A, B, etc.) are assigned by concentration with letter A representing the highest mean concentration. BERA assessment zones that do not share a letter are significantly different (α = 0.05). Those that share a letter are not significantly different.

[b]The ANCOVA model tests if concentration is dependent upon assessment zone while controlling for lipid content which is added as a covariate to the model. The p-value for the significance of the assessment zone in the model is shown. Values that are significant at α = 0.05 are shown in bold. Modeling and post hoc testing was conducted on natural log-transformed data. The ANCOVA model was not conducted for metals concentrations.

[c]The lipid covariate was not marginally significant (α= 0.05) when added to the model, an indication that the assessment zone explains the majority of the variance in concentrations.
Non-detects included at the 1/2 quantitation limit.
The following analytes were not evaluated due to low frequency of detection: Total Alkylated PAHs, Total HMW PAHs, bis(2-Ethylhexyl)phthalate, cadmium, and nickel.

A potential low bias was noted when Phase III PAH results were compared to USEPA split sample PAH results.
BERA assessment zones are depicted in Figure 4-35.

Acronyms and Abbreviations:

-- Not statistically significant at alpha = 0.05.
% = percent
ANOVA = analysis of variance
ANCOVA = analysis of covariance
BERA = Baseline Ecological Risk Assessment
BHC = hexachlorocyclohexane
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligrams per kilogram
ng/kg = nanograms per kilogram
(ND=0) = Only detected isomers were included in the summation
NA = Not applicable
NBSA = Newark Bay Study Area
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
TCDD = tetrachlorodibenzo-p-dioxin
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
µg/kg = micrograms per kilogram

Table 5-1
Estimated Annual Tributary Chemical Loads (1975 - 2000)

Parameter	Units	Estimated Annual Load	
		Hackensack River	Passaic River
Suspended sediment	kg/yr	395,000	22,700,000
Dissolved organic carbon	kg/yr	215,000	4,260,000
Particulate organic carbon	kg/yr	113,000	589,000
PCBs (total)	kg/yr	74	7,200
PCDD/PCDFs (sediment-bound)	g/yr	2.2	260
PAHs (total)	kg/yr	15	1,000
Organochlorine pesticides (total)	g/yr	420	6,400
Mercury (total)	kg/yr	0.073	8.0
Lead (total)	kg/yr	20	2,100
Cadmium (total)	kg/yr	0.26	88

Note:

Data are from the Concentrations and Loads of Organic Compounds and Trace Elements in Tributaries to Newark and Raritan Bays, New Jersey report (Wilson and Bonin 2007).

Acronyms and Abbreviations:

g/yr = gram per year
kg/yr = kilogram per year
PAH = polycyclic aromatic hydrocarbons
PCB = polychlorinated biphenyl

Reference:

Wilson, T.P. and J.L. Bonin. 2007. Concentrations and Loads of Organic Compounds and Trace Elements in Tributaries to Newark and Raritan Bays, New Jersey. Prepared for the New Jersey Toxics Reduction Workplan for NY-NJ Harbor Ambient Monitoring of Loading to Major Tributaries at Head-of-Tide Study I-C. U.S. Geological Survey Scientific Investigations Report 2007-5059.

Table 5-2
Average Surface Water Concentrations of Suspended Sediment, Organic Carbon, and Selected COPCs in the NBSA and Tributaries

Parameter	Units	Water Column Sampling Depth	Number of Detects / Number of Samples: Mean (Standard Deviation)				
			Lower Passaic River[a]	Hackensack River[b]	Kill Van Kull[c]	Arthur Kill[d]	Newark Bay[e]
Dissolved Organic Carbon	mg/L	Near Surface	160/160: 3.45 (1.22)	28/28: 3.1 (0.881)	23/23: 1.92 (0.488)	23/23: 2.05 (0.422)	133/133: 2.42 (0.535)
		Near Bottom	159/160: 3.12 (1.34)	28/28: 2.95 (0.819)	23/23: 1.8 (0.476)	23/23: 1.87 (0.487)	95/95: 2.16 (0.522)
Particulate Organic Carbon	mg/L	Near Surface	113/140: 2.02 (1.52)	21/24: 1.26 (0.498)	12/19: 0.829 (0.473)	12/19: 0.739 (0.226)	84/117: 0.924 (0.434)
		Near Bottom	118/140: 2.66 (2.29)	20/24: 1.47 (0.555)	15/19: 1.13 (0.894)	13/19: 0.832 (0.448)	64/83: 1.08 (0.639)
Suspended Solids	mg/L	Near Surface	160/160: 23 (16.7)	28/28: 19.4 (8.19)	23/23: 10.3 (7.19)	23/23: 7.97 (2.57)	133/133: 12.7 (7.88)
		Near Bottom	160/160: 39.8 (38.5)	28/28: 27.9 (13.2)	23/23: 21.6 (23.7)	23/23: 13.2 (5.49)	95/95: 18.4 (13.3)
2,3,7,8-Tetrachlorodibenzo-p-dioxin	pg/L	Near Surface	138/160: 16.5 (148)	17/24: 1.5 (0.989)	2/19: 0.657 (0.444)	5/19: 0.595 (0.243)	48/113: 1.09 (0.917)
		Near Bottom	135/160: 20.4 (145)	18/24: 1.84 (1.2)	0/19: 0.614 (0.247)	1/19: 0.602 (0.289)	30/82: 1.1 (1.3)
		High Volume (bottom)	6/6: 5.23 (2.57)	--	4/4: 0.189 (0.093)	--	4/4: 0.789 (1.28)
Total PCB Congeners (209)	ng/L	Near Surface	160/160: 17 (11.3)	24/24: 9.71 (2.96)	19/19: 4.2 (1.02)	19/19: 4.9 (1.3)	113/113: 6.9 (2.94)
		Near Bottom	160/160: 24.5 (24.4)	24/24: 11.5 (3.7)	19/19: 4.91 (1.77)	19/19: 5.73 (1.84)	82/82: 6.61 (3.33)
		High Volume (bottom)	6/6: 17.1 (4.94)	--	4/4: 11.6 (5.29)	--	4/4: 7.65 (8.49)
Total DDx (4,4')	ng/L	Near Surface	100/100: 1.88 (1.32)	14/14: 0.682 (0.274)	10/14: 0.422 (0.346)	11/14: 1.51 (2.12)	65/73: 0.657 (0.426)
		Near Bottom	99/100: 2.79 (3.03)	16/16: 0.983 (0.621)	9/14: 0.631 (1.05)	13/14: 1.63 (1.48)	54/57: 0.719 (0.524)
Total PAHs	ng/L	Near Surface	100/100: 596 (415)	16/16: 291 (218)	14/14: 75.7 (65.1)	14/14: 96.7 (80.9)	72/72: 185 (139)
		Near Bottom	100/100: 885 (844)	16/16: 489 (418)	14/14: 101 (82)	14/14: 192 (240)	57/57: 230 (304)
Mercury	ng/L	Near Surface	160/160: 49.6 (52)	28/28: 48.2 (30.4)	23/23: 8.69 (5.69)	23/23: 12 (5.96)	133/133: 20.2 (15)
		Near Bottom	160/160: 92.5 (124)	28/28: 62.4 (28.4)	23/23: 14.7 (13.9)	23/23: 21.6 (17.7)	95/95: 25.4 (33.9)
Mercury (dissolved)	ng/L	Near Surface	160/160: 5 (7.2)	28/28: 2.59 (1.85)	16/23: 1.21 (1.43)	19/23: 1.73 (1.48)	123/133: 3.23 (5.73)
		Near Bottom	159/160: 7.81 (13.1)	28/28: 5.5 (8.2)	20/23: 2.55 (7.1)	17/23: 3.16 (3.58)	89/95: 3.38 (5.13)

Notes:
Near surface and near bottom are data collected from two depths per station and event during the small volume chemical water quality monitoring program conducted from 2011 through 2013 as described in the Quality Assurance Project Plan, AECOM (2011). near surface were collected 3 feet from the water surface. Near bottom were collected 3 feet from the bottom. Sampling stations are shown on Figure 2-10. One-half the quantitation limit is substituted for non-detect data. Dissolved mercury was filtered in the field using 0.45 µm filters. Dissolved organic carbon samples were filtered in the laboratory.

High volume data were collected during the high volume chemical water quality monitoring program (AECOM 2019). Samples were collected a depth of 3 feet from the bottom. Only dioxins and PCBs were analyzed and only at the following stations: NNE, NBE, NBS, 042, 102, and KVK shown on Figure 2-10.

[a]Mean of all Lower Passaic River stations located below Dundee Dam, stations 000, 014, 042, 067, 102, Tidal 1, and Tidal 2 on Figure 2-10.

[b]Mean of data from station HKN on Figure 2-10.

[c]Mean of data from station KVK on Figure 2-10.

[d]Mean of data from station ARK on Figure 2-10 which is at the mouth of the Arthur Kill within the NBSA boundary.

[e]Mean of data from stations NNE, NBN, NNW, NBE, and NBS on Figure 2-10.

Acronyms and Abbreviations:
-- = not sampled
DDx = sum of dichlorodiphenyldichloroethane, dichlorodiphenyldichloroethylene, and dichlorodiphenyltrichloroethane isomers
HV = high volume
NBSA = Newark Bay Study Area
mg/L = milligram per liter
ng/L = nanogram per liter
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
pg/L = picogram per liter

References:
AECOM. 2011. Quality Assurance Project Plan/Field Sampling Plan Addendum. Remedial Investigation Water Column Monitoring/Small Volume Chemical Data Collection. Lower Passaic River Restoration Project. Revision 2. August, 2011.

AECOM. 2019. High Volume Chemical Water Column Monitoring Sampling Program Characterization Summary. Lower Passaic River Study Area RI/FS. May 2019.

Table 5-3
Solids - Model-Computed Annual Average Mass Balance in Newark Bay Region (MT/yr) for Period 1996-2013

Region	Description	Average Erosion	Average Deposition	Average Net Erosion	Water Column Flux In	Water Column Flux Out	CSO Load	Navigation Scour
1	Passaic Channel OU2*	96,664	111,711	-4,306	268,646	-264,339	0	10,741
38	Kearny Point OU2*	98,220	108,363	-1,819	596,303	-594,465	0	8,324
23	Kearny Point NBSA	20,584	20,923	-339	540,443	-540,098	0	0
35	North Channel + Hackensack Channel	262,250	289,714	-7,893	2,564,417	-2,556,536	0	19,570
39	NE Subtidal Flat	301,305	300,114	1,191	733,158	-734,646	302	0
21	NW Subtidal Flat	54,936	55,506	-570	177,153	-176,571	0	0
27	E Subtidal Flat	310,398	319,483	-8,142	693,879	-685,791	47	942
34	Port Newark Channel	18,208	79,410	-33,237	189,745	-156,508	0	27,965
20	Subtidal Flat & CDF	49,417	51,246	-1,829	278,242	-276,410	0	0
33	Elizabeth Channel	48,885	111,922	-33,463	238,536	-205,797	721	29,574
32	Port Channels	468,170	720,065	-65,882	2,173,293	-2,109,475	2,046	186,013
22	SW Subtidal Flat	172,220	171,557	662	380,471	-381,486	355	0
26	Shooters Island Shallows	7,203	10,312	-3,109	132,089	-128,979	0	0
25	South Shore / Industrial Dock Area	36,987	43,676	-6,171	291,542	-285,582	208	517

Note:
* Based on model routines that adjust bed elevations based on bathymetry surveys in the OU2 areas.
Boundaries of the sub-regions are shown on Figure 5-MOD-8.
Passaic Channel and Kearny Point OU2 areas included in the results represent approximately 35% of OU2.
Table reports results provided by HDR that also include additional terms. These additional terms, while small in magnitude, would need to be included in a complete mass balance summation.

Acronyms and Abbreviations:
CDF = confined disposal facility
CSO = combined sewer overflow
E = east
MT/yr = metric ton per year
NBSA = Newark Bay Study Area
NE = northeast
NW = northwest
OU = Operable Unit
SW = southwest

Table 5-4
2,3,7,8-TCDD - Model-Computed Annual Average Fluxes from/to Sediment Bed in Newark Bay Sub-Regions (mg/m^2/yr) for Period 1996-2013

Region	Description	Navigation Scour Loss	Resuspension Loss	Bed Diffusion Loss	Deposition Source	Total Loss	Total Source	Gain (+) or Loss (-) (Net Flux)
1	Passaic Channel OU2	0.0041	0.019	4.9E-06	0.025	0.023	0.025	0.0021
38	Kearny Point OU2	0.0011	0.013	2.2E-06	0.014	0.014	0.014	-0.000050
23	Kearny Point NBSA	0	0.010	1.2E-05	0.011	0.010	0.011	0.00012
35	North Channel + Hackensack Channel	0.00060	0.010	9.3E-06	0.012	0.011	0.012	0.00068
39	NE Subtidal Flat	0	0.013	1.8E-05	0.013	0.013	0.013	-0.00010
21	NW Subtidal Flat	0	0.0093	1.3E-05	0.010	0.0093	0.010	0.00037
27	E Subtidal Flat	0.0000012	0.0074	1.1E-05	0.0078	0.0074	0.0078	0.00033
20	Subtidal Flat & CDF	0	0.0069	8.6E-06	0.0075	0.0069	0.0075	0.00061
22	SW Subtidal Flat	0	0.0040	7.4E-06	0.0036	0.0040	0.0036	-0.00030
34	Port Newark Channel	0.0033	0.0022	7.1E-06	0.010	0.0055	0.010	0.00484
33	Elizabeth Channel	0.0028	0.0045	6.6E-06	0.011	0.0073	0.011	0.00402
32	Port Channels	0.0011	0.0037	5.1E-06	0.0056	0.0049	0.0056	0.00075
26	Shooters Island Shallows	0	0.0028	4.7E-06	0.0037	0.0028	0.0037	0.00091
25	South Shore / Industrial Dock Area	0.0000063	0.0028	6.0E-06	0.0034	0.0028	0.0034	0.00067
Subtotal 1	OU2 (Passaic Channel OU2 and Kearny Point OU2)	0.0051	0.032	7.2E-06	0.039	0.037	0.039	0.0020
Subtotal 2	NBSA (All Remaining Mass Balance Regions)	0.0078	0.077	0.00011	0.10	0.085	0.10	0.013

Note:
Boundaries of the sub-regions are shown on Figure 5-MOD-8.
Passaic Channel and Kearny Point OU2 areas included in the results represent approximately 35% of OU2.

Acronyms and Abbreviations:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
CDF = confined disposal facility
E = east
mg/m^2/yr = milligrams per square meter per year
NBSA = Newark Bay Study Area
NE = northeast
NW = northwest
OU = Operable Unit
SW = southwest

Table 5-5
Mercury - Model-Computed Annual Average Fluxes from/to Sediment Bed in Newark Bay Sub-Regions (mg/m²/yr) for Period 1996-2013

Region	Description	Navigation Scour Loss	Resuspension Loss	Bed Diffusion Loss	Deposition Source	Total Loss	Total Source	Gain (+) or Loss (-) (Net Flux)
1	Passaic Channel OU2	31	196	0.053	241	226	241	15
38	Kearny Point OU2	6.8	120	0.079	127	127	127	-0.49
23	Kearny Point NBSA	0	109	0.51	108	109	108	-0.85
35	North Channel + Hackensack Channel	9.3	121	0.36	131	130	131	1.0
39	NE Subtidal Flat	0	142	0.40	134	142	134	-7.8
21	NW Subtidal Flat	0	105	0.51	102	106	102	-3.25
27	E Subtidal Flat	0.039	90	0.46	90	91	90	-0.088
20	Subtidal Flat & CDF	0	92	0.68	91	93	91	-1.9
22	SW Subtidal Flat	0	73	0.98	62	74	62	-12
34	Port Newark Channel	39	29	0.04	112	68	112	44
33	Elizabeth Channel	42	66	0.12	147	108	147	40
32	Port Channels	29	80	0.61	114	109	114	5.1
26	Shooters Island Shallows	0	58	0.20	76	58	76	18
25	South Shore / Industrial Dock Area	0.23	64	0.46	73	64	73	8.2
Subtotal 1	OU2 (Passaic Channel OU2 and Kearny Point OU2)	38	316	0.13	368	354	368	14.1
Subtotal 2	NBSA (All Remaining Mass Balance Regions)	119	1027	5.3	1241	1151	1241	90

Note:
Boundaries of the sub-regions are shown on Figure 5-MOD-8.
Passaic Channel and Kearny Point OU2 areas included in the results represent approximately 35% of OU2.

Acronyms and Abbreviations:
CDF = confined disposal facility
E = east
mg/m²/yr = milligrams per square meter per year
NBSA = Newark Bay Study Area
NE = northeast
NW = northwest
OU = Operable Unit
SW = southwest

Table 5-6
Total DDx (4,4') - Model-Computed Annual Average Fluxes from/to Sediment Bed in Newark Bay Region (mg/m^2/yr) for Period 1996-2013

Region	Description	Navigation Scour Loss	Resuspension Loss	Bed Diffusion Loss	Deposition Source	Total Loss	Total Source	Gain (+) or Loss (-) (Net Flux)
1	Passaic Channel OU2	1.2	7.8	0.0031	9.6	9.0	9.6	0.57
38	Kearny Point OU2	0.27	4.8	-0.0026	5.1	5.0	5.1	0.041
23	Kearny Point NBSA	0	4.1	0.0066	4.2	4.1	4.2	0.077
35	North Channel + Hackensack Channel	0.41	4.8	0.011	5.3	5.2	5.3	0.16
39	NE Subtidal Flat	0	5.3	0.023	5.2	5.3	5.2	-0.069
21	NW Subtidal Flat	0	4.1	0.014	4.2	4.1	4.2	0.083
27	E Subtidal Flat	0.0017	3.6	0.016	3.6	3.6	3.6	0.072
20	Subtidal Flat & CDF	0	3.8	0.011	3.9	3.8	3.9	0.071
22	SW Subtidal Flat	0	5.1	0.015	4.5	5.1	4.5	-0.61
34	Port Newark Channel	1.8	1.2	0.0095	4.9	3.1	4.9	1.9
33	Elizabeth Channel	1.9	2.8	0.012	6.5	4.7	6.5	1.7
32	Port Channels	2.3	5.7	0.018	8.3	8.0	8.3	0.34
26	Shooters Island Shallows	0	4.0	0.017	5.6	4.0	5.6	1.6
25	South Shore / Industrial Dock Area	0.011	4.9	0.024	5.7	4.9	5.7	0.81
Subtotal 1	OU2 (Passaic Channel OU2 and Kearny Point OU2)	1.5	13	0.00047	15	14	15	0.62
Subtotal 2	NBSA (All Remaining Mass Balance Regions)	6.4	49	0.18	62	56	62	6.1

Note:
Boundaries of the sub-regions are shown on Figure 5-MOD-8.
Passaic Channel and Kearny Point OU2 areas included in the results represent approximately 35% of OU2.

Acronyms and Abbreviations:
CDF = confined disposal facility
E = east
mg/m^2/yr = milligrams per square meter per year
NBSA = Newark Bay Study Area
NE = northeast
NW = northwest
OU = Operable Unit
SW = southwest

Table 5-7
Tetra-PCB - Model-Computed Annual Average Fluxes from/to Sediment Bed in Newark Bay Region (mg/m^2/yr) for Period 1996-2013

Region	Description	Navigation Scour Loss	Resuspension Loss	Bed Diffusion Loss	Deposition Source	Total Loss	Total Source	Gain (+) or Loss (-) (Net Flux)
1	Passaic Channel OU2	3.3	20	0.00342	25	23	25	1.7
38	Kearny Point OU2	0.78	12	-0.00834	13	13	13	-0.093
23	Kearny Point NBSA	0	11	0.01422	11	11	11	0.090
35	North Channel + Hackensack Channel	0.98	12	0.0208	14	13	14	0.34
39	NE Subtidal Flat	0	14	0.0480	13	14	13	-0.58
21	NW Subtidal Flat	0	11	0.0297	11	11	11	-0.12
27	E Subtidal Flat	0.0044	9.1	0.0301	9.2	9.1	9.2	0.15
20	Subtidal Flat & CDF	0	9.0	0.01789	9.4	9.0	9.4	0.41
22	SW Subtidal Flat	0	7.5	0.01493	6.7	7.5	6.7	-0.85
34	Port Newark Channel	4.7	3.0	0.01594	13	7.8	12.8	5.0
33	Elizabeth Channel	4.7	7.1	0.0195	16	11.8	16.3	4.4
32	Port Channels	3.1	8.6	0.0254	12	11.7	12.3	0.64
26	Shooters Island Shallows	0	6.3	0.0181	8.3	6.3	8.3	2.0
25	South Shore / Industrial Dock Area	0.026	6.8	0.0289	7.9	6.9	7.9	0.97
Subtotal 1	OU2 (Passaic Channel OU2 and Kearny Point OU2)	4.0	32	-0.0049	38	36	38	1.6
Subtotal 2	NBSA (All Remaining Mass Balance Regions)	14	105	0.28	131	119	131	12

Note:
Boundaries of the sub-regions are shown on Figure 5-MOD-8.
Passaic Channel and Kearny Point OU2 areas included in the results represent approximately 35% of OU2.

Acronyms and Abbreviations:
CDF = confined disposal facility
E = east
mg/m^2/yr = milligrams per square meter per year
NBSA = Newark Bay Study Area
NE = northeast
NW = northwest
OU = Operable Unit
PCB = polychlorinated biphenyl
SW = southwest

Table 5-8
Annual Boundary Fluxes of 2,3,7,8-TCDD

	NB & Passaic		NB & Hackensack		NB & Kill Van Kull		NB & Arthur Kill	
2,3,7,8-TCDD (g)	Into the Bay	Out of Bay	Into the Bay	Out of Bay	Into the Bay	Out of Bay	Into the Bay	Out of Bay
1996	45.60	18.62	61.42	64.63	18.76	22.91	9.21	12.68
1997	24.04	14.00	40.57	42.65	13.77	16.47	7.78	9.81
1998	21.62	12.53	34.67	36.57	11.92	14.63	7.21	8.32
1999	29.28	11.33	27.06	28.64	11.73	13.86	7.69	9.67
2000	13.35	11.49	23.63	24.84	10.21	11.19	6.37	7.28
2001	14.49	10.71	22.91	23.95	9.54	10.79	5.96	6.94
2002	8.94	8.16	17.72	18.51	8.04	9.11	5.24	5.86
2003	18.74	9.46	26.02	27.07	9.83	10.93	5.05	6.19
2004	15.88	8.73	23.52	24.61	8.57	9.08	4.19	5.85
2005	16.57	7.48	24.20	25.14	9.46	10.61	5.23	6.89
2006	15.61	7.60	22.67	23.55	8.44	9.37	4.18	5.85
2007	28.11	7.97	31.35	32.49	12.31	15.73	6.52	9.16
2008	16.34	8.64	25.64	26.57	9.01	10.07	4.73	6.12
2009	13.13	8.26	20.54	21.48	7.60	8.01	4.32	5.26
2010	33.42	8.80	41.92	43.29	11.14	13.49	6.22	9.21
2011	197.29	13.47	168.18	175.01	46.83	73.89	24.09	45.19
2012	38.33	26.75	73.70	78.57	15.19	18.65	8.58	13.07
2013	23.47	14.98	37.75	39.62	11.14	13.24	6.21	8.69
Grand Total	**574.21**	**208.96**	**723.47**	**757.18**	**233.51**	**292.02**	**128.78**	**182.05**
Net into Bay (g)		**365.26**		**(33.71)**		**(58.51)**		**(53.27)**
Net into Bay (g/yr)		20.3		-1.87		-3.25		-2.96

Notes:
Values in parentheses represent negative values

Acronyms and Abbreviations:
g = grams
g/yr = grams per year
NB = Newark Bay

Table 5-9
Annual Boundary Fluxes of Tetra-PCB

Tetra-PCB (kg)	NB & Passaic		NB & Hackensack		NB & Kill Van Kull		NB & Arthur Kill	
	Into the Bay	Out of Bay	Into the Bay	Out of Bay	Into the Bay	Out of Bay	Into the Bay	Out of Bay
1996	38.37	22.57	81.32	84.47	113.51	101.17	40.95	51.39
1997	28.69	20.89	73.55	76.27	97.98	89.35	38.61	47.44
1998	26.22	19.07	64.65	66.83	85.48	81.25	37.86	42.46
1999	27.77	16.80	52.46	54.19	79.08	74.93	36.50	40.83
2000	20.81	18.71	54.53	56.33	85.15	76.43	35.16	40.90
2001	19.69	16.76	50.62	52.01	75.26	68.87	32.87	37.93
2002	13.87	13.85	42.54	43.75	66.68	62.73	30.83	34.28
2003	20.87	13.26	45.43	46.51	65.54	57.78	26.42	31.11
2004	20.37	13.53	44.65	45.79	61.36	52.03	22.16	28.90
2005	19.93	12.73	45.44	46.72	65.92	58.28	25.82	31.72
2006	18.85	11.88	41.45	42.43	59.39	50.69	20.98	27.77
2007	27.15	12.63	48.14	49.26	64.03	56.74	23.56	31.25
2008	17.96	11.93	41.42	42.31	55.45	48.79	21.85	26.70
2009	16.23	12.34	38.70	39.77	56.60	47.74	22.27	27.06
2010	21.07	11.12	41.15	42.13	54.67	47.47	21.78	27.21
2011	88.20	12.58	94.86	98.20	70.14	70.74	24.45	41.40
2012	24.66	18.08	56.96	59.53	53.77	45.94	18.63	26.58
2013	19.22	13.57	41.59	42.78	49.18	41.68	18.13	24.72
Grand Total	**469.91**	**272.28**	**959.46**	**989.26**	**1,259.17**	**1,132.62**	**498.84**	**619.66**
Net into Bay (kg)		**197.63**		**(29.80)**		**126.54**		**(120.82)**
Net into Bay (kg/yr)		11.0		-1.7		7.0		-6.7

Notes:
Values in parentheses represent negative values

Acronyms and Abbreviations:
kg = kilograms
kg/yr = kilograms per year
NB = Newark Bay

Table 5-10
Annual Boundary Fluxes of Total DDx (4,4')

Total DDx (4,4') (kg)	NB & Passaic		NB & Hackensack		NB & Kill Van Kull		NB & Arthur Kill	
	Into the Bay	Out of Bay	Into the Bay	Out of Bay	Into the Bay	Out of Bay	Into the Bay	Out of Bay
1996	12.59	8.06	30.09	30.78	35.27	44.35	116.74	106.76
1997	9.71	7.65	28.06	28.65	32.85	42.23	107.13	98.29
1998	10.25	8.31	29.84	30.48	35.14	50.19	125.46	109.09
1999	10.71	7.75	26.20	26.69	34.15	48.10	136.30	120.71
2000	7.69	6.97	22.17	22.54	27.56	36.87	106.09	96.29
2001	7.73	6.85	22.38	22.72	28.21	38.36	115.78	104.92
2002	7.32	7.42	24.62	25.06	33.87	47.12	159.47	144.18
2003	8.32	5.86	22.13	22.25	28.84	36.81	97.95	87.24
2004	7.29	5.24	19.00	19.13	23.08	27.34	87.07	81.19
2005	7.18	5.41	20.32	20.57	26.77	32.36	102.57	95.73
2006	7.03	4.82	18.56	18.59	22.89	27.25	78.56	73.47
2007	9.15	4.84	19.32	19.34	21.77	25.40	73.50	70.13
2008	7.63	5.97	21.89	22.11	28.46	36.22	141.16	129.91
2009	6.91	5.58	18.74	18.92	22.67	26.12	79.80	74.91
2010	8.27	5.05	19.66	19.81	23.87	28.50	78.22	71.73
2011	27.02	4.49	32.61	33.35	20.88	24.01	52.96	54.87
2012	8.16	6.27	20.67	21.35	18.15	19.41	60.02	60.57
2013	7.25	5.62	19.23	19.43	23.09	27.72	135.95	128.54
Grand Total	**170.24**	**112.16**	**415.50**	**421.78**	**487.51**	**618.36**	**1,854.72**	**1,708.53**
Net into Bay (kg)		**58.07**		**(6.28)**		**(130.84)**		**146.19**
Net into Bay (kg/yr)		3.2		-0.3		-7.3		8.1

Notes:
Values in parentheses represent negative values

Acronyms and Abbreviations:
kg = kilograms
kg/yr = kilograms per year
NB = Newark Bay

Table 5-11
Annual Boundary Fluxes of Mercury

Mercury (kg)	NB & Passaic		NB & Hackensack		NB & Kill Van Kull		NB & Arthur Kill	
	Into the Bay	Out of Bay	Into the Bay	Out of Bay	Into the Bay	Out of Bay	Into the Bay	Out of Bay
1996	306.19	205.22	749.94	772.69	868.18	821.26	436.63	512.18
1997	244.21	194.66	695.26	722.12	815.04	779.98	435.56	504.02
1998	229.22	182.14	620.98	642.13	760.53	761.24	463.42	487.97
1999	213.82	156.49	496.24	512.16	704.93	694.18	459.56	476.85
2000	181.32	164.94	486.82	504.10	655.04	623.16	378.84	417.61
2001	174.47	152.71	471.13	485.10	624.16	600.85	374.37	408.79
2002	126.77	131.04	411.29	424.72	587.99	579.06	391.24	411.79
2003	190.99	128.37	446.85	456.60	575.88	527.08	334.02	362.30
2004	190.02	132.87	427.83	439.46	521.68	448.73	255.39	309.58
2005	170.45	121.30	419.84	432.36	529.96	478.29	288.68	329.64
2006	173.81	117.25	407.50	416.35	505.01	444.33	250.01	301.64
2007	252.64	124.99	473.30	482.51	542.38	500.58	261.31	328.62
2008	152.83	109.66	377.69	385.28	449.55	403.55	249.58	283.83
2009	144.98	114.74	355.89	365.96	451.58	389.18	240.77	276.83
2010	193.55	109.03	398.41	407.10	456.07	407.38	243.37	284.68
2011	614.28	115.13	718.07	742.19	543.23	528.15	211.89	338.20
2012	199.10	151.08	462.31	485.58	434.27	363.11	175.02	235.79
2013	171.05	123.42	376.44	386.82	418.02	356.87	198.34	254.36
Grand Total	**3,929.71**	**2,535.04**	**8,795.79**	**9,063.23**	**10,443.50**	**9,706.99**	**5,648.00**	**6,524.68**
Net into Bay (kg)		**1,394.68**		**(267.44)**		**736.50**		**(876.68)**
Net into Bay (kg/yr)		77.5		-14.9		40.9		-48.7

Notes:
Values in parentheses represent negative values

Acronyms and Abbreviations:
kg = kilograms
kg/yr = kilograms per year
NB = Newark Bay

Table 5-13
Summary Statistics for USEPA REMAP Surface Sediment Data in the NBSA

Analyte Group	Analyte	Unit	Mean (Standard Deviation : Percent Frequency of Detection)					Maximum Detected Concentration Observed		
			1993-94 (n= 18)	1998 (n=13)[a]	2003 (n=11)	2008 (n=11)	2013 (n=11)	Value	Year	Station
Dioxins/Furans	2,3,7,8-TCDD	ng/kg	--	65.7 (40.2 : 100%)	49.4 (66.4 : 100%)	--	45.4 (33.1 : 100%)	236	2003	NB305
	Total WHO Dioxin TEQ(Human/Mammal)(ND=0)	ng/kg	--	95.9 (55.3 : 100%)	67.2 (75.7 : 100%)	--	68.4 (41.8 : 100%)	278	2003	NB305
PCBs (Aroclors)	Total PCBs	µg/kg	--	--	--	Not Detected	1.8 (2.33 : 45%)	6.5	2013	NB413
Pesticides	Dieldrin	µg/kg	2.51 (1.71 : 100%)	Not Detected	Not Detected	Not Detected	Not Detected	6.67	1993	NB047
	Heptachlor epoxide	µg/kg	0.186 (0.222 : 56%)	Not Detected	Not Detected	Not Detected	Not Detected	0.59	1993	NB103
	Hexachlorobenzene	µg/kg	2.62 (1.9 : 100%)	Not Detected	1.97 (2.65 : 27%)	Not Detected	Not Detected	7.7	2003	NB307
	Total DDx (2,4' & 4,4') (ND=0)	µg/kg	147 (250 : 100%)	175 (293 : 85%)	106 (77.6 : 100%)	1.54 (1.67 : 18%)	4.15 (5.03 : 55%)	1,090	1993	NB047
	Total DDx (4,4') (ND=0)	µg/kg	123 (206 : 100%)	156 (255 : 85%)	89.4 (63.8 : 100%)	1.54 (1.67 : 18%)	3.07 (3.06 : 55%)	892	1993	NB047
	Total alpha + gamma chlordane	µg/kg	--	0.338 (1.22 : 8%)	--	Not Detected	Not Detected	4.4	1998	NB226
	cis-Nonachlor	µg/kg	--	Not Detected	--	Not Detected	Not Detected	Not Detected		
PAHs	Total HMW PAHs	µg/kg	6530 (4740 : 100%)	7100 (8010 : 100%)	5590 (3600 : 100%)	2380 (6310 : 100%)	2590 (3570 : 100%)	30,100	1998	NB227
	Total LMW PAHs	µg/kg	1380 (753 : 100%)	1520 (1640 : 92%)	1490 (1590 : 100%)	392 (1170 : 55%)	362 (371 : 100%)	6,080	1998	NB227
	Total PAHs	µg/kg	7910 (5410 : 100%)	8610 (9620 : 100%)	7080 (4880 : 100%)	2770 (7480 : 100%)	2960 (3920 : 100%)	36,200	1998	NB227
Metals	Arsenic	mg/kg	11.4 (4.39 : 100%)	14.1 (4.52 : 100%)	14.5 (6.85 : 100%)	9.93 (2.17 : 100%)	12.1 (4.52 : 100%)	25.7	2003	NB309
	Cadmium	mg/kg	2.4 (2.9 : 100%)	1.25 (1.41 : 69%)	2.89 (1.47 : 100%)	1.08 (0.556 : 100%)	1.12 (0.445 : 100%)	12.9	1993	NB102
	Chromium	mg/kg	138 (61.6 : 100%)	104 (26.8 : 100%)	112 (33.4 : 100%)	74.8 (19.6 : 100%)	116 (41.3 : 100%)	244	1993	NB102
	Copper	mg/kg	116 (69.7 : 100%)	145 (76.5 : 100%)	131 (73.4 : 100%)	109 (64.7 : 100%)	84.1 (42 : 100%)	300	1998	NB223
	Lead	mg/kg	147 (119 : 100%)	119 (62.6 : 92%)	162 (68.5 : 100%)	101 (50.3 : 100%)	93.1 (41.3 : 100%)	550	1993	NB102
	Mercury	mg/kg	2.31 (1.36 : 100%)	2.95 (1.69 : 100%)	1.83 (0.881 : 100%)	1.36 (0.593 : 100%)	1.47 (0.556 : 100%)	7.4	1998	NB223
	Nickel	mg/kg	43.8 (16.9 : 100%)	39.5 (23.9 : 100%)	37.9 (10.1 : 100%)	28.5 (10.4 : 100%)	47.6 (20.7 : 100%)	115	1998	NB231
	Selenium	mg/kg	--	Not Detected	1.3 (0.77 : 91%)	Not Detected	0.645 (0.35 : 100%)	2.8	2003	NB309
	Silver	mg/kg	2.23 (1.31 : 100%)	2.3 (1.03 : 100%)	2.71 (1.35 : 100%)	3.95 (0.989 : 100%)	1.29 (0.575 : 100%)	5.8	2008	NB413
	Zinc	mg/kg	244 (161 : 100%)	243 (103 : 100%)	245 (139 : 100%)	236 (215 : 100%)	180 (84.1 : 100%)	870	2008	NB413

Notes:
Non-detect concentrations are included at the 1/2 the reporting limit for mean and standard deviation estimates.
[a] Only 12 samples were analyzed for dioxins and furans in 1998.

Acronyms and Abbreviations:
-- not analyzed
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
HMW = high molecular weight
LMW = low molecular weight
mg/kg = milligram per kilogram
NBSA = Newark Bay Study Area
n = number
ND = non-detect
ng/kg = nanogram per kilogram
(ND=0) = Only detected isomers were included in the summation
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
REMAP = Regional Environmental Monitoring and Assessment Program
TEQ = toxic equivalency
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
USEPA = U.S. Environmental Protection Agency
WHO = World Health Organization
µg/kg = microgram per kilogram
% = percent

Table 5-14
Ranges of Modeled and Observed Particulate COPC Concentrations in the Water Column

Parameter	Units	Source	Passaic River	Hackensack River	Kill Van Kull	Arthur Kill	Newark Bay
Total PCBs	ng/kg	SVCWCM 2011[a]	518,000 - 915,000	527,000	416,000	536,000	490,000 - 630,000
		HVCWCM[b]	840,000, 770,000	--	550,000	--	883,000, 53,000, 264,000
		Newark Bay RI/FS Model[c] (Tetra PCB)	130,000 - 353,000 (223,000)	140,000 - 322,000 (224,000)	71,000 - 413,000 (195,000)	144,000 - 483,000 (285,000)	--
2,3,7,8-TCDD	ng/kg	SVCWCM 2011[a]	103 - 1,400	79.6	63.4[d]	59.8[d]	63 - 110[e]
		HVCWCM[b]	380, 260	--	10.2	--	157, 11.6, 20
		Newark Bay RI/FS Model	92 - 603 (204)	85 - 381 (151)	13 - 169 (40)	38 - 230 (74)	--
Total DDx (4,4')	pg/g	SVCWCM 2011[a]	63,900 - 98,500	39,400	38,800	131,000	49,600 - 59,900
		Newark Bay RI/FS Model	43,000 - 126,000 (77,000)	50,000 - 131,000 (82,000)	21,000 - 150,000 (67,000)	64,000 - 390,000 (189,000)	--
Mercury	µg/kg	SVCWCM 2011[a]	1,590 - 2,380	2,180	756	1,370	917 - 1,520
		Newark Bay RI/FS Model	1,188 - 2,801 (2,000)	1,278 - 2,979 (2,100)	602 - 3,351 (1,700)	1,078 - 3,782 (2,200)	--

Notes:

[a]Solids concentrations are estimated from water and suspended solids concentrations measured in the small volume chemical water column monitoring program. For organic compounds for which only total concentrations were measured, solids concentrations were estimated by dividing the total water concentration by the suspended solids concentration. For mercury, for which both total and dissolved concentrations were measured, the dissolved concentration was first subtracted from the total concentration before dividing by the suspended solids concentration. Sampling was conducted from 2011 through 2013 as described in the Quality Assurance Project Plan, AECOM (2011). Sampling stations are shown on Figure 2-10. The arithmetic means are presented in the table. Ranges of arithmetic means are provided for water bodies with more than one sampling station. One-half the reporting limit is substituted for non-detect data in the arithmetic mean calculation. Only stations located downstream of Dundee Damn are included in the Passaic River ranges. The Arthur Kill average is based on data from station ARK on Figure 2-10 which is technically within the NBSA boundary. The range shown for Newark Bay is based on the other 5 NBSA stations: NNE, NBN, NNW, NBE, and NBS (Figure 2-10).

[b]Solids concentrations were measured from particles retained on a 0.7 um GFF in the high volume chemical water quality monitoring program, AECOM (2019) which sampled for dioxins and PCBs only at a subset of the stations shown on Figure 2-10. Arithmetic means for all stations in the water body are shown. Passaic River stations are 042 and 102, respectively. Newark Bay stations are NNE, NBE, and NBS, respectively. The Kill Van Kull station was sampled on the incoming tide only. All results were detected.

[c]Model reports Tetra PCB, not Total PCB.

[d]Frequency of detection is less than 20%.

[e]Frequency of detection ranges from 15% to 55% at Newark Bay stations.

Newark Bay RI/FS Model values show the range of values based on model results for 1996 to 2013. The arithmetic mean shown in parentheses.

Table 5-14
Ranges of Modeled and Observed Particulate COPC Concentrations in the Water Column

Acronyms and Abbreviations:

-- = Not Available or Applicable. The Hackensack and Arthur Kill were not sampled during the high volume program. Model results are only shown for boundary conditions in tributaries.
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
COPC = constituent of potential concern
DDx = sum of dichlorodiphenyldichloroethane, dichlorodiphenyldichloroethylene, and dichlorodiphenyltrichloroethane isomers
HVCWCM = high volume chemical water column monitoring
NBSA = Newark Bay Study Area
ng/kg = nanogram per kilogram
PCB = polychlorinated biphenyl
SVCWCM = small volume chemical water column monitoring
µg/kg = microgram per kilogram

References:

AECOM. 2011. Quality Assurance Project Plan/Field Sampling Plan Addendum. Remedial Investigation Water Column Monitoring/Small Volume Chemical Data Collection. Lower Passaic River Restoration Project. Revision 2. August, 2011.

AECOM. 2019. High Volume Chemical Water Column Monitoring Sampling Program Characterization Summary. Lower Passaic River Study Area RI/FS. May 2019.

Table 5-15
Concentrations and Calculated Long-Term Rates of Decline for Selected COCs in Dateable Phase I and II Core Intervals

COC	Unit	Sampling Program for Core	Geographic Area	Core Location ID	Geomorphic Unit	Be-7 Bearing	Start Depth of Dated Core Interval (feet below sediment surface)			Concentration in Dated Depth Interval					Long-Term Annual Rate of Decline (or Increase if Negative)		
							1980	1963 (Cs-137 Peak)	1954 (Cs-137 Horizon)	Surface Interval (Phase III)	Surface Interval (Phase I/II)	1980	1963 (Cs-137 Peak)	1954 (Cs-137 Horizon)	Since 1980	Since 1963[a]	Since 1954[a]
2,3,7,8-TCDD	ng/kg	Phase II	North	94	Navigation Channel	Yes	--	25.5	--	--	117	--	204	--		1.3%	
2,3,7,8-TCDD	ng/kg	Phase II	North	80	Subtidal Flat	Yes	2.5	5.5	9.5	60.6	137	232	589	1440	3.7%	4.3%	5.1%
2,3,7,8-TCDD	ng/kg	Phase I	North	58	Intertidal	No	--	0.5	1.5	--	149	--	1060	235		4.7%	0.9%
2,3,7,8-TCDD	ng/kg	Phase I	North	57	Subtidal Flat	Yes	0.5	2.5	--	71.8	93.1	289	990	--	3.9%	5.0%	
2,3,7,8-TCDD	ng/kg	Phase II	North	79	Subtidal Flat	Yes	1.5	3.5	5.5	71.8	112	1030	3005	4510	7.4%	7.0%	6.7%
2,3,7,8-TCDD	ng/kg	Phase II	North	93	Subtidal Flat (Disturbed)	No	--	--	0.5	1096	423	--	--	1850			0.8%
2,3,7,8-TCDD	ng/kg	Phase II	North	78	Subtidal Flat (Disturbed)	No	9.5	17.5	23.5	101	136	3800	4090	8750	10.1%	7.0%	7.2%
2,3,7,8-TCDD	ng/kg	Phase II	North	77	Subtidal Flat (Disturbed)	Yes	0.5	2.5	5.5	107	147	391	2680	325	3.6%	6.1%	1.8%
2,3,7,8-TCDD	ng/kg	Phase I	North	56	Subtidal Flat (Disturbed)	No	1.5	2.5	5	107	145	1160	1760	2290	6.6%	5.3%	4.9%
2,3,7,8-TCDD	ng/kg	Phase II	North	76	Subtidal Flat (Disturbed)	No	1.5	3.5	7.5	85.6	105	436	2090	3360	4.5%	6.0%	5.9%
2,3,7,8-TCDD	ng/kg	Phase I	North	51	Subtidal Flat (Disturbed)	No	1.5	5	--	85.6	89.6	307	3220	--	3.5%	6.8%	
2,3,7,8-TCDD	ng/kg	Phase II	Central	74	Subtidal Flat (Disturbed)	No	2.5	5.5	9.5	--	83.3	560	4230	3200	7.1%	8.9%	6.9%
2,3,7,8-TCDD	ng/kg	Phase I	Central	44	Subtidal Flat (Disturbed)	Yes	2.5	--	--	--	76.55	357	--	--	6.2%		
2,3,7,8-TCDD	ng/kg	Phase II	Central	92	Subtidal Flat (Disturbed)	No	2.5	5.5	9.5	43.2	67.2	395	2020	3280	6.1%	7.3%	7.0%
2,3,7,8-TCDD	ng/kg	Phase I	Central	37	Subtidal Flat	Yes	--	0.5	1.5	73.8	93.7	--	405	715		3.2%	3.7%
2,3,7,8-TCDD	ng/kg	Phase II	Central	73	Subtidal Flat	No	0.5	1.5	2.5	60.1	164	95.5	286	451	1.3%	2.9%	3.3%
2,3,7,8-TCDD	ng/kg	Phase I	Central	32	Subtidal Flat	Yes	0.5	2.5	--	60.1	67.3	1100	680	--	8.1%	4.6%	
2,3,7,8-TCDD	ng/kg	Phase II	Central	91	Subtidal Flat (Disturbed)	Yes	0.5	2.5	3.5	53.5	70.2	110	417	964.5	2.0%	3.9%	4.7%
2,3,7,8-TCDD	ng/kg	Phase I	Central	28	Subtidal Flat (Disturbed)	Yes	1.5	2.5	5	--	48.8	160	198	3.94	4.7%	3.3%	-4.9%
2,3,7,8-TCDD	ng/kg	Phase II	Central	72	Subtidal Flat	Yes	0.5	1.5	2.5	--	54	70.6	102	43.1	1.0%	1.4%	-0.4%
2,3,7,8-TCDD	ng/kg	Phase II	South	98	Subtidal Flat (Disturbed)	Yes	2.5	5.5	9.5	--	45.6	79.3	96	108	2.0%	1.7%	1.6%
2,3,7,8-TCDD	ng/kg	Phase I	South	23	Subtidal Flat	Yes	--	0.5	1.5	148	63.6	--	223	30.9		0.8%	-2.5%
2,3,7,8-TCDD	ng/kg	Phase II	South	71	Transitional Slope	Yes	1.5	3.5	5.5	--	29.4	38.8	441	647	1.0%	6.2%	5.8%
2,3,7,8-TCDD	ng/kg	Phase I	South	16	Transitional Slope	Yes	--	0.5	--	--	24.2	--	25.7	--		0.1%	
2,3,7,8-TCDD	ng/kg	Phase I	South	15	Subtidal Flat	No	0.5	1.5	2.5	77.5	68.2	166	811	148	2.1%	4.4%	1.0%
2,3,7,8-TCDD	ng/kg	Phase II	South	70	Subtidal Flat (Disturbed)	No	0.5	2.5	3.5	31.2	141	257	866	970	5.9%	6.3%	5.5%
2,3,7,8-TCDD	ng/kg	Phase II	South	90	Subtidal Flat (Disturbed)	No	3.5	--	7.5	15.1	30.5	308	--	859	8.4%		6.5%
2,3,7,8-TCDD	ng/kg	Phase II	South	89	Transitional Slope	Yes	2.5	3.5	11.5	188	60.9	1330	1037	3750	5.4%	3.2%	4.8%
2,3,7,8-TCDD	ng/kg	Phase II	South	82	Industrial Waterfront	Yes	3.5	--	7.5	--	55.8	149	--	688	3.6%		4.7%
2,3,7,8-TCDD	ng/kg	Phase I	South	12	Industrial Waterfront	No	0.5	1.5	5	74.8	230	245	223	394	3.3%	2.1%	2.7%
2,3,7,8-TCDD														**Average**	**4.7%**	**4.4%**	**3.5%**
Mercury	µg/kg	Phase II	North	94	Navigation Channel	Yes	--	25.5	--	--	1600	--	5200	--		2.7%	
Mercury	µg/kg	Phase II	North	80	Subtidal Flat	Yes	2.5	5.5	9.5	1320	2200	6700	11500	13500	4.5%	4.1%	3.8%
Mercury	µg/kg	Phase I	North	58	Intertidal	No	--	0.5	1.5	--	2900	--	8600	3300		2.6%	0.3%
Mercury	µg/kg	Phase I	North	57	Subtidal Flat	Yes	0.5	2.5	--	1630	2400	5900	11300	--	3.6%	3.7%	
Mercury	µg/kg	Phase II	North	79	Subtidal Flat	Yes	1.5	3.5	5.5	1630	2700	12700	12600	16500	5.7%	3.9%	3.7%
Mercury	µg/kg	Phase II	North	93	Subtidal Flat (Disturbed)	No	--	--	0.5	5875	3900	--	--	12400			1.2%
Mercury	µg/kg	Phase II	North	78	Subtidal Flat (Disturbed)	No	9.5	17.5	23.5	1260	1700	14800	15700	15100	6.8%	4.8%	4.0%
Mercury	µg/kg	Phase II	North	77	Subtidal Flat (Disturbed)	Yes	0.5	2.5	5.5	2540	2200	6300	10400	7400	2.5%	2.7%	1.7%
Mercury	µg/kg	Phase I	North	56	Subtidal Flat (Disturbed)	No	1.5	2.5	5	2540	3100	13800	10800	15300	4.7%	2.7%	2.9%
Mercury	µg/kg	Phase II	North	76	Subtidal Flat (Disturbed)	No	1.5	3.5	7.5	1820	3200	6000	16250	15200	3.3%	4.1%	3.4%
Mercury	µg/kg	Phase I	North	51	Subtidal Flat (Disturbed)	No	1.5	5	--	1820	2500	7000	14700	--	3.7%	3.9%	
Mercury	µg/kg	Phase II	Central	74	Subtidal Flat (Disturbed)	No	2.5	5.5	9.5	--	3200	9900	19100	11500	4.2%	4.1%	2.4%
Mercury	µg/kg	Phase I	Central	44	Subtidal Flat (Disturbed)	Yes	2.5	--	--	--	2200	8400	--	--	5.4%		
Mercury	µg/kg	Phase II	Central	92	Subtidal Flat (Disturbed)	No	2.5	5.5	9.5	1350	2900	10100	14100	10900	5.6%	4.4%	3.4%
Mercury	µg/kg	Phase I	Central	37	Subtidal Flat	Yes	--	0.5	1.5	1730	2200	--	8200	6600		2.9%	2.2%
Mercury	µg/kg	Phase II	Central	73	Subtidal Flat	No	0.5	1.5	2.5	1230	5400	2200	9300	8000	1.6%	3.8%	3.0%
Mercury	µg/kg	Phase I	Central	32	Subtidal Flat	Yes	0.5	2.5	--	1230	1500	4600	7400	--	3.7%	3.4%	
Mercury	µg/kg	Phase II	Central	91	Subtidal Flat (Disturbed)	Yes	0.5	2.5	3.5	1440	2300	2900	5000	5850	1.9%	2.3%	2.3%
Mercury	µg/kg	Phase I	Central	28	Subtidal Flat (Disturbed)	Yes	1.5	2.5	5	--	1400	2300	6900	2500	2.0%	3.8%	1.1%
Mercury	µg/kg	Phase II	Central	72	Subtidal Flat	Yes	0.5	1.5	2.5	--	1400	2100	3400	2400	1.5%	2.0%	1.0%

Table 5-15
Concentrations and Calculated Long-Term Rates of Decline for Selected COCs in Dateable Phase I and II Core Intervals

COC	Unit	Sampling Program for Core	Geographic Area	Core Location ID	Geomorphic Unit	Be-7 Bearing	Start Depth of Dated Core Interval (feet below sediment surface)			Concentration in Dated Depth Interval					Long-Term Annual Rate of Decline (or Increase if Negative)		
							1980	1963 (Cs-137 Peak)	1954 (Cs-137 Horizon)	Surface Interval (Phase III)	Surface Interval (Phase I/II)	1980	1963 (Cs-137 Peak)	1954 (Cs-137 Horizon)	Since 1980	Since 1963[a]	Since 1954[a]
Mercury	µg/kg	Phase II	South	98	Subtidal Flat (Disturbed)	Yes	2.5	5.5	9.5	--	1900	6000	5600	3900	4.3%	2.5%	1.4%
Mercury	µg/kg	Phase I	South	23	Subtidal Flat	Yes	--	0.5	1.5	4800	3000	--	7600	1700		0.9%	-1.7%
Mercury	µg/kg	Phase II	South	71	Transitional Slope	Yes	1.5	3.5	5.5	--	1400	1900	7850	7600	1.1%	3.9%	3.2%
Mercury	µg/kg	Phase I	South	16	Transitional Slope	Yes	--	0.5	--	--	1000	--	1500	--		1.0%	
Mercury	µg/kg	Phase I	South	15	Subtidal Flat	No	0.5	1.5	2.5	3510	7000	630	21600	5800	-4.8%	3.4%	0.8%
Mercury	µg/kg	Phase II	South	70	Subtidal Flat (Disturbed)	No	0.5	2.5	3.5	2080	4500	8900	9300	9050	4.0%	2.8%	2.4%
Mercury	µg/kg	Phase II	South	90	Subtidal Flat (Disturbed)	No	3.5	--	7.5	838	2100	9800	--	12100	6.8%		4.3%
Mercury	µg/kg	Phase II	South	89	Transitional Slope	Yes	2.5	3.5	11.5	7120	2800	46300	36900	18100	5.2%	3.1%	1.5%
Mercury	µg/kg	Phase II	South	82	Industrial Waterfront	Yes	3.5	--	7.5	--	7700	78400	--	40000	8.6%		3.1%
Mercury	µg/kg	Phase I	South	12	Industrial Waterfront	No	0.5	1.5	5	5220	17400	19300	13100	30750	3.6%	1.7%	2.9%
Mercury														**Average**	**3.7%**	**3.1%**	**2.3%**
Total DDx (4,4')	µg/kg	Phase II	North	94	Navigation Channel	Yes	--	25.5	--	--	32	--	52	--		1.1%	
Total DDx (4,4')	µg/kg	Phase II	North	80	Subtidal Flat	Yes	2.5	5.5	9.5	25	26	43	75	110	1.5%	2.1%	2.4%
Total DDx (4,4')	µg/kg	Phase I	North	58	Intertidal	No	--	0.5	1.5	--	51	--	150	130		2.6%	1.8%
Total DDx (4,4')	µg/kg	Phase I	North	57	Subtidal Flat	Yes	0.5	2.5	--	30	27	69	77	--	2.3%	1.8%	
Total DDx (4,4')	µg/kg	Phase II	North	79	Subtidal Flat	Yes	1.5	3.5	5.5	30	16	54	145	360	1.6%	3.0%	4.0%
Total DDx (4,4')	µg/kg	Phase II	North	93	Subtidal Flat (Disturbed)	No	--	--	0.5	99.5	230	--	--	280			1.7%
Total DDx (4,4')	µg/kg	Phase II	North	78	Subtidal Flat (Disturbed)	No	9.5	17.5	23.5	40	51	120	160	340	3.1%	2.6%	3.5%
Total DDx (4,4')	µg/kg	Phase II	North	77	Subtidal Flat (Disturbed)	Yes	0.5	2.5	5.5	32	20	36	72	55	0.3%	1.5%	0.9%
Total DDx (4,4')	µg/kg	Phase I	North	56	Subtidal Flat (Disturbed)	No	1.5	2.5	5	32	35	89	170	400	2.8%	3.2%	4.1%
Total DDx (4,4')	µg/kg	Phase II	North	76	Subtidal Flat (Disturbed)	No	1.5	3.5	7.5	36	24	60	135	700	1.4%	2.5%	4.8%
Total DDx (4,4')	µg/kg	Phase I	North	51	Subtidal Flat (Disturbed)	No	1.5	5	--	36	35	140	310	--	3.8%	4.1%	
Total DDx (4,4')	µg/kg	Phase II	Central	74	Subtidal Flat (Disturbed)	No	2.5	5.5	9.5	--	33	100	190	360	4.1%	4.0%	4.5%
Total DDx (4,4')	µg/kg	Phase I	Central	44	Subtidal Flat (Disturbed)	Yes	2.5	--	--	--	23	91	--	--	5.5%		
Total DDx (4,4')	µg/kg	Phase II	Central	92	Subtidal Flat (Disturbed)	No	2.5	5.5	9.5	30	27	67	250	490	2.2%	4.0%	4.5%
Total DDx (4,4')	µg/kg	Phase I	Central	37	Subtidal Flat	Yes	--	0.5	1.5	24	41	--	150	330		3.5%	4.2%
Total DDx (4,4')	µg/kg	Phase II	Central	73	Subtidal Flat	No	0.5	1.5	2.5	26	49	41	94	110	1.3%	2.4%	2.3%
Total DDx (4,4')	µg/kg	Phase I	Central	32	Subtidal Flat	Yes	0.5	2.5	--	26	33	64	100	--	2.5%	2.5%	
Total DDx (4,4')	µg/kg	Phase II	Central	91	Subtidal Flat (Disturbed)	Yes	0.5	2.5	3.5	27	19	27	64	355	0.0%	1.6%	4.2%
Total DDx (4,4')	µg/kg	Phase I	Central	28	Subtidal Flat (Disturbed)	Yes	1.5	2.5	5	--	25	51	100	5	2.9%	3.3%	-3.2%
Total DDx (4,4')	µg/kg	Phase II	Central	72	Subtidal Flat	Yes	0.5	1.5	2.5	--	39	59	42	29	1.5%	0.2%	-0.6%
Total DDx (4,4')	µg/kg	Phase II	South	98	Subtidal Flat (Disturbed)	Yes	2.5	5.5	9.5	--	52	100	150	43	2.4%	2.4%	-0.4%
Total DDx (4,4')	µg/kg	Phase I	South	23	Subtidal Flat	Yes	--	0.5	1.5	75	110	--	100	48		0.5%	-0.7%
Total DDx (4,4')	µg/kg	Phase II	South	71	Transitional Slope	Yes	1.5	3.5	5.5	--	13	25	78	290	2.4%	4.1%	5.9%
Total DDx (4,4')	µg/kg	Phase I	South	16	Transitional Slope	Yes	--	0.5	--	--	23	--	130	--		4.1%	
Total DDx (4,4')	µg/kg	Phase I	South	15	Subtidal Flat	No	0.5	1.5	2.5	120	**<120**	560	270	74	4.3%	1.5%	-0.8%
Total DDx (4,4')	µg/kg	Phase II	South	70	Subtidal Flat (Disturbed)	No	0.5	2.5	3.5	69	75	110	210	465	1.3%	2.1%	3.1%
Total DDx (4,4')	µg/kg	Phase II	South	90	Subtidal Flat (Disturbed)	No	3.5	--	7.5	26	26	130	--	300	4.5%		3.9%
Total DDx (4,4')	µg/kg	Phase II	South	89	Transitional Slope	Yes	2.5	3.5	11.5	360	95	280	300	950	-0.7%	-0.3%	1.6%
Total DDx (4,4')	µg/kg	Phase II	South	82	Industrial Waterfront	Yes	3.5	--	7.5	--	210	93	--	200	-3.0%		-0.1%
Total DDx (4,4')	µg/kg	Phase I	South	12	Industrial Waterfront	No	0.5	1.5	5	220	**<170**	**<240**	**<140**	1020	0.0%	-2.2%	2.5%
Total DDx (4,4)														**Average**	**2.0%**	**2.2%**	**2.3%**
Total PCB congeners	µg/kg	Phase II	North	94	Navigation Channel	Yes	--	25.5	--	--	551	--	1490	--		2.3%	
Total PCB congeners	µg/kg	Phase II	North	80	Subtidal Flat	Yes	2.5	5.5	9.5	275	490	1380	3090	4990	4.5%	4.6%	4.7%
Total PCB congeners	µg/kg	Phase I	North	58	Intertidal	No	--	0.5	1.5	--	1730	--	3770	709		1.9%	-1.7%
Total PCB congeners	µg/kg	Phase I	North	57	Subtidal Flat	Yes	0.5	2.5	--	430	573	2070	4200	--	4.4%	4.3%	
Total PCB congeners	µg/kg	Phase II	North	79	Subtidal Flat	Yes	1.5	3.5	5.5	430	709	6250	6420	4090	7.4%	5.1%	3.6%
Total PCB congeners	µg/kg	Phase II	North	93	Subtidal Flat (Disturbed)	No	--	--	0.5	3165	1070	--	--	2220			-0.6%

Table 5-15
Concentrations and Calculated Long-Term Rates of Decline for Selected COCs in Dateable Phase I and II Core Intervals

COC	Unit	Sampling Program for Core	Geographic Area	Core Location ID	Geomorphic Unit	Be-7 Bearing	Start Depth of Dated Core Interval (feet below sediment surface)			Concentration in Dated Depth Interval					Long-Term Annual Rate of Decline (or Increase if Negative)		
							1980	1963 (Cs-137 Peak)	1954 (Cs-137 Horizon)	Surface Interval (Phase III)	Surface Interval (Phase I/II)	1980	1963 (Cs-137 Peak)	1954 (Cs-137 Horizon)	Since 1980	Since 1963[a]	Since 1954[a]
Total PCB congeners	µg/kg	Phase II	North	78	Subtidal Flat (Disturbed)	No	9.5	17.5	23.5	484	761	11000	14200	6730	8.7%	6.4%	4.2%
Total PCB congeners	µg/kg	Phase II	North	77	Subtidal Flat (Disturbed)	Yes	0.5	2.5	5.5	555	646	1930	5880	2310	3.5%	4.5%	2.3%
Total PCB congeners	µg/kg	Phase I	North	56	Subtidal Flat (Disturbed)	No	1.5	2.5	5	555	1090	6320	6530	5290	6.8%	4.7%	3.6%
Total PCB congeners	µg/kg	Phase II	North	76	Subtidal Flat (Disturbed)	No	1.5	3.5	7.5	511	581	2540	6955	2010	4.5%	4.9%	2.2%
Total PCB congeners	µg/kg	Phase I	North	51	Subtidal Flat (Disturbed)	No	1.5	5	--	511	642	2740	7730	--	4.7%	5.1%	
Total PCB congeners	µg/kg	Phase II	Central	74	Subtidal Flat (Disturbed)	No	2.5	5.5	9.5	--	489	3630	8240	4410	7.4%	6.4%	4.1%
Total PCB congeners	µg/kg	Phase I	Central	44	Subtidal Flat (Disturbed)	Yes	2.5	--	--	--	679	3600	--	--	6.7%		
Total PCB congeners	µg/kg	Phase II	Central	92	Subtidal Flat (Disturbed)	No	2.5	5.5	9.5	368	500	4040	8110	5710	6.7%	5.8%	4.4%
Total PCB congeners	µg/kg	Phase I	Central	37	Subtidal Flat	Yes	--	0.5	1.5	369	469	--	1750	1800		2.9%	2.6%
Total PCB congeners	µg/kg	Phase II	Central	73	Subtidal Flat	No	0.5	1.5	2.5	390	1680	725	3330	3980	1.7%	4.0%	3.7%
Total PCB congeners	µg/kg	Phase I	Central	32	Subtidal Flat	Yes	0.5	2.5	--	390	520	1230	5250	--	3.2%	4.9%	
Total PCB congeners	µg/kg	Phase II	Central	91	Subtidal Flat (Disturbed)	Yes	0.5	2.5	3.5	535	485	743	5060	2850	0.9%	4.2%	2.7%
Total PCB congeners	µg/kg	Phase I	Central	28	Subtidal Flat (Disturbed)	Yes	1.5	2.5	5	--	461	752	3250	38.7	2.0%	4.7%	-4.9%
Total PCB congeners	µg/kg	Phase II	Central	72	Subtidal Flat	Yes	0.5	1.5	2.5	--	585	763	1040	433	1.0%	1.3%	-0.6%
Total PCB congeners	µg/kg	Phase II	South	98	Subtidal Flat (Disturbed)	Yes	2.5	5.5	9.5	--	414	1140	1120	1630	3.8%	2.3%	2.6%
Total PCB congeners	µg/kg	Phase I	South	23	Subtidal Flat	Yes	--	0.5	1.5	1680	818	--	2500	685		0.7%	-1.4%
Total PCB congeners	µg/kg	Phase II	South	71	Transitional Slope	Yes	1.5	3.5	5.5	--	431	662	3575	2520	1.6%	4.8%	3.3%
Total PCB congeners	µg/kg	Phase I	South	16	Transitional Slope	Yes	--	0.5	--	--	395	--	632	--		1.1%	
Total PCB congeners	µg/kg	Phase I	South	15	Subtidal Flat	No	0.5	1.5	2.5	314	1520	5070	7480	1090	7.7%	6.0%	2.0%
Total PCB congeners	µg/kg	Phase II	South	70	Subtidal Flat (Disturbed)	No	0.5	2.5	3.5	392	1680	3160	4450	2510	5.8%	4.6%	3.0%
Total PCB congeners	µg/kg	Phase II	South	90	Subtidal Flat (Disturbed)	No	3.5	--	7.5	95.1	918	8640	--	9360	12.5%		7.4%
Total PCB congeners	µg/kg	Phase II	South	89	Transitional Slope	Yes	2.5	3.5	11.5	614	972	12400	9805	4180	8.3%	5.2%	3.1%
Total PCB congeners	µg/kg	Phase II	South	82	Industrial Waterfront	Yes	3.5	--	7.5	--	3270	11400	--	32100	4.6%		4.3%
Total PCB congeners	µg/kg	Phase I	South	12	Industrial Waterfront	No	0.5	1.5	5	2170	7700	4590	5610	3525	2.1%	1.8%	0.8%
Total PCB congeners														**Average**	**5.0%**	**4.0%**	**2.3%**

Notes:
The calculated rate of decline is based on the change in concentration from the dated core interval (i.e. 1980, 1963, or 1954) until 2016 as represented by the co-located Phase III sample concentration. If no Phase III sample was collected at the location, the calculated rate of decline is based on the change in concentration from the dated core interval until 2005 or 2007 as represented by the surface interval in the core.
The dates assigned to core sampling intervals are as described in the Phase I and II Sediment Deposition Report (Tierra 2011). All dateable cores are included. The interval that includes 1980 is assigned the date of 1980. The interval that includes the Cs-137 peak concentration is assigned the date of 1963. The interval that includes the Cs-137 horizon is assigned the date of 1954. Cs-137 dating was used to define the 1980 interval for all cores except 044, for which the Pb-210 dating methods were used.
Cores are ordered by Bay mile from north to south.
[a]Historical rates of decline are estimated for areas where historical disturbance and subsequent high deposition occurred and is based on datable cores where Cs-137 peaks were observed. Since contaminant loading was ongoing after 1963, these rates may not represent natural recovery rates after sources were controlled.
Non-detects are reported at the quantitation limit, appear in bold font, and are indicated by the "less than" symbol (<).

Acronyms and Abbreviations:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
-- = indicates that no sample interval could be assigned to that date
< = less than
Be-7 = beryllium-7
COC = constituent of concern
Cs-137 = cesium-137
Pb-210 = lead-210
PCB = polychlorinated biphenyl
Total DDx = sum of dichlorodiphenyltrichloroethane, dichlorodiphenyldichloroethane and dichlorodiphenyldichloroethylene
µg/kg = micrograms per kilogram
% = percent

References:
Tierra. 2011. Final Newark Bay Study Area Remedial Investigation Phase I and Phase II Sediment Deposition Report. Revision 1. October.

Table 5-17
Acid Volatile Sulfide and Simultaneously Extracted Metals in NBSA Sediments

Geographic Area	Location ID	TOC (%)	∑SEM (µmol/g)	AVS (µmol/g)	∑SEM - AVS (µmol/g)	∑SEM - AVS/ f_{oc} (µmol/g-oc)
North	NB03SED122ACL	0.65%	1.22	--	--	--
	NB03SED122BCL	1.5%	1.0	0.89	0.11	7.1
	NB03SED122CCL	3.3%	1.1	0.96	0.19	5.8
	NB03SED123ACL	0.50%	1.6	4.7	-3.1	-622
	NB03SED123BCL	0.70%	2.4	1.5	0.93	134
	NB03SED132ACL	0.36%	1.5	2.2	-0.72	-199
	NB03SED132BCL	0.17%	0.30	1.2	-0.90	-535
	NB03SED133CL	5.4%	2.8	2.6	0.22	4.0
	NB03SED136	3.3%	1.7	14	-12	-364
	NB03SED137	5.7%	1.4	14	-13	-224
	NB03SED138	5.3%	1.5	1.2	0.31	5.8
	NB03SED139	2.9%	1.5	0.82	0.66	22
	NB03SED140	1.8%	1.5	1.1	0.43	24
	NB03SED158	2.7%	0.97	3.5	-2.5	-94
	NB03SED159	3.9%	1.5	30	-29	-738
	NB03SED160	2.7%	2.8	5.8	-3.0	-110
	NB03SED161	4.4%	1.8	14	-12	-279
	NB03SED162	3.4%	1.4	2.8	-1.4	-41
	NB03SED163	5.5%	1.6	16	-14	-255
	NB03SED164	2.8%	1.1	2.1	-1.0	-36
	NB03SED165	7.3%	1.4	13	-12	-161
	NB03SED166	5.4%	2.1	34	-32	-594
	NB03SED167	0.92%	1.3	1.2	0.13	14
	NB03SED168	3.5%	1.8	6.7	-4.9	-138
	NB03SED169	1.6%	1.0	5.3	-4.3	-261
Central	NB03SED124CL	0.12%	1.27	--	--	--
	NB03SED125CL	0.54%	1.3	3.0	-1.7	-310
	NB03SED127ACL	0.26%	0.97	4.6	-3.6	-1401
	NB03SED127BCL	1.2%	2.1	2.2	-0.12	-10
	NB03SED141	3.2%	1.4	14	-13	-391
	NB03SED142	2.2%	1.5	<0.63	<1.5	<68
	NB03SED143	4.8%	3.1	18	-15	-315
	NB03SED144	1.9%	1.9	16	-14	-736
	NB03SED145	2.1%	1.8	1.1	0.71	33
	NB03SED156	3.2%	1.2	4.2	-3.0	-95
	NB03SED157	2.6%	1.5	16	-15	-573
	NB03SED170	3.2%	1.5	28	-27	-848
	NB03SED171	2.8%	1.9	20	-18	-655
	NB03SED172	5.2%	2.7	8.6	-5.9	-114
South	NB03SED129CL	4.9%	12	3.2	9	189
	NB03SED130CL	2.0%	1.7	5.0	-3.3	-169
	NB03SED131ACL	0.89%	0.69	4.4	-3.7	-411
	NB03SED131BCL	0.12%	0.52	4.3	-3.8	-3262
	NB03SED134CL	3.3%	13	13	0.48	15
	NB03SED135CL	1.8%	1.7	6.5	-4.8	-262
	NB03SED146	2.0%	1.2	3.8	-2.6	-132
	NB03SED147	4.1%	2.9	37	-34	-834
	NB03SED148	2.6%	3.3	25	-22	-835
	NB03SED149	6.1%	3.4	21	-17	-287
	NB03SED150	5.0%	1.9	7.0	-5.1	-101
	NB03SED151	4.1%	3.7	86	-82	-2000
	NB03SED152	6.7%	2.2	5.9	-3.6	-55
	NB03SED153	2.7%	1.3	8.9	-7.6	-281
	NB03SED154	15%	5.6	54	-48	-319
	NB03SED155	0.32%	0.63	<0.63	<0.63	<199
	NB03SED173	4.7%	2.3	14	-11	-244
	NB03SED174	4.4%	1.6	18	-17	-381
	NB03SED175	1.4%	1.5	1.8	0	-25
	NB03SED176	3.9%	4.2	11	-7	-181
	NB03SED177	6.1%	0.37	0.66	0	-4.7
	NB03SED178	4.8%	1.9	7.4	-5	-113

Table 5-17
Acid Volatile Sulfide and Simultaneously Extracted Metals in NBSA Sediments

Note:
AVS-SEM summations were calculated as described in USEPA guidance (USEPA 2005).

Acronyms and Abbreviations:
< = not detected. The value of the quantitation limit is shown for sediment.
∑ = sum of
AVS = acid volatile sulfide
f_{oc} = fraction of organic carbon
ID = identification
NBSA = Newark Bay Study Area
SEM = simultaneously extracted metals (cadmium, copper, lead, nickel, and zinc)
TOC = total organic carbon
USEPA = U.S. Environmental Protection Agency
µmol/g = micromoles per gram
µmol/g-oc = micromoles per gram of organic carbon
% = percent

Reference:
USEPA. 2005. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver and Zinc). EPA-600-R-02-011. Office of Research and Development. Washington, DC 20460.

Table 6-2
COPCs Evaluated in the Baseline Human Health Risk Assessment

Chemical	Sediment	Surface Water	Blue crab Tissue	Fish Tissue
Dioxin-like Compounds				
All 17 2,3,7,8-chlorine substituted dioxin and furan congeners (e.g. 2,3,7,8-TCDD)	✓	✓	✓	✓
Dioxin TEQ	✓	✓	✓	✓
All 12 Dioxin-like PCB Congeners	✓	✓	✓	✓
PCB TEQ	✓	✓	✓	✓
Non-dioxin-like PCBs				
Total PCBs (not dioxin-like)	✓		✓	✓
Pesticides/Herbicides				
2,4'-DDD			✓	✓
2,4'-DDE				✓
2,4'-DDT				✓
4,4'-DDD			✓	✓
4,4'-DDE			✓	✓
4,4'-DDT			✓	✓
Chlordane alpha (cis)			✓	✓
Chlordane gamma (trans)			✓	✓
Dieldrin			✓	✓
Heptachlor epoxide			✓	✓
Hexachlorobenzene			✓	✓
Mirex			✓	✓
Nonachlor cis-			✓	✓
Nonachlor trans-			✓	✓
Oxychlordane			✓	✓
PAHs				
Benzo(a)anthracene	✓	✓	✓	✓
Benzo(a)pyrene	✓	✓	✓	✓
Benzo(b)fluoranthene	✓	✓	✓	✓
Benzo(j,k)fluoranthene			✓	
Benzo(k)fluoranthene	✓	✓	✓	
Chrysene	✓	✓	✓	✓
Dibenzo(a,h)anthracene	✓	✓	✓	✓
Indeno[1,2,3-cd]-pyrene	✓	✓	✓	✓
Naphthalene		✓		
Other organic compounds				
Benzaldehyde			✓	✓
Chloroform		✓		
PHC as gasoline	✓			
Pyridine			✓	✓
TPH (C9-C40)	✓			
Trichloroethylene		✓		

Table 6-2
COPCs Evaluated in the Baseline Human Health Risk Assessment

Chemical	Sediment	Surface Water	Blue crab Tissue	Fish Tissue
Inorganics				
Aluminum	✓		✓	✓
Antimony	✓	✓	✓	✓
Arsenic, organic			✓	✓
Arsenic, inorganic	✓	✓	✓	✓
Cadmium	✓		✓	✓
Chromium (VI)	✓	✓		
Chromium [as Cr(III)]	✓	✓	✓	✓
Copper	✓		✓	✓
Iron	✓	✓	✓	✓
Lead	✓		✓	✓
Manganese	✓	✓	✓	✓
Mercury	✓	✓	✓	✓
Methyl mercury			✓	✓
Nickel	✓			
Selenium			✓	✓
Silver			✓	✓
Thallium	✓	✓	✓	✓
Titanium		✓	✓	✓
Vanadium	✓		✓	✓
Zinc	✓		✓	✓

Notes:
This is a list of COPCs fully evaluated in the BHHRA. For a complete list of chemicals evaluated in uncertainty analyses, see Table 3-13 of the BHHRA (GSH 2019).

Acronyms and Abbreviations:
BHHRA = baseline human health risk assessment
COPEC = constituent of potential ecological concern
DDD = dichlorodiphenyldichloroethane
DDE = dichlorodiphenyldichloroethylene
DDT = dichlorodiphenyltrichloroethane
PAH = polycyclic aromatic hydrocarbons
PCB = polychlorinated biphenyls
PHC = petroleum hydrocarbons
TCDD = tetrachlorodibenzo-p-dioxin
TEQ = toxic equivalent
TPH = total petroleum hydrocarbons
VOC = volatile organic compound

Source:
GSH. 2019. Final Baseline Human Health Risk Assessment. Newark Bay Study Area. December.

Table 6-3
Summary of Cancer Risks for Reasonable Maximum Exposure

Receptor Population	Age Group	Accessible Surface sediment	Surface Water	Mixed Fish Diet	Crab Muscle and Hepatopancreas
Angler/ Sportsman	Child	Incomplete Pathway		**3E-04**	**3E-04**
	Adolescent	2E-06	8E-08	**3E-04**	**3E-04**
	Adult	4E-06	5E-08	**6E-04**	**6E-04**
	Adult/Child	4E-06	5E-08	**8E-04**	**8E-04**
Swimmer	Child	1E-06	2E-07	Incomplete Pathways	
	Adolescent	2E-06	5E-07		
	Adult	1E-06	9E-08		
	Adult/Child	2E-06	3E-07		
Wader	Child	1E-06	3E-08		
	Adolescent	2E-06	6E-08		
	Adult	1E-06	1E-08		
	Adult/Child	2E-06	4E-08		
Boater	Child	Incomplete Pathway			
	Adolescent	2E-06	3E-07		
	Adult	4E-07	3E-07		
	Adult/Child	Not Applicable			
Worker	Adult	3E-06	Not quantified		

Notes:
Entries in **bold** indicate that the cumulative potential carcinogenic risk exceeds 10^{-4}, the NCP risk range.
Adult/child gives risks for adult and child age groups summed to yield a 26-year total exposure duration.

Table 6-4
Summary of Cancer Risks for Central Tendency Exposure

Receptor Population	Age Group	Accessible Surface sediment	Surface Water	Mixed Fish Diet	Crab Muscle and Hepatopancreas
Angler/ Sportsman	Child	Incomplete Pathway		**9E-06**	**2E-05**
	Adolescent	4E-07	8E-09	**1E-05**	**2E-05**
	Adult	6E-07	5E-09	**2E-05**	**3E-05**
	Adult/Child	6E-07	5E-09	**3E-05**	**5E-05**
Swimmer	Child	2E-07	4E-08	Incomplete Pathways	
	Adolescent	3E-07	1E-07		
	Adult	2E-07	2E-08		
	Adult/Child	3E-07	5E-08		
Wader	Child	2E-07	1E-08		
	Adolescent	3E-07	7E-09		
	Adult	2E-07	1E-09		
	Adult/Child	3E-07	6E-09		
Boater	Child	Incomplete Pathway			
	Adolescent	3E-07	7E-08		
	Adult	6E-08	4E-08		
	Adult/Child	Not Applicable			
Worker	Adult	3E-07	Not quantified		

Notes:
Adult/child gives risks for adult and child age groups summed to yield a 26-year total exposure duration.

Table 6-5
Summary of Noncancer Hazard Indices for Reasonable Maximum Exposure

Receptor Population	Age Group	Accessible Surface sediment	Surface Water	Mixed Fish Diet	Crab Muscle and Hepatopancreas
Angler/ Sportsman	Child	Incomplete Pathway		**40**	**50**
	Adolescent	0.1	0.002	**30**	**30**
	Adult	0.1	0.001	**30**	**30**
Swimmer	Child	0.1	0.008	Incomplete Pathways	
	Adolescent	0.1	0.01		
	Adult	0.03	0.003		
Wader	Child	0.2	0.001		
	Adolescent	0.1	0.002		
	Adult	0.03	0.0004		
Boater	Child	Incomplete Pathway			
	Adolescent	0.1	0.009		
	Adult	0.02	0.009		
Worker	Adult	0.09	Not quantified		

Notes:
Entries in bold indicate that one or more target organ specific hazard indices exceed one.

Table 6-6
Summary of Noncancer Hazard Indices for Central Tendency Exposure

Receptor Population	Age Group	Accessible Surface sediment	Surface Water	Mixed Fish Diet	Crab Muscle and Hepatopancreas
Angler/ Sportsman	Child	Incomplete Pathway		**4**	**7**
	Adolescent	0.04	0.0005	**2**	**4**
	Adult	0.04	0.0004	**2**	**4**
Swimmer	Child	0.05	0.004	Incomplete Pathways	
	Adolescent	0.03	0.006		
	Adult	0.01	0.001		
Wader	Child	0.05	0.0004		
	Adolescent	0.03	0.0004		
	Adult	0.01	0.0001		
Boater	Child	Incomplete Pathway			
	Adolescent	0.03	0.005		
	Adult	0.004	0.003		
Worker	Adult	0.03	Not quantified		

Notes:
Entries in **bold** indicate that one or more target organ specific hazard indices exceed one.

Table 6-7
Contaminants of Potential Concern for Reasonable Maximum Exposure

Group	Potential COC	Accessible Surface Sediment	Mixed Fish Diet	Crab Muscle and Hepatopancreas
Dioxins/Furans	2,3,7,8-TCDD		X	X
	TCDD-TEQ		X	X
PCBs	DL-PCB-TEQ		X	X
	Total Non-DL PCBs		X	X
PAHs	Benzo(a)pyrene		X	
	Dibenz(a,h,)anthracene		X	
Pesticides and Organics	2,4'-DDD		X	
	4,4'-DDD, 4'4'-DDE		X	X
	Alpha-Chlordane		X	
	Dieldrin		X	X
	Heptachlor epoxide		X	X
	Trans-Nonachlor		X	X
	Pyridine		X	X
Inorganics	Arsenic	X	X	X
	Cadmium			X
	Cobalt		X	X
	Copper		X	X
	Mercury		X	X
	Methyl Mercury		X	X

Table 6-10
COPECs Evaluated for Shellfish, Fish, and Wildlife Receptors in the BERA

COPEC	COPECs for the NBSA BERA						
	Benthic Invertebrate Tissue	Fish Tissue	Fish Egg	Fish Diet	Bird Egg	Bird Diet	Mammal Diet
Dioxins/Furans							
2,3,7,8-TCDD	X	X	X		X	X	X
Total Dioxin/Furan TEQ Fish		X	X				
Total Dioxin/Furan TEQ Bird					X	X	
Total Dioxin/Furan TEQ Mammal							X
PCBs							
Total PCBs	X	X	X		X	X	X
Total PCB TEQ Fish		X	X				
Total PCB TEQ Bird					X	X	
Total PCB TEQ Mammal							X
Total Dioxin/Furan/PCB TEQ Fish		X	X				
Total Dioxin/Furan/PCB TEQ Bird					X	X	
Total Dioxin/Furan/PCB TEQ Mammal							X
Pesticides							
Total DDx (2,4' & 4,4')	X	X			X	X	X
Dieldrin	X	X			X	X	X
Total Chlordane	X	X			X	X	X
Hexachlorobenzene	X	X			X	X	X
PAHs							
Total HMW PAH	X						
Total LMW PAH	X						
Total PAH	X			X	X	X	X
Inorganics							
Arsenic	X	X		X		X	X
Cadmium	X			X	X	X	X
Chromium	X	X		X		X	X
Copper	X	X		X		X	X
Lead	X	X		X		X	X
Mercury/Methylmercury	X	X	X	X	X	X	X
Nickel	X			X		X	X
Selenium	X	X		X		X	X
Silver	X	X		X		X	X
Zinc	X	X		X		X	X

Notes:

[a] Total chlordane is the sum of heptachlor epoxide, oxychlordane, heptachlor endo-epoxide, trans-nonachlor, alpha-chlordane, cis-nonachlor, gamma-chlordane, and heptachlor.

X = Indicates the constituent is a COPEC for the species and line of evidence

Table 6-11a
Weight of Evidence Risk Summary for NBSA BERA

Receptor	Preliminary COC[a]	Primary LOE	Summary of LOE	Risk Conclusions	Risk Driver[b]
Assessment Endpoint: Survival, growth, and/or reproduction of benthic invertebrates					
Benthic Invertebrate Communities	see Table 6-11b for Sediment Quality Triad risk conclusions			Localized Risk per SQT	
Polychaete Worm	2,3,7,8-TCDD, Total PCBs, Arsenic	SQT	• Localized risk to benthic communities (see Table 6-11b for conclusions of SQT) • No effect on growth/survival in site-specific toxicity tests (Iannuzzi et al. 2008)	Localized Risk per SQT	
Softshell Clam	2,3,7,8-TCDD, Total PCBs	Tissue HQs	• LPR FFS HQs ≥ 1 • LPR FFS TRVs based on bivalve data • Site-specific study on eastern oyster indicates potential bivalve reproductive impairment (Wintermyer and Cooper 2003)	Possible	Yes
Softshell Clam	Arsenic, Lead	Tissue HQs	• High magnitude of the HQs ≥ 1 • High uncertainty with invertebrate tissue HQ approach	Possible	Yes
Softshell Clam	Mercury	Tissue HQs	• NBSA and LPR FFS HQs ≥ 1 in all scenarios • Low magnitude of the HQs ≥ 1 • Invertebrate tissue HQ approach for mercury/methylmercury less uncertain	Possible	Yes
Softshell Clam	Total HMW PAHs, Cadmium, Chromium, Copper, Nickel, Selenium, Silver, Zinc	Tissue HQs	• Low magnitude of the HQs ≥ 1 • High uncertainty with invertebrate tissue HQ approach • Selenium and silver present at concentrations near or below background	Unlikely	No
Blue Crab	2,3,7,8-TCDD, Total PCBs	Tissue HQs	• LPR FFS HQs ≥ 1 • High magnitude of the HQs ≥ 1 • LPR FFS TRVs based on bivalve data and considered uncertain for crabs	Possible	Yes
Blue Crab	Total DDx (2,4' & 4,4')	Tissue HQs	• High magnitude of the HQs ≥ 1 based on alternate NBSA TRVs • High uncertainty with invertebrate tissue HQ approach	Possible	Yes
Blue Crab	Mercury, Methylmercury	Tissue HQs	• NBSA and LPR FFS HQs ≥ 1 in all scenarios • Low magnitude of the HQs ≥ 1 • Invertebrate tissue HQ approach for mercury/methylmercury less uncertain	Possible	Yes
Blue Crab	Dieldrin, Arsenic, Cadmium, Copper, Mercury, Methylmercury, Selenium, Silver	Tissue HQs	• Low magnitude of the HQs ≥ 1 • High uncertainty with invertebrate tissue HQ approach • Selenium and silver present at concentrations near or below background	Unlikely	No

Table 6-11a
Weight of Evidence Risk Summary for NBSA BERA

Receptor	Preliminary COC[a]	Primary LOE	Summary of LOE	Risk Conclusions	Risk Driver[b]
Assessment Endpoint: Survival, growth, and/or reproduction of fish					
Mummichog/Killifish	Dioxins/Furans and TEQ (2,3,7,8-TCDD, Total Dioxin/Furan TEQ Fish, PCB TEQ Fish, Dioxin/Furan/PCB TEQ Fish), Total PCBs	Tissue HQs	• LPR FFS WB tissue HQs > 10 • Alternate NBSA WB tissue HQs > 1 • NBSA WB tissue HQs < 1 • Egg HQs < 1 • Site-specific pathology data did not show abnormalities • Site-specific reproductive study indicates endocrine impairments. relative to populations that are not urban-adapted (Bugel et al. 2010, 2011, 2014)	Possible	Yes
Mummichog/Killifish	Total PCB TEQ Fish	Tissue HQs	• Tissue LOAEL HQs < 1 for most scenarios • Egg HQs < 1 • Low magnitude of the HQs ≥ 1 • Site-specific pathology data did not show abnormalities	Unlikely	No
Mummichog/Killifish	Total DDx (2,4' & 4,4')	Tissue HQs	• LOAEL HQs < 1 in most scenarios • Low magnitude of HQs ≥ 1 in Southwest Zone • Site-specific pathology data did not show abnormalities	Unlikely	No
Mummichog/Killifish	Cadmium	Tissue HQs	• Cadmium not detected in fish tissue • Low magnitude of dietary HQs ≥ 1 • Diet assumptions overestimate dietary exposure • Site-specific pathology data did not show abnormalities	Unlikely	No
Mummichog/Killifish	Copper	Background	• Tissue copper at/within background • Dietary HQs < 1 • Low magnitude of tissue HQs ≥ 1 • Diet assumptions overestimate dietary exposure • Site-specific pathology data did not show abnormalities	Unlikely	No
Mummichog/Killifish	Mercury, Methylmercury	Tissue HQs	• WB Tissue HQs < 1 • Dietary HQs < 1 in most scenarios • Low magnitude of dietary HQs ≥ 1 in Southwest Zone • Egg LOAEL HQs < 1 • Site-specific pathology data did not show abnormalities	Unlikely	No
Mummichog/Killifish	Silver	Background	• Tissue LOAEL HQs < 1 in most scenarios • Silver < background in sediment • Low magnitude of tissue HQs ≥ 1 in North Zone • Dietary LOAEL HQs < 1 • Low confidence in both tissue and dietary TRVs • Site-specific pathology data did not show abnormalities	Unlikely	No

Table 6-11a
Weight of Evidence Risk Summary for NBSA BERA

Receptor	Preliminary COC[a]	Primary LOE	Summary of LOE	Risk Conclusions	Risk Driver[b]
American Eel	Dioxins/Furans and TEQ (2,3,7,8-TCDD, Total Dioxin/Furan TEQ Fish, Dioxin/Furan/PCB TEQ Fish)	Tissue HQs	• LPR FFS WB tissue HQs approaching 10 • NBSA WB tissue HQs < 1 • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Possible	Yes
American Eel	Total PCBs	Tissue HQs	• NBSA WB tissue HQs < 1 • Low magnitude of the WB tissue HQs ≥ 1 based on LPR FFS TRVs • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
American Eel	Total DDx (2,4' & 4,4')	Tissue HQs	• NBSA WB tissue HQs < 1 • Low magnitude of the WB tissue HQs ≥ 1 based on LPR FFS TRVs in North Zone • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
American Eel	Cadmium	Tissue HQs	• Cadmium not detected in fish tissue • Low magnitude of dietary HQs ≥ 1 • Diet assumptions overestimate dietary exposure • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
American Eel	Copper	Dietary HQs	• Dietary HQs < 1 for all scenarios • Low magnitude of tissue HQs ≥ 1 in Southwest Zone • Diet assumptions overestimate dietary exposure • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
American Eel	Mercury/Methylmercury	Tissue HQs	• Tissue LOAEL HQs < 1 in most scenarios • Dietary LOAEL HQs < 1 in most scenarios • Low magnitude of LOAEL HQs ≥ 1 • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No

Table 6-11a
Weight of Evidence Risk Summary for NBSA BERA

Receptor	Preliminary COC[a]	Primary LOE	Summary of LOE	Risk Conclusions	Risk Driver[b]
American Eel	Selenium	Background	• Selenium < background in sediment • Tissue LOAEL HQs < 1 in most scenarios • Low magnitude of tissue HQs ≥ 1 in Southeast Zone • Dietary HQs < 1 • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
Summer/Winter Flounder	Dioxins/Furans and TEQ (2,3,7,8-TCDD, Total Dioxin/Furan TEQ Fish, Dioxin/Furan/PCB TEQ Fish)	Tissue HQs	• LPR FFS WB tissue HQs approaching 10 • NBSA WB tissue HQs < 1 • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Possible	Yes
Summer/Winter Flounder	Total PCBs	Tissue HQs	• LOAEL HQs < 1 for most scenarios • Low magnitude of the HQs ≥ 1 in the North Zone • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
Summer/Winter Flounder	Cadmium	Tissue HQs	• Cadmium not detected in fish tissue • Low magnitude of dietary HQs ≥ 1 • Dietary HQs in Southwest Zone calculated using clam MDC • Diet assumptions overestimate dietary exposure • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
Summer/Winter Flounder	Copper	Dietary HQs	• Dietary HQs < 1 • WB tissue HQs < 1 in most scenarios • Low magnitude of tissue HQs ≥ 1 in North Zone • Diet assumptions overestimate dietary exposure • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
Summer/Winter Flounder	Mercury/Methylmercury	Tissue HQs	• Tissue LOAEL HQs < 1 • Low magnitude of dietary HQs ≥ 1 • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No

Table 6-11a
Weight of Evidence Risk Summary for NBSA BERA

Receptor	Preliminary COC[a]	Primary LOE	Summary of LOE	Risk Conclusions	Risk Driver[b]
White Perch	Dioxins/Furans and TEQ (2,3,7,8-TCDD, Total Dioxin/Furan TEQ Fish, Dioxin/Furan/PCB TEQ Fish)	Tissue HQs	• WB tissue LOAEL HQs ≥ 1 for most scenarios • WB tissue LPR FFS LOAEL HQs > 10 for all scenarios • Liver LOAEL HQs < 1 • Liver HQs superseded by WB tissue HQs • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Possible	Yes
White Perch	Total PCB TEQ, Total PCBs	Tissue HQs	• WB tissue LOAEL HQs < 1 in most scenarios • Low magnitude of the WB tissue HQs ≥ 1 • Liver LOAEL HQs < 1 • Liver HQs superseded by WB tissue HQs • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
White Perch	Total DDx (2,4' & 4,4')	Tissue HQs	• WB tissue LOAEL HQs > 1 in most cases • Low magnitude of the tissue LOAEL HQ ≥ 1 • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Possible	Yes
White Perch	Arsenic, Zinc	Tissue HQs	• Tissue and dietary HQs < 1 • Low magnitude of the liver HQs ≥ 1 (arsenic) or based on unbounded NOAEL (zinc) • Liver HQs superseded by WB tissue HQs • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
White Perch	Cadmium	Tissue HQs	• Cadmium not detected in fish tissue • Low magnitude of dietary HQs ≥ 1 • Diet assumptions overestimate dietary exposure • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
White Perch	Chromium	Tissue HQs	• WB tissue and dietary HQs < 1 in most scenarios • Tissue and dietary TRVs conservative • Liver HQs superseded by WB tissue HQs • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No

Table 6-11a
Weight of Evidence Risk Summary for NBSA BERA

Receptor	Preliminary COC[a]	Primary LOE	Summary of LOE	Risk Conclusions	Risk Driver[b]
White Perch	Copper	Dietary HQs	• Dietary HQs < 1 • Low confidence in the tissue and dietary TRVs • Diet assumptions overestimate dietary exposure • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Uncertain	Uncertain
White Perch	Mercury	Tissue HQs	• WB Tissue LOAEL HQs < 1 • Low magnitude of dietary HQs ≥ 1 • Liver HQs < 1 • Liver HQs superseded by WB tissue HQs • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
White Perch	Selenium, Silver	Background	• Selenium related to background conditions • Tissue and dietary HQs < 1 • Liver HQs ≥ 1 based on unbounded NOAEL • Liver HQs superseded by WB tissue HQs • Site-specific pathology data did not show abnormalities • Long-term fish community monitoring indicate no impairment relative to nearby regional locations	Unlikely	No
Assessment Endpoint: Survival, growth, and/or reproduction of birds					
Spotted sandpiper	Total Dioxin/Furan/PCB TEQ Bird, Total HMW PAH, Lead, Mercury	Dietary HQs	• LOAEL HQs < 1 for most scenarios • Low magnitude of HQs ≥ 1 • Diet and SUF assumptions likely overestimate risk • MDC used as EPC in some cases	Unlikely	No
Great blue heron	Total Dioxin/Furan/PCB TEQ Bird, Total PCB TEQ Bird, Total DDx (2,4' & 4,4'), Mercury, Methylmercury	Dietary HQs	• LOAEL HQs < 1 for most scenarios • Low magnitude of HQs ≥ 1 • Diet and SUF assumptions likely overestimate risk • MDC used as EPC in some cases	Unlikely	No
Double-crested cormorant	Total Dioxin/Furan/PCB TEQ Bird, Total PCB TEQ Bird, Total PCBs	Site- and Species-Specific LOE	• Low magnitude of HQs ≥ 1 • NBSA and LPR FFS TRVs are conservative • Site-specific nesting, reproduction, and development study (Parsons 2003) did not show adverse effects	Unlikely	No
Double-crested cormorant	Total DDx (2,4' & 4,4')	Site-Specific LOE	• Low magnitude of dietary and egg HQs ≥ 1 • Site-specific nesting, reproduction, and development study (Parsons 2003) did not show adverse effects	Unlikely	No

Table 6-11a
Weight of Evidence Risk Summary for NBSA BERA

Receptor	Preliminary COC[a]	Primary LOE	Summary of LOE	Risk Conclusions	Risk Driver[b]
Double-crested cormorant	Mercury, Methylmercury	Dietary HQs	• LOAEL HQs < 1 for most scenarios • Low magnitude of dietary and egg HQs ≥ 1 • Site-specific nesting, reproduction, and development study (Parsons 2003) did not show adverse effects	Unlikely	No
Double-crested cormorant	Copper	Dietary HQs	• LOAEL HQs < 1 for most scenarios • Low magnitude of dietary HQs ≥ 1 • Site-specific nesting, reproduction, and development study (Parsons 2003) did not show adverse effects	Unlikely	No
Lesser scaup	Lead	Dietary HQs	• LOAEL HQs < 1 for most scenarios • Low magnitude of HQs ≥ 1 • EPCs for Southwest Zone calculated using clam MDCs	Unlikely	No
Assessment Endpoint: Survival, growth, and/or reproduction of mammals					
River Otter	2,3,7,8-TCDD, Total Dioxin/Furan TEQ , Dioxin/Furan/PCB TEQ, Total PCBs	Dietary HQs	• LOAEL HQs < 1 in most scenarios • Low magnitude of HQs ≥ 1 • SUF assumptions likely overestimate risk	Unlikely	No
Muskrat	Mercury	Dietary HQs	• LOAEL HQs < 1 in most scenarios • Low magnitude of HQs ≥ 1	Unlikely	No
Harbor Seal	None	Dietary HQs	• All HQs < 1	Not expected	No
Assessment Endpoint: Survival, growth, and/or reproduction of reptiles					
Diamondback terrapin	None	Qualitative Evaluation	• Exposures assumed to be similar to or less than for mammals in NBSA • Surface water quality acceptable • Quantitative assessment for some metals in LPRSA (Windward 2019) did not find unacceptable risk	Not expected	No

Table 6-11a
Weight of Evidence Risk Summary for NBSA BERA

Notes:

[a] Preliminary COCs are identified as COPECs/receptors with a LOAEL HQ ≥ to 1 for any exposure areas or evaluation scenarios.

[b] Risk Drivers identified based on LOAEL HQs ≥ 1 and supporting LOEs.

Acronyms and Abbreviations:

< = less than
≥ = greater than or equal to
-- = not applicable
BERA = Baseline Ecological Risk Assessment
COPEC = constituent of potential ecological concern
DDx = dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
EPC = exposure point concentration
FFS = focused feasibility study (USEPA 2014)
HQ = hazard quotient
LOAEL = lowest observed adverse effect limit
LOE = line of evidence
LPR = Lower Passaic River
MDC = maximum detected concentration
NOAEL = no observed adverse effect limit
NBSA = Newark Bay Study Area
PCB = polychlorinated biphenyl
SQT = sediment quality triad
SUF = site use factor
TCDD = tetrachlorodibenzo-p-dioxin
TEQ = toxic equivalent
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
TRV = toxicity reference value
WB = whole-body

References:

Iannuzzi, T.J., T.N. Armstrong, E.R. Long, J. Iannuzzi, and D.F. Ludwig. 2008. Sediment quality triad assessment of an industrialized estuary of the northeastern USA. *Environ Monit Assess* 139:257-275.

Bugel S.M., L.A. White, and K.R. Cooper. 2010. Impaired reproductive health of killifish (*Fundulus heteroclitus*) inhabiting Newark Bay, NJ, a chronically contaminated estuary. *Aquat Toxicol* 96:182-193.

Bugel, S.M., L.A. White, and K.R. Cooper. 2011. Decreased vitellogenin inducibility and 17ß-estradiol levels correlated with reduced egg production in killifish (*Fundulus heteroclitus*) from Newark Bay, New Jersey. *Aquat Toxicol* 105:1-12.

Bugel, S.M., J.A. Bonventre, L.A. White, R.L Tanguay, and K.R. Cooper. 2014. Chronic exposure of killifish to a highly polluted environment desensitizes estrogen-responsive reproductive and biomarker genes. *Aquat Toxicol* 152:222-231.

Parsons, K.C. 2003. Chemical Residues in Cormorants from New York Harbor and Control Location. NYSDEC. February 28.

Wintermyer, M.L., and K.R. Cooper. 2003. Dioxin/furan and polychlorinated biphenyl concentrations in eastern oyster (*Crassostrea virginica* Gmelin) tissues and the effects on egg fertilization and development. *J Shellfish Res* 22(3):737-746.

Windward. 2019. Lower Passaic River Study Area Baseline Ecological Risk Assessment. Final. June.

Table 6-11b
Sediment Quality Triad Evaluation Weight of Evidence Summary and Conclusions

Category	Line of Evidence	Summary
BIC	• Most BIC metrics are similar to or greater than Jamaica Bay reference. • NY/NJ B-IBI scores suggested impact for 1/30 stations; slightly impacted for 8/30 stations; not impacted for 21/30 stations. • Most BIC metrics were not associated with sediment or porewater chemistry.	There is no evidence that chemical concentrations are impacting the BIC composition in the NBSA.
Acute Toxicity	• Two of 30 SQT stations exhibited acute toxicity, 151 and 154 located along the southwestern shoreline (Figure 4-28). • Average survival as a percent of control was comparable to reference. • Multiple chemicals are elevated in sediment and porewater at stations 151 and 154. • Acute toxicity is correlated with multiple chemicals in sediment and porewater: metals, pesticides, PCBs, PAHs and dioxins/furans. • Areas of predicted acute toxicity are of limited extent, most occurring in the south geographic area (Figure 6-5).	Areas of elevated chemical concentrations likely to cause acute toxicity in the NBSA are of limited areal extent (Figure 6-5). Multiple chemicals are associated with acute toxicity: metals, pesticides, PCBs, PAHs and dioxins/furans. Mean amphipod survival as a percent of control in the NBSA is comparable to that of Jamaica Bay.
Chronic Toxicity	• Six of 30 SQT stations exhibited 28-day survival significantly different than control, two in the north, two in the central, and two in the south geographic areas (Figure 4-28). A total of 11 stations had 28-day survival less than 80% of control although only 5 of these were significantly different than control. Six stations had 28-day survival less than control minus the minimum detectable difference (MDD). The MDD was 33%. • Growth and reproductive endpoints were significantly different than control at 18 and 13 stations respectively. • Multiple chemicals in sediment and porewater are correlated with chronic toxicity endpoints: metals, pesticides, PCBs, PAHs and dioxins/furans. • Areas of predicted chronic toxicity (Figure 6-6) in the north and south are similarly located as those where acute toxicity is predicted.	Chronic toxicity endpoints are associated with chemical concentrations but there is more unexplained variability in the chronic endpoints. Model-predicted chronic toxicity is also of limited extent in the NBSA (Figure 6-6). Multiple chemicals are associated with chronic toxicity: metals, pesticides, PCBs, PAHs and dioxins/furans.
Sediment Chemistry	• High frequency of exceedances (up to 100%) of threshold (i.e., T20, ERL, and PEL) sediment quality guidelines for all chemical groups (BERA Table 6-6). • Less frequent exceedances of median values (i.e., T50, ERM, PEL). • 15/30 SQT samples exceeded the T80 value for mercury. • These screening level guidelines were not predictive of toxicity in the NBSA and therefore provided little information about risks to benthic invertebrates. • For PAHs, sum of toxic units exceed 1 in 7 samples.	Sediment quality guidelines were exceeded for most chemicals although these guidelines were not predictive of toxicity in the NBSA and therefore provided little information about risks to benthic invertebrates. Exceedances of PAH toxic units indicate potential PAH risk.
Porewater Chemistry	• High frequency (20/30) of exceedances of chronic water quality criteria for at least one of following chemicals: arsenic, copper, zinc, total PCBs, and total DDx (4,4'). • Low frequency (5/30) of exceedances of acute water quality criteria: one for arsenic, one for copper and three for zinc.	Water quality criteria were exceeded for arsenic, copper, zinc, total PCBs, and total DDx (4,4'). PAHs exceed values predictive of toxicity.
SQT Scoring	Two of 30 SQT stations (i.e., 151 and 154) are classified as medium impact. Depending on the scoring method 11 to 19 stations are classified as low impact with the remainder (i.e., 9 to 17 depending on the scoring method) classified as no impact.	Most SQT stations are classified as low or no impact.
SQT Conclusions	**• Potential risk to the benthic community is possible in localized areas due to elevated concentrations of multiple co-occurring COPECs, including dioxins/furans, PCBs, pesticides (particularly total DDx (2,4 and 4,4')), PAHs, and many inorganics (particularly, but not limited to, arsenic, cadmium, chromium, and mercury).** **• Outside of these areas, benthic communities compare favorably with reference conditions in Jamaica Bay.**	

Acronyms and Abbreviations:
BERA = Baseline Ecological Risk Assessment
BIC = Benthic Invertebrate Community
B-IBI = Benthic Index of Biotic Integrity
COPECs = constituents of potential ecological concern
DDx = dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
ERL = effect range-low
ERM = effect range-median
NBSA = Newark Bay Study Area
NY/NJ = New York/New Jersey
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
PEL = probable effect level
SQT = sediment quality triad
Tp = the concentration at which "p" percent of samples are predicted to be toxic

Reference:
GSH. 2020. Final Baseline Ecological Risk Assessment. Newark Bay Study Area. August.

FIGURES

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: MEstifanos
Newark Bay (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig1-1_NewarkRegionalMap.mxd 11/4/2021 11:30:58 AM

NEW YORK
FOCUS AREA
NEW JERSEY

LEGEND:
NEWARK BAY STUDY AREA BOUNDARY

DUNDEE DAM
SADDLE RIVER
PASSAIC COUNTY
THIRD RIVER
BERGEN COUNTY
OVERPECK CREEK
BERRYS CREEK CANAL
BELLMANS CREEK
LOWER 17 MILES OF THE PASSAIC RIVER (OU4)
MILL CREEK
BERRYS CREEK
CROMAKILL CREEK
KINGSLAND CREEK
SECOND RIVER
SAWMILL CREEK
80 AND 120 LISTER AVENUE (OU1)
FRANKS CREEK
LOWER 8.3 MILES OF THE PASSAIC RIVER (OU2)
ESSEX COUNTY
LAWYERS CREEK
HARRISON CREEK
PLUM CREEK
PIERSONS CREEK
HACKENSACK RIVER
HUDSON COUNTY
PORT NEWARK CHANNEL
PORT NEWARK
NEWARK LIBERTY INTERNATIONAL AIRPORT
ELIZABETH CHANNEL
NEWARK BAY (OU3)
PERIPHERAL DITCH
PORT ELIZABETH
SOUTH ELIZABETH CHANNEL
UPPER NEW YORK BAY
ELIZABETH RIVER
PLATTY KILL CREEK
MORSES CREEK
SHOOTERS ISLAND
ARLINGTON MARSH
KILL VAN KULL
MARINERS MARSH
OLD PLACE CREEK
UNION COUNTY
PILES CREEK
PRALLS ISLAND
RAHWAY RIVER
FRESH KILLS
ARTHUR KILL
MIDDLESEX COUNTY
RARITAN RIVER
RARITAN BAY

LEGEND:
- RIVER/BAY MILE
- 80 AND 120 LISTER AVENUE (OU1)
- LOWER 8.3 MILES OF THE PASSAIC RIVER (OU2)
- LOWER 17 MILES OF THE PASSAIC RIVER (OU4)
- NEWARK BAY STUDY AREA BOUNDARY (OU3)

NOTES:

1. BASEMAP INFORMATION FROM NOAA CHARTS 12331, 12333, AND 12337, DATED MAY 4, 1995.
2. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
3. NEWARK BAY REVISED CENTERLINE AND "BAY MILES" (ADJUSTED FOR FFS RM-0 ON LOWER PASSAIC RIVER) BASED ON DISCUSSION BETWEEN GSH AND USEPA ON DECEMBER 10, 2018.
4. REFERENCE:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 2 4 Miles
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

NEWARK BAY REGIONAL MAP

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
1-1

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: MEstifanos
Newark Bay (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig1-2_NBRegionalFeatures.mxd 4/6/2021 1:58:38 PM

LEGEND:

- NAVIGATION CHANNEL
- REACH BOUNDARY
- NEWARK BAY STUDY AREA BOUNDARY

NOTES:

1. AERIAL PHOTOS DATED 2019 (ESRI CLOUD IMAGERY).
2. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD 83.
3. PORT AUTHORITY OF NEW YORK AND NEW JERSEY HOWLAND HOOK MARINE TERMINAL LEASED BY AND ALSO KNOWN AS NEW YORK CONTAINER TERMINAL.
4. BASE MAP INFORMATION, REACH BOUNDARIES AND NEWARK BAY NAVIGATION CHANNEL IS FROM NOAA CHARTS 12333 AND 12337, DATED DECEMBER 2012 (UPDATED 8/13/2018) AND FEBRUARY 2013 (UPDATED 8/13/2018), RESPECTIVELY. NAVIGATION CHANNEL BOUNDARIES SHOWN ARE APPROXIMATE. CHANNEL DREDGING AND DEEPENING AS PART OF THE HARBOR DEEPENING PROJECT (50-FOOT) IS COMPLETE; CONTACT USACE OPERATIONS DIVISION TO REFERENCE THE MOST CURRENT CHANNEL BOUNDARIES.
5. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
6. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
7. REFERENCE:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 0.8 1.6 Miles

GRAPHIC SCALE

80 AND 120 LISTER AVENUE (OU1)
ROUTE 1 & 9 BRIDGE
POINT-NO-POINT REACH
KEARNY POINT
HACKENSACK RIVER
PASSAIC RIVER
CONRAIL BRIDGE REMNANTS
PIERSONS CREEK
LIGHT "5"
KEARNY POINT REACH
DROYERS POINT REACH
LIGHT "NB"
DROYERS POINT
TURNING BASIN
LOWER PASSAIC RIVER RESTORATION PROJECT (LPRRP) DOWNSTREAM BOUNDARY
NEWARK LIBERTY INTERNATIONAL AIRPORT
PORT NEWARK CHANNEL
PORT NEWARK INSHORE REACH
PORT NEWARK INSHORE CHANNEL
LEHIGH VALLEY LIFT BRIDGE
NORTH REACH
JERSEY CITY
ELIZABETH CHANNEL
PORT NEWARK
PORT NEWARK PIERHEAD CHANNEL
PORT NEWARK BRANCH REACH
NEWARK BAY BRIDGE (VINCENT R. CASCIANO I-78 MEMORIAL BRIDGE)
PORT ELIZABETH INSHORE CHANNEL
PORT ELIZABETH BRANCH REACH
PORT NEWARK PIERHEAD REACH
MIDDLE REACH (NORTH)
PORT NEWARK BRANCH CHANNEL
NEWARK
NEWARK BAY CDF (CELL 1S)
NEWARK BAY
PORT ELIZABETH BRANCH CHANNEL
MIDDLE REACH (SOUTH)
PORT ELIZABETH MARINE TERMINAL
PERIPHERAL DITCH
PORT ELIZABETH PIERHEAD CHANNEL
SOUTH ELIZABETH CHANNEL
PORT ELIZABETH SOUTH REACH
SOUTH REACH
ELIZABETH
BAYONNE
ELIZABETH RIVER
BAYONNE BRIDGE
NORTH OF SHOOTERS ISLAND REACH
BERGEN POINT WEST REACH
BERGEN POINT EAST REACH
ELIZABETHPORT REACH
ARTHUR KILL LIFT BRIDGE
SHOOTERS ISLAND
SOUTH OF SHOOTERS ISLAND REACH
PORT RICHMOND
KILL VAN KULL
HOWLAND HOOK MARINE TERMINAL
PORT IVORY
MARINERS HARBOR
GULFPORT REACH
GOETHALS BRIDGE
ARTHUR KILL
STATEN ISLAND
PRALLS ISLAND

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

NEWARK BAY REGIONAL FEATURES

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
1-2

PIERSONS CREEK

PORT-NEWARK CHANNEL

NEWARK LIBERTY INTERNATIONAL AIRPORT

NEWARK BAY

ELIZABETH CHANNEL

PERIPHERAL DITCH

SOUTH ELIZABETH CHANNEL

ELIZABETH RIVER

SHOOTERS ISLAND

KILL VAN KULL

DEFERRED WORK AREA

LEGEND:

- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- DEFERRED WORK AREA

NBSA HDP CONTRACT AREAS

- 5 - COMPLETE (2004)
- S-AK-1/S-NB-2 - COMPLETE (2012)
- S-AK-2 - COMPLETE (2013)
- S-AK-3 - COMPLETE (2016)
- S-AK-4 - COMPLETE (2017)
- S-E-1 - COMPLETE (2010)
- S-KVK-2 - COMPLETE (2007)
- S-NB-1 - COMPLETE (2011)
- S-SR-2 - COMPLETE (2015)

NOTES:

1. BASE MAP SOURCE: TOPO-METRICS, 1"=100', ORIGINAL MYLAR POSITIVES OF AERIAL PHOTOMETRICS SURVEY (1982).
2. CONTRACT AREAS OBTAINED FROM A FIGURES PROVIDED BY THE U.S. ARMY CORPS OF ENGINEERS (USACE) ENTITLED "CONSOLIDATED IMPLEMENTATION OF THE NEW YORK AND NEW JERSEY HARBOR DEEPENING PROJECT (HDP)" DATED JANUARY 2004 AND "NEW YORK HARBOR, CHANNEL NAVIGATION IMPROVEMENT, ARTHUR KILL CHANNEL CONTRACT 4, GENERAL PLAN" DATED JULY 2014. HDP CONTRACT AREAS ARE SEPARATE FROM REACH BOUNDARIES.
3. THE CONTRACT FOR S-NB-2 WAS COMBINED WITH THE CONTRACT FOR S-AK-1. THE COMBINED AREA IS CALLED S-AK-1.
4. ABBREVIATIONS ARE AS FOLLOWS:
   NBSA = NEWARK BAY STUDY AREA
   HDP = HARBOR DEEPENING PROJECT (50 FT)
5. DEFERRED WORK AREA ESTIMATED FROM FIGURE PROVIDED BY THE U.S. ARMY CORPS OF ENGINEERS (USACE) ENTITLED "NEW YORK HARBOR, CHANNEL NAVIGATION IMPROVEMENT, ARTHUR KILL CHANNEL CONTRACT 4, GENERAL PLAN" DATED JULY 2014.
6. BASE MAP INFORMATION, REACH BOUNDARIES AND NEWARK BAY NAVIGATION CHANNEL IS FROM NOAA CHARTS 12333 AND 12337, DATED DECEMBER 2012 (UPDATED 8/13/2018) AND FEBRUARY 2013 (UPDATED 8/13/2018), RESPECTIVELY. NAVIGATION CHANNEL BOUNDARIES SHOWN ARE APPROXIMATE. CHANNEL DREDGING AND DEEPENING AS PART OF THE HARBOR DEEPENING PROJECT (50-FOOT) IS COMPLETE; CONTACT USACE OPERATIONS DIVISION TO REFERENCE THE MOST CURRENT CHANNEL BOUNDARIES.
7. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
8. THE HARBOR DEEPENING PROJECT TARGETED AN ELEVATION OF -45 FT IN KILL VAN KULL AND -40 FT IN ARTHUR KILL
9. REFERENCE:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 0.8 1.6 Miles

GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

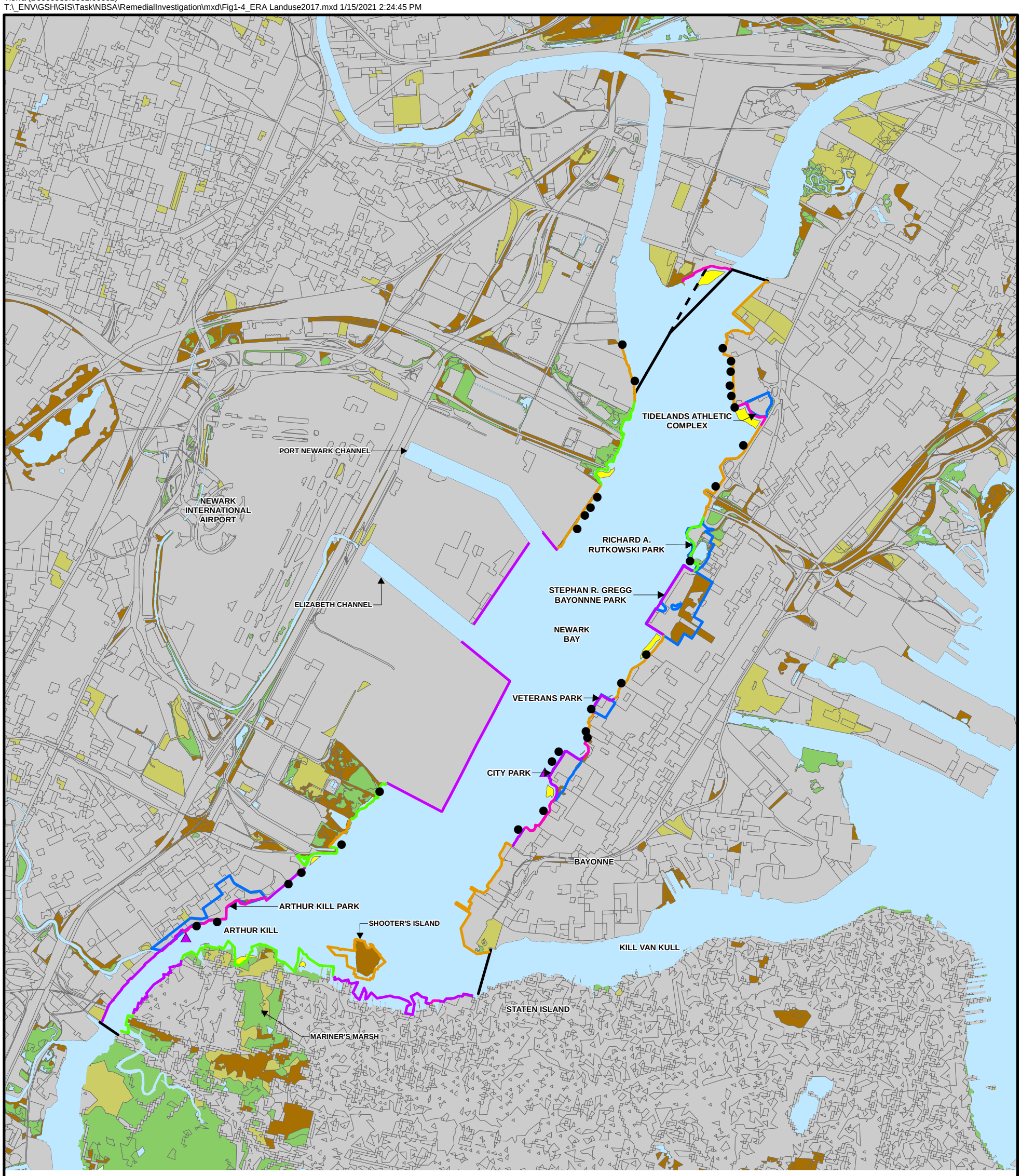
NBSA HARBOR DEEPENING PROJECT (50 ft)

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
1-3

City: Citrix DivGroup: IM/DV Created By: K. Sinsabaugh Last Saved By: avi00815
Project (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig1-3_HarborDeepening.mxd 2/15/2022 10:25:29 AM

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Tierra (B0009989.0061.00002)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig1-4_ERA Landuse2017.mxd 1/15/2021 2:24:45 PM



LEGEND:

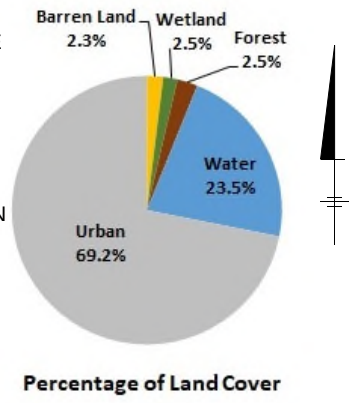
- BOAT RAMP
- DISCHARGE PIPE OBSERVATION
- BARREN LAND
- FOREST
- URBAN
- WATER
- WETLANDS
- PARKS AND RECREATIONAL AREAS
- INTERTIDAL AREA
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY

OBSERVED SHORELINE HABITAT:

- BULKHEAD
- MIXED INTERTIDAL
- RIPRAP
- VEGETATION

NOTES:

1. 2012 NEW JERSEY LAND USE DATA (UPDATED IN 2015) DOWNLOADED FROM THE NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION GEOGRAPHIC INFORMATION SYSTEM WEBSITE AT www.state.nj.us/dep/gis.
2. 2011 NEW YORK NATIONAL LAND COVER DATA DOWNLOADED FROM THE NEW YORK STATE GEOGRAPHIC INFORMATION SYSTEMS CLEARINGHOUSE AT www.nysgis.state.ny.us.
3. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
4. THE PIE CHART PROVIDED REPRESENTS THE BREAKDOWN OF LAND USE FOR THE ENTIRE AREA SHOWN IN THE FIGURE. THIS INCLUDES INFORMATION FROM THE FOLLOWING MUNICIPALITIES: ELIZABETH, BAYONNE CITY, KEARNY TOWN, NEWARK CITY, JERSEY CITY, AND STATEN ISLAND BOROUGH.
5. THE INTERTIDAL AREAS SHOWN ARE CONSISTENT WITH THOSE PRESENTED IN THE PROBLEM FORMULATION (TIERRA 2013) AND VERIFIED DURING THE RECONNAISSANCE SURVEY (TIERRA 2015).
6. OBSERVATIONS MADE IN 2013 REGARDING DISCHARGE PIPES, INTERTIDAL AREAS, BOAT RAMPS, AND SHORELINE HABITAT (TIERRA 2015).
7. REFERENCES:
A. TIERRA. 2013. FINAL NEWARK BAY STUDY AREA PROBLEM FORMULATION. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. JUNE.
B. TIERRA. 2015. NEWARK BAY STUDY AREA RECONNAISSANCE SURVEY REPORT. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. APRIL.
C. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.



Percentage of Land Cover

0 4,000 8,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

LAND USE/ECOLOGICAL HABITATS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
1-4

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: MEstifanos
Newark Bay (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-1_FinalPhII_Sed_Samp_Locs.mxd 4/6/2021 2:02:59 PM

LEGEND:

- PHASE I SEDIMENT CORE LOCATION
- PHASE II SEDIMENT CORE LOCATION
- CO-LOCATED CORE LOCATION
- ABANDONED CORE LOCATION; NO SAMPLES COLLECTED
- PHASE I BAZ INVESTIGATION LOCATION
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- POTENTIAL HIGH NET DEPOSITION AREA

GEOMORPHIC AREAS:

- HISTORICALLY DISTURBED SUBTIDAL FLATS
- INDUSTRIAL WATERFRONT
- INTERTIDAL AREA
- NAVIGATION CHANNEL
- PORT CHANNEL
- SUBTIDAL FLATS
- TRANSITIONAL SLOPES
- **049** PHASE I CORE ID
- **102*** PHASE II CORE ID

0 0.8 1.6 Miles

GRAPHIC SCALE

PASSAIC RIVER
HACKENSACK RIVER
PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
PERIPHERAL DITCH
NEWARK BAY CDF (CELL 1S)
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
MORSES CREEK
PILES CREEK
CONRAIL BRIDGE REMNANTS
KILL VAN KULL
BAYONNE BRIDGE
GOETHALS BRIDGE
ARTHUR KILL
SHOOTERS ISLAND
PRALLS ISLAND

NOTES:

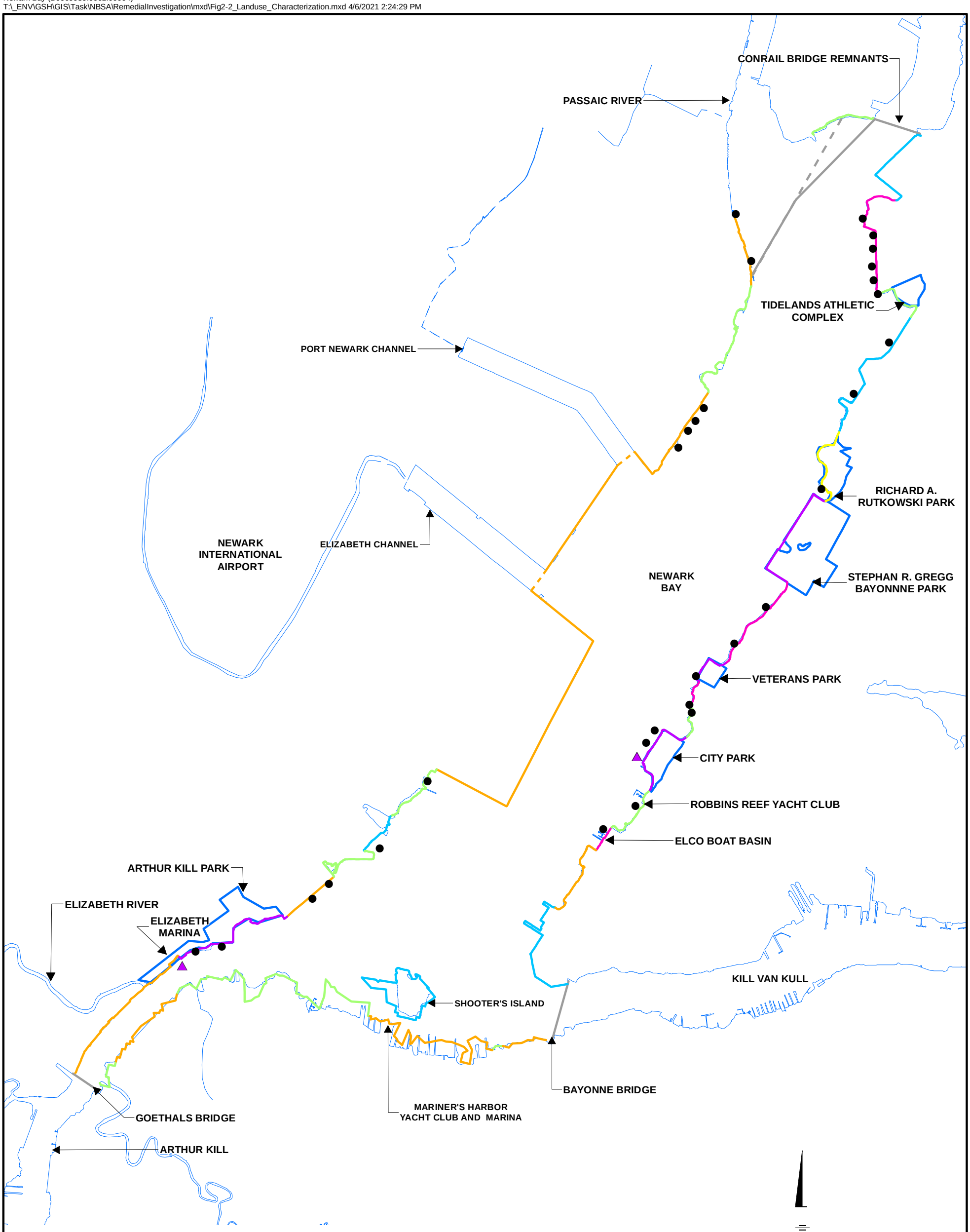
1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. THE GEOMORPHIC AREAS SHOWN ARE CONSISTENT WITH THOSE PRESENTED IN THE PHASE II RIWP (TIERRA 2007).
4. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
5. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
6. REFERENCES:
A. TIERRA. 2007. NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION WORK PLAN, SEDIMENT SAMPLING AND SOURCE IDENTIFICATION PROGRAM, NEWARK BAY, NEW JERSEY, PHASE II, REVISION 2, AMENDMENT 1. NOVEMBER.
B. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

PHASE I AND PHASE II SEDIMENT COLLECTION LOCATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-1



LEGEND:

- DISCHARGE PIPE OBSERVATION
- BOAT RAMP
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- SHORELINE
- UNDERGROUND TRIBUTARY
- PARKS AND RECREATIONAL AREAS

OBSERVED SHORELINE USE:

- DISTURBED UPLANDS
- HABITAT
- HABITAT/RECREATIONAL
- INDUSTRIAL/COMMERCIAL
- RECREATIONAL
- RESIDENTIAL

0 3,000 6,000 Feet

GRAPHIC SCALE

NOTES:

1. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA- APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS, BUT MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
2. DISCHARGE PIPE OBSERVATIONS SHOWN DO NOT REPRESENT COMPREHENSIVE INVENTORY OF DISCHARGE PIPES LOCATED ALONG THE SHORELINE.
3. OBSERVATIONS MADE IN 2013 REGARDING SHORELINE USE (TIERRA 2015).
4. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
5. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
6. REFERENCES:
A. TIERRA. 2015. NEWARK BAY STUDY AREA RECONNAISSANCE SURVEY REPORT. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. APRIL.
B. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SHORELINE HUMAN USE CHARACTERIZATION

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE 2-2

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: MEstifanos
Newark Bay (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-3_Overall Crab Clam Sediment Sampling Locations.mxd 4/15/2021 7:45:50 AM

LEGEND:

- CLAM AND SEDIMENT SAMPLING LOCATION
- INTERTIDAL CRAB SAMPLING LOCATION
- CRAB ZONE SAMPLING LOCATION
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY

BERA ASSESSMENT ZONES

- NORTH
- SOUTHEAST
- SOUTHWEST

PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
SHOOTERS ISLAND
KILL VAN KULL

122B 122C 122A 122
123A 123B 133 133 123
132A 132B 132
124 124
125 125
126
127A 127 127B
131B 131A 131
130 130
135
129 129
134 134

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. THE GRAY SQUARES REPRESENT LOCATIONS WHERE CRAB TRAPS WERE PLACED TO COLLECT INDIVIDUAL CRABS TO COMPRISE THE COMPOSITE CRAB ZONE SAMPLED (NEWARK BAY NORTH, CENTRAL, AND SOUTH). COMPOSITE CRAB ZONE SAMPLES WERE NOT GEOREFERENCED AND ARE NOT SHOWN ON THIS FIGURE. THE GREEN DIAMONDS REPRESENT INTERTIDAL CRAB SAMPLE LOCATIONS THAT WERE GEOREFERENCED.
4. ZONES WERE ADDED TO THE BIOTA SAMPLING PROGRAM TO CONFIRM ADEQUATE COVERAGE AND DO NOT REPRESENT DECISION UNITS.
5. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
6. REFERENCE:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 2,500 5,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CRAB, CLAM, AND SEDIMENT SAMPLING LOCATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-3

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: MEstifanos
Newark Bay (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-4_FishSamplingLocs_2014Fall.mxd 4/15/2021 7:59:39 AM

LEGEND:

- EEL POT
- MINNOW TRAP
- SEINE
- TRAWL*
- TRAWL LINE
- GILLNET
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY

BERA ASSESSMENT ZONES

- NORTH
- SOUTHEAST
- SOUTHWEST

PIERSONS CREEK

PORT NEWARK CHANNEL

ELIZABETH CHANNEL

NEWARK LIBERTY INTERNATIONAL AIRPORT

NEWARK BAY CDF (CELL 1S)

PERIPHERAL DITCH

SOUTH ELIZABETH CHANNEL

KILL VAN KULL

SHOOTERS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. * LOCATIONS WHERE START AND END COORDINATES WERE NOT RECORDED.
4. ZONES WERE ADDED TO THE BIOTA SAMPLING PROGRAM TO CONFIRM ADEQUATE COVERAGE AND DO NOT REPRESENT DECISION UNITS.
5. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
6. REFERENCE:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 2,500 5,000 Feet

GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

FISH SAMPLING LOCATIONS - FALL 2014

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-4

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: MEstifanos
Newark Bay (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-5_FishSamplingLocs_2015Spring.mxd 4/15/2021 8:02:50 AM

LEGEND:

- ANGLING-DRIFT
- EEL POT
- TROTLINE
- ANGLING-TROLL
- GILLNET
- TRAWL
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY

BERA ASSESSMENT ZONES

- NORTH
- SOUTHEAST
- SOUTHWEST

PIERSONS CREEK

PORT NEWARK CHANNEL

ELIZABETH CHANNEL

NEWARK LIBERTY INTERNATIONAL AIRPORT

NEWARK BAY CDF (CELL 1S)

PERIPHERAL DITCH

SOUTH ELIZABETH CHANNEL

KILL VAN KULL

SHOOTERS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. ZONES WERE ADDED TO THE BIOTA SAMPLING PROGRAM TO CONFIRM ADEQUATE COVERAGE AND DO NOT REPRESENT DECISION UNITS.
4. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
5. REFERENCE:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 2,500 5,000 Feet

GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

FISH SAMPLING LOCATIONS - SPRING/SUMMER 2015

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-5

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: MEstifanos
Newark Bay (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-6_FishSamplingLocs_2016Spring.mxd 4/15/2021 8:07:06 AM

LEGEND:

- GILLNET
- TRAWL
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY

BERA ASSESSMENT ZONES

- NORTH
- SOUTHEAST
- SOUTHWEST

PIERSONS CREEK

PORT NEWARK CHANNEL

ELIZABETH CHANNEL

NEWARK LIBERTY INTERNATIONAL AIRPORT

NEWARK BAY CDF (CELL 1S)

PERIPHERAL DITCH

SOUTH ELIZABETH CHANNEL

KILL VAN KULL

SHOOTERS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
4. ZONES WERE ADDED TO THE BIOTA SAMPLING PROGRAM TO CONFIRM ADEQUATE COVERAGE AND DO NOT REPRESENT DECISION UNITS.
4. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
5. REFERENCE:
A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 2,500 5,000 Feet

GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

FISH SAMPLING LOCATIONS - SPRING 2016

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-6

LEGEND:

- CLAM AND SEDIMENT SAMPLING LOCATION
- SURFACE WATER COLLECTION LOCATION

ANALYSES
- BHHRA
- SQT/PW
- SQT/PW+Bio
- SQT/PW+BHHRA
- SQT/PW+Bio+BHHRA

OBJECTIVE OF SAMPLING LOCATION (FOOTNOTE 8)
- (GEOMORPHIC) NAVIGATION CHANNELS
- (GEOMORPHIC) SUBTIDAL FLATS
- (GEOMORPHIC) TRANSITIONAL SLOPES
- (GEOMORPHIC) INTERTIDAL AREAS
- POTENTIAL HUMAN-SEDIMENT CONTACT LOCATION
- SHORELINE
- UNDERGROUND TRIBUTARY
- FORMER OU2/OU3 BOUNDARY

GEOMORPHIC AREAS:
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- INDUSTRIAL WATERFRONT
- INTERTIDAL AREA
- NAVIGATION CHANNEL
- PORT CHANNEL
- SUBTIDAL FLATS
- TRANSITIONAL SLOPES

OBSERVED SHORELINE USE:
- DISTURBED UPLANDS
- HABITAT
- HABITAT/RECREATIONAL
- INDUSTRIAL/COMMERCIAL
- RECREATIONAL
- RESIDENTIAL

0 2,500 5,000 Feet
GRAPHIC SCALE

HACKENSACK RIVER
CONRAIL BRIDGE REMNANTS
PASSAIC RIVER
PIERSONS CREEK
PORT NEWARK CHANNEL
INDUSTRIAL/COMMERCIAL ACCESS AREA
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
ARTHUR KILL
KILL VAN KULL
SHOOTERS ISLAND
LEHIGH VALLEY RAILROAD BRIDGE
NEW JERSEY TURNPIKE
RICHARD A RUTOWSKI PARK
VETERANS PARK
TRAILER PARK
BAYONNE BRIDGE

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. AERIAL PHOTOS DATED 2015 (ESRI CLOUD IMAGERY).
3. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
4. THE GEOMORPHIC AREAS SHOWN ARE CONSISTENT WITH THOSE PRESENTED IN THE CSM (GSH 2019).
5. SQT REPRESENTS THREE ANALYSES: SEDIMENT CHEMISTRY, BENTHIC INVERTEBRATE COMMUNITY, AND TOXICITY TESTING WITH L. PLUMULOSUS (10-DAY AND 28-DAY).
6. SURFACE WATER WAS NOT A TARGETED SAMPLING MATRIX. SURFACE WATER WAS COLLECTED AND USED IN THE FIELD FACILITY FOR THE SHIPMENT OF SEDIMENT FOR POREWATER NALYSES.
7. CLAM AND SEDIMENT SAMPLING LOCATIONS SHOWN ARE IDENTICAL TO THOSE ON FIGURE 2-3.
8. GEOMORPHIC AREA DESIGNATIONS FOR EACH SAMPLING LOCATION ARE BASED ON THE FIELD-COLLECTED GEOGRAPHIC COORDINATES OF THE ACTUAL SAMPLING LOCATIONS AS RECORDED DURING SEDIMENT COLLECTION ACTIVITIES. (GSH 2017)
9. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
10. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
11. REFERENCES:

A. GSH. 2019. NEWARK BAY STUDY AREA CONCEPTUAL SITE MODEL. REVISION 3. JANUARY.
B. GSH. 2017. SEDIMENT QUALITY TRIAD AND POREWATER FIELD REPORT. NEWARK BAY STUDY AREA. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. REVISION 1. SEPTEMBER.
C. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE -BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SQT AND POREWATER SAMPLING STATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-7

City: SYR Div/Group: IM/DV Created By: ksinsabaugh Last Saved By: MEstifanos
Newark Bay (B0009989.0045.00006)
T:\ ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-8_PhIIISedimentCollectionLocations.mxd 3/30/2021 12:47:32 PM

LEGEND:

- ACTUAL PHASE III SEDIMENT SAMPLING LOCATION
- INDIVIDUAL LOCATIONS WHICH COMPRISE COMPOSITE SAMPLES
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREA

PROPOSED USEPA SUBUNIT

- 1
- 2
- 3
- 4
- 5
- 6

PASSAIC RIVER
PIERSONS CREEK
PORT NEWARK CHANNEL
COMP01
ELIZABETH CHANNEL
COMP10
COMP02
NEWARK BAY CDF (CELL 1S)
NEWARK LIBERTY INTERNATIONAL AIRPORT
COMP04
SOUTH ELIZABETH CHANNEL
COMP03
PERIPHERAL DITCH
COMP05
COMP08
COMP06
COMP09
KILL VAN KULL
COMP07
SHOOTERS ISLAND
ARTHUR KILL
PRALLS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. COMPOSITE SAMPLES WERE COLLECTED IN THE DREDGED PORTION OF THE NAVIGATION CHANNEL DURING THE 2016 PHASE III SAMPLING PROGRAM.
4. THE PHASE III SEDIMENT INVESTIGATION FIELD REPORT (GSH 2017) PROVIDES INFORMATION REGARDING SAMPLE LOCATIONS WHICH WERE SHIFTED FROM PROPOSED LOCATIONS, OR WERE ABANDONED DUE TO LACK OF RECOVERY.
5. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
6. REFERENCES:

A. GSH. 2017. NEWARK BAY STUDY AREA PHASE III SEDIMENT INVESTIGATION FIELD REPORT. REVISION 1. JUNE.
B. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 3,000 6,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

PHASE III SEDIMENT COLLECTION LOCATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-8

City: SYR Div/Group: IM/DV Created By: ksinsabaugh Last Saved By: MEstifanos
Newark Bay (B0009989.0045.00006)
T:\ ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-9a_SedimentSamplingLocations-North.mxd 3/30/2021 12:52:26 PM

LEGEND:

- ▲ INDIVIDUAL LOCATIONS WHICH COMPRISE COMPOSITE SAMPLES
- ● ACTUAL PHASE III SEDIMENT SAMPLING LOCATION
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREA

PROPOSED USEPA SUBUNIT

- 1
- 2
- 3
- 4
- 5
- 6

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. THE AREA OF EACH GRID CELL WAS CALCULATED AS DESCRIBED BY USEPA (2002). SAMPLE POINTS WERE PLACED IN ALL GRID CELLS WITH AN AREA GREATER THAN 50% OF CALCULATED CELL SIZE.
4. COMPOSITE SAMPLES WERE COLLECTED IN THE DREDGED PORTION OF THE NAVIGATION CHANNEL DURING THE 2016 PHASE III SAMPLING PROGRAM.
5. THE PHASE III SEDIMENT INVESTIGATION FIELD REPORT (GSH 2017) PROVIDES INFORMATION REGARDING SAMPLE LOCATIONS WHICH WERE SHIFTED FROM PROPOSED LOCATIONS, OR WERE ABANDONED DUE TO LACK OF RECOVERY.
6. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
7. REFERENCES:

A. USEPA. 2002. GUIDANCE ON CHOOSING A SAMPLING DESIGN FOR ENVIRONMENTAL DATA COLLECTION FOR USE IN DEVELOPING A QUALITY ASSURANCE PROJECT PLAN, EPA QA/G-5S. EPA/240/R-02-005. DECEMBER.
B. GSH. 2017. NEWARK BAY STUDY AREA PHASE III SEDIMENT INVESTIGATION FIELD REPORT. REVISION 1. JUNE.
C. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 1,000 2,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT SAMPLING LOCATIONS - NORTH

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-9a

City: SYR Div/Group: IM/DV Created By: ksinsabaugh Last Saved By: MEstifanos
Newark Bay (B0009989.0045.00006)
T:\ ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-9b_SedimentSamplingLocations-Central.mxd 3/30/2021 12:57:23 PM

LEGEND:

- ▲ INDIVIDUAL LOCATIONS WHICH COMPRISE COMPOSITE SAMPLES
- ● ACTUAL PHASE III SEDIMENT SAMPLING LOCATION
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREA

PROPOSED USEPA SUBUNIT

- 1
- 2
- 3
- 4
- 5
- 6

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. THE AREA OF EACH GRID CELL WAS CALCULATED AS DESCRIBED BY USEPA (2002). SAMPLE POINTS WERE PLACED IN ALL GRID CELLS WITH AN AREA GREATER THAN 50% OF CALCULATED CELL SIZE.
4. COMPOSITE SAMPLES WERE COLLECTED IN THE DREDGED PORTION OF THE NAVIGATION CHANNEL DURING THE 2016 PHASE III SAMPLING PROGRAM.
5. THE PHASE III SEDIMENT INVESTIGATION FIELD REPORT (GSH 2017) PROVIDES INFORMATION REGARDING SAMPLE LOCATIONS WHICH WERE SHIFTED FROM PROPOSED LOCATIONS, OR WERE ABANDONED DUE TO LACK OF RECOVERY.
6. REFERENCES:
A. USEPA. 2002. GUIDANCE ON CHOOSING A SAMPLING DESIGN FOR ENVIRONMENTAL DATA COLLECTION FOR USE IN DEVELOPING A QUALITY ASSURANCE PROJECT PLAN, EPA QA/G-5S. EPA/240/R-02-005. DECEMBER.
B. GSH. 2017. NEWARK BAY STUDY AREA PHASE III SEDIMENT INVESTIGATION FIELD REPORT. REVISION 1. JUNE.

PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK BAY CDF (CELL 1S)
SOUTH ELIZABETH CHANNEL

COMP01 COMP02 COMP03 COMP04 COMP05 COMP06 COMP10

0 1,300 2,600 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT SAMPLING LOCATIONS - CENTRAL

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-9b

City: SYR Div/Group: IM/DV Created By: ksinsabaugh Last Saved By: MEstifanos
Newark Bay (B0009989.0045.00006)
T:\ ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-9c_SedimentSamplingLocations-South.mxd 3/30/2021 1:04:49 PM

LEGEND:

- ACTUAL PHASE III SEDIMENT SAMPLING LOCATION
- INDIVIDUAL LOCATIONS WHICH COMPRISE COMPOSITE SAMPLES
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREA

PROPOSED USEPA SUBUNIT

- 1
- 2
- 3
- 4
- 5
- 6

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. THE AREA OF EACH GRID CELL WAS CALCULATED AS DESCRIBED BY USEPA (2002). SAMPLE POINTS WERE PLACED IN ALL GRID CELLS WITH AN AREA GREATER THAN 50% OF CALCULATED CELL SIZE.
4. COMPOSITE SAMPLES WERE COLLECTED IN THE DREDGED PORTION OF THE NAVIGATION CHANNEL DURING THE 2016 PHASE III SAMPLING PROGRAM.
5. THE PHASE III SEDIMENT INVESTIGATION FIELD REPORT (GSH 2017) PROVIDES INFORMATION REGARDING SAMPLE LOCATIONS WHICH WERE SHIFTED FROM PROPOSED LOCATIONS, OR WERE ABANDONED DUE TO LACK OF RECOVERY.
6. REFERENCES:
   A. USEPA. 2002. GUIDANCE ON CHOOSING A SAMPLING DESIGN FOR ENVIRONMENTAL DATA COLLECTION FOR USE IN DEVELOPING A QUALITY ASSURANCE PROJECT PLAN, EPA QA/G-5S. EPA/240/R-02-005. DECEMBER.
   B. GSH. 2017. NEWARK BAY STUDY AREA PHASE III SEDIMENT INVESTIGATION FIELD REPORT. REVISION 1. JUNE.

0 1,600 3,200 Feet

GRAPHIC SCALE

SOUTH ELIZABETH CHANNEL

SHOOTERS ISLAND

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT SAMPLING LOCATIONS - SOUTH

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-9c

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: MEstifanos
Tierra (B0009989.0025.00001)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-10_SW_SampleLocs.mxd 4/6/2021 3:37:31 PM

LEGEND:

- PHYSICAL AND CHEMICAL SURFACE WATER SAMPLE LOCATION
- CHEMICAL ONLY SURFACE WATER SAMPLE LOCATION
- PHYSICAL ONLY SURFACE WATER SAMPLE LOCATION
- TIDAL 1
- TIDAL 2
- NEWARK BAY STUDY AREA
- FORMER OU2/OU3 BOUNDARY
- SHORELINE
- UNDERGROUND TRIBUTARY

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. CHEMICAL DATA WERE COLLECTED DURING EIGHT FIELD SAMPLING EVENTS (2011-2013) BY THE COOPERATING PARTIES GROUP IN ACCORDANCE WITH THE QUALITY ASSURANCE PROJECT PLAN AND FIELD SAMPLING PLAN ADDENDUM (AECOM 2011).
4. PHYSICAL DATA WERE COLLECTED IN MARCH - NOVEMBER 2010 BY THE COOPERATING PARTIES GROUP IN ACCORDANCE WITH THE QUALITY ASSURANCE PROJECT PLAN/FIELD SAMPLING PLAN ADDENDUM (AECOM 2010).
5. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
6. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
7. THE LOCATION OF TIDAL 1 VARIED BY EVENT AND IS APPROXIMATELY ONE MILE DOWNSTREAM OF THE SALT WEDGE. THE LOCATION OF TIDAL 2 VARIED BY EVENT AND IS APPROXIMATELY HALFWAY BETWEEN TIDAL 1 AND STATION 014 BUT NOT ABOVE STATION 042.
8. REFERENCES:
   A. AECOM. 2011. QUALITY ASSURANCE PROJECT PLAN/FIELD SAMPLING PLAN ADDENDUM, REMEDIAL INVESTIGATION WATER COLUMN MONITORING/SMALL VOLUME CHEMICAL DATA COLLECTION, LOWER PASSAIC RIVER RESTORATION PROJECT. REVISION 2.
   B. AECOM 2010. REMEDIAL INVESTIGATION WATER COLUMN MONITORING/ PHYSICAL DATA COLLECTION FOR THE LOWER PASSAIC RIVER, NEWARK BAY AND WET WEATHER MONITORING: LOWER PASSAIC RIVER RESTORATION PROJECT. QUALITY ASSURANCE PROJECT PLAN. REVISION 5.
   C. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 1.25 2.5 Miles

GRAPHIC SCALE

PASSAIC
ESSEX
BERGEN
HUDSON
UNION
175
DUNDEE DAM
SR1
SADDLE RIVER
135
3R1
102
2R1
067
PASSAIC RIVER
HACKENSACK RIVER
HKN
042
014
PIERSONS CREEK
CONRAIL BRIDGE REMNANTS
000
PORT NEWARK CHANNEL
NNE
ELIZABETH CHANNEL
NBN
NNW
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
NBE
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
NBS
KILL VAN KULL
ARK
KVK
MORSES CREEK
GOETHALS BRIDGE
ARTHUR KILL
BAYONNE BRIDGE
SHOOTERS ISLAND
PILES CREEK

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE WATER SAMPLE LOCATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-10

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: MEstifanos
Newark Bay (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig2-11_EPA_REMAP_Locs_NBSA.mxd 4/6/2021 3:44:10 PM

LEGEND:

- 1993/1994 REMAP
- 1998 REMAP
- 2003 REMAP
- 2008 REMAP
- 2013 REMAP
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- NAVIGATION CHANNEL
- HISTORICALLY DISTURBED SUBTIDAL FLAT

0 3,000 6,000 Feet

GRAPHIC SCALE

PASSAIC RIVER
PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
GOETHALS BRIDGE
ARTHUR KILL
SHOOTERS ISLAND
BAYONNE BRIDGE
KILL VAN KULL
CONRAIL BRIDGE REMNANTS

NB065 NB104 NB427 NB329 NB227 NB025 NB427 NB027 NB110 NB217 NB452 NB452 NB102 NB416 NB325 NB216 NB416 NB105 NB454 NB454 NB112 NB406 NB206 NB406 NB327 NB326 NB036 NB039 NB226 NB426 NB426 NB412 NB412 NB306 NB212 NB106 NB201 NB305 NB401 NB401 NB103 NB431 NB431 NB231 NB301 NB044 NB222 NB113 NB223 NB423 NB310 NB312 NB423 NB045 NB052 NB202 NB053 NB213 NB309 NB413 NB413 NB307 NB047 NB211

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
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4. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
5. REFERENCE:
A USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

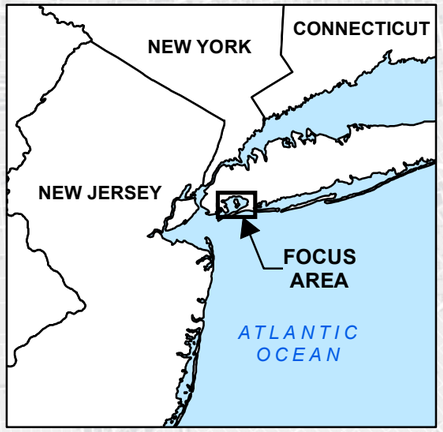
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

EPA REMAP LOCATIONS IN THE NEWARK BAY STUDY AREA - 1993 THROUGH 2013

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-11



JB012
NY-0239-A
JB309
JB214*
JB471
JB471
JB307
JB310
NY-0235-A
JB008
JB008
JB101
JB487
JB002*
JB403
JB487
JB319*
JB403
JB203
JB416*
JB416*
JB115*
JB216
JB323
JB380
JB103
JB407
JB407
JB301
JB207
NY03-0236*
NY05-0010
JB410*
NY-0032-A*
JB210*
JB322*
JB410*
JB316
JB215
JB015
JB117
JB374
JB106
JB104*
JB317*
JB303
JB213
JB033
JB033
JB415*
JB108*
JB481*
JB415*
JB459*
JB359
JB481*
JB211
JB031*
JB459*
JB031*
JB464*
JB464*
JB202
JB313
JB204
JB358
JB404
JB467*
JB467*
NY04-0234
JB018
JB018
JB006*
JB110*
JB209
JB111
JB409*
JB409*
JB315
JB222*
JB422*
JB354*
JB119*
JB422*
JB386*
JB112*
JB026*
JB026*
JB022*
JB472
JB472
JB474
JB474
JB381
JB454*
JB454*
JB372
JB120*
JB466*
JB466*
JB406*
JB206
JB406*
JB371
JB113*
NY05-0002
JB423
JB364
JB223
JB423
JB405*
JB405*
JB205*
JB366
JB041*
JB041*
JB368
JB114*
JB417*
JB039
JB039
JB468*
JB367
JB212*
JB458*
JB458*
JB361
JB417*
JB217*
JB480*
JB480*
JB042*
JB042*
JB486*
JB043*
JB043*
NY-0029-A*
JB219*
NY-0029-A*
JB486*
JB401*
JB201*
JB306
JB419*
JB419*
JB305

Howard Beach
Ralph Creek
Rosedale
South Valley Stream
Queens Nassau
John F Kennedy Int'l Airport
Woodmere
East Pond
Jamaica Bay
CANARSIE POL
West Pond
RULERS BAR HASSOCK
RULERS BAR HASSOCK
Cedarhurst
Inwood
Lawrence
Norton Basin
Far Rockaway
Nassau
RUFFLE BAR
Gerritsen Creek
Dead Horse Bay
Arverne
Rockaway Park
Queens
Breezy Point

LEGEND:

- 1993/1994 REMAP
- 1998 REMAP
- 2003 REMAP
- 2008 REMAP
- 2013 REMAP
- 2000-2005 NCA PROGRAM NEW YORK/NEW JERSEY HARBOR
- * SAMPLING LOCATION USED TO DEFINE REFERENCE CONDITIONS FOR JAMAICA BAY

NOTE:

1. THE FOLLOWING CRITERIA WERE REQUIRED FOR A JAMAICA BAY SAMPLING LOCATION TO BE USED IN DEFINING REFERENCE CONDITIONS: SQT TRIAD (I.E., CHEMISTRY, 10-DAY LABORATORY TOXICITY, AND COMMUNITY TAXONOMY) MUST BE COMPLETE, GREATER THAN 80% *AMPELISCA ABDITA* SURVIVAL, NO EFFECTS RANGE-MEDIAN (ERM) EXCEEDANCES IN THE SEDIMENT, AND NO MORE THAN THREE EFFECTS RANGE LOW (ERL) EXCEEDANCES IN THE SEDIMENT.

0 4,000 8,000 Feet

GRAPHIC SCALE

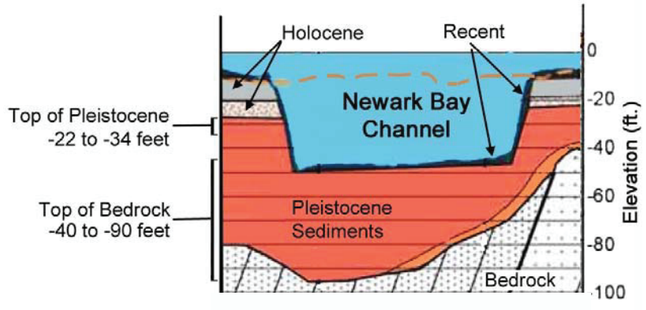
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

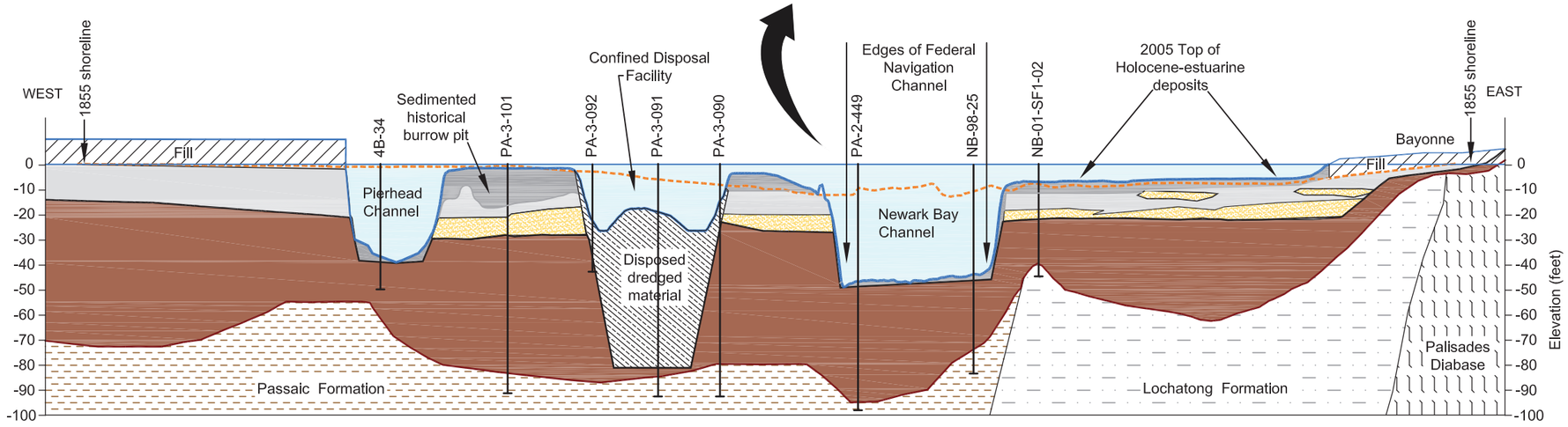
LEVEL 3 SEDIMENT SAMPLE LOCATIONS IN JAMAICA BAY

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-12

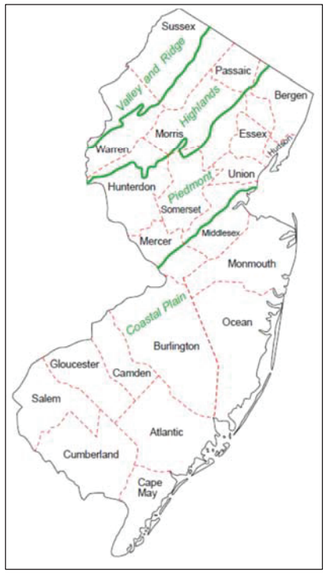
City: Citrix Div/Group: IM Created By: K. SINSABAUGH Last Saved By: avi00815
GSH (B0009869.0061.00013)
T:_ENVGSH\GIS\Task\NBSAI\RemedialInvestigation\mxd\Fig2-12_SedSampLocs_JamaicaBay.mxd 5/19/2021 7:22:29 AM





LEGEND:

- TOP OF BORING/SEA LEVEL
- 1855 - BATHYMETRY
- HOLOCENE
- 2005 - BATHYMETRY
- TOP OF PLEISTOCENE
- TOP OF BEDROCK
- BOTTOM OF BORING



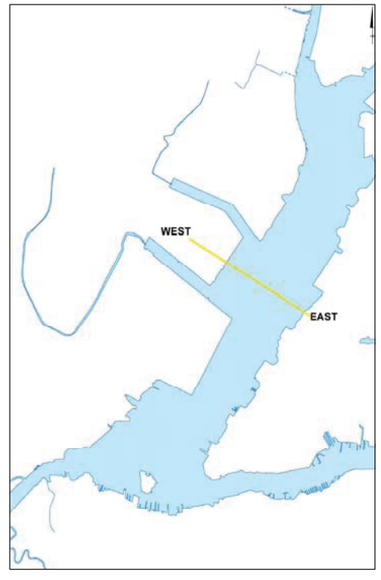
PHYSIOGRAPHIC PROVINCES AND COUNTIES OF NEW JERSEY

KEY:

- FILL
- BLACK FLUID MUD TO SILT (RECENT SEDIMENTS)
- GRAY SILT AND SAND (HOLOCENE ESTUARY DEPOSITS)
- GRAY AND BROWN SAND (HOLOCENE ESTUARY DEPOSITS)
- RED BROWN COBBLES, BOULDERS, CLAY AND SILT (PLEISTOCENE DEPOSITS)
- DIABASE
- RED BROWN SHALE AND SILTSTONE
- GRAY SANDSTONE AND BLACK SHALE

NOTES:

1. ELEVATIONS ARE RELATIVE TO THE USACE's NEW YORK HARBOR TIDAL DATUM MLW NGVD 29.
2. NEWARK BAY CHANNEL DETAIL AND LITHOLOGICAL INFORMATION ARE FROM THE USACE GEOMORPHOLOGICAL REPORT DATED DECEMBER 31, 2006.
3. INFORMATION FOR PHYSIOGRAPHIC PROVINCES OF NEW JERSEY WAS EXTRACTED FROM A NEW JERSEY GEOLOGICAL SURVEY (NJGS) INFORMATION CIRCULAR THAT CAN BE FOUND ON THE NJGS WEBSITE (WWW.STATE.NJ.US/DEP/NJGS).



CROSS SECTION LOCATION MAP

0 800' 1600'

GRAPHIC HORIZONTAL SCALE
VERTICAL EXAGGERATION = 15x

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

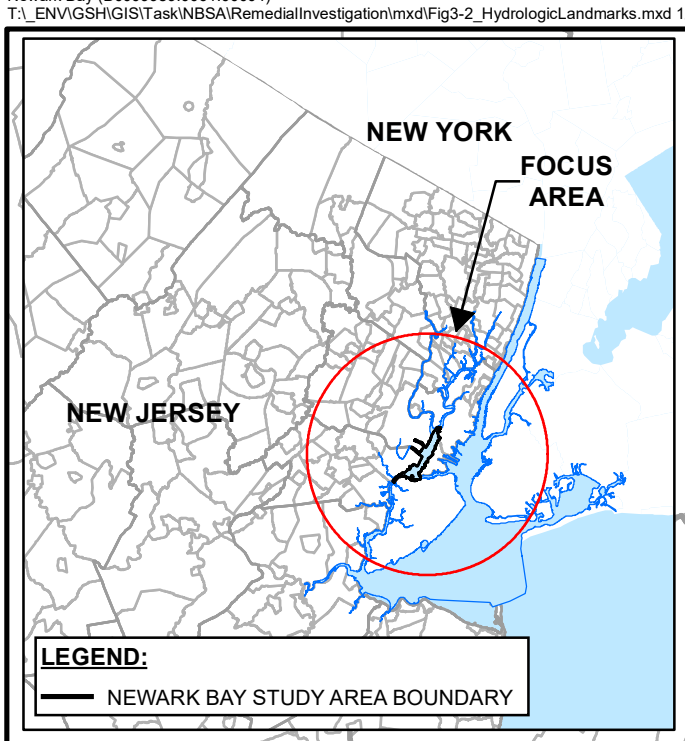
GEOLOGIC CROSS-SECTION

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
3-1

SYR-85-PGL JHR KLS LAYER: ON=*; OFF=REF* (FRZ)
G:\ENVCAD\Concord\RETURN-TO\Syracuse-NY\B0009989\0058\0005\DWG\09989V02.DWG SAVED:8/10/2017 8:48 AM LAYOUT:4-1 PAGESETUP:----- PENTABLE:PLTFULL.CTB PRINTED:8/10/2017 9:01 AM BY:ASREYES
PROJECTNAME:----
XREFS: IMAGES:
Inset Fig 4-1 CrossSection.jpg
Physio Prov and Counties.jpg

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: MEstifanos
Newark Bay (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig3-2_HydrologicLandmarks.mxd 1/20/2021 4:12:42 PM



NEW MILFORD GAUGE
LITTLE FALLS GAUGE
DUNDEE DAM
SADDLE RIVER
WOOD-RIDGE BORO
THIRD RIVER
BELLMANS CREEK
BERRYS CREEK CANAL
BERRYS CREEK
KINGSLAND CREEK
CROMAKILL CREEK
SECOND RIVER
SAWMILL CREEK
80 AND 120 LISTER AVENUE (OU1)
FRANKS CREEK
PASSAIC RIVER
LAWYERS CREEK
ROUTE 1 & 9 BRIDGE
HARRISON CREEK
PLUM CREEK
PIERSONS CREEK
PORT NEWARK CHANNEL
PORT NEWARK
HACKENSACK RIVER
CONRAIL BRIDGE REMNANTS
LEHIGH VALLEY LIFT BRIDGE
NEWARK BAY BRIDGE (VINCENT R. CASCIANO I-78 MEMORIAL BRIDGE)
NEWARK BAY
NEWARK LIBERTY INTERNATIONAL AIRPORT
ELIZABETH CHANNEL
PERIPHERAL DITCH
PORT ELIZABETH
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
BAYONNE BRIDGE
PLATTY KILL CREEK
UPPER NEW YORK BAY
ARTHUR KILL LIFT BRIDGE
MORSES CREEK
GOETHALS BRIDGE
SHOOTERS ISLAND
KILL VAN KULL
ARLINGTON MARSH
MARINERS MARSH
OLD PLACE CREEK
PILES CREEK
PRALLS ISLAND
RAHWAY RIVER
FRESH KILLS
ARTHUR KILL
RARITAN RIVER
RARITAN BAY
PASSAIC COUNTY
BERGEN COUNTY
HUDSON COUNTY
ESSEX COUNTY
UNION COUNTY
MIDDLESEX COUNTY
STATEN ISLAND
PARAMUS BORO
NEW MILFORD BORO
RIVER EDGE BORO
BERGENFIELD BORO
TENAFLY
PATERSON CITY
ELMWOOD PARK BORO
ROCHELLE PARK TWP
MAYWOOD BORO
SADDLE BROOK TWP
TEANECK TWP
ENGLEWOOD BORO
CLIFTON CITY
GARFIELD CITY
LODI BORO
HACKENSACK CITY
BOGOTA BORO
SOUTH HACKENSACK TWP
HASBROUCK HEIGHTS BORO
LEONIA BORO
TETERBORO BORO
RIDGEFIELD PARK VILLAGE
LITTLE FERRY BORO
PALISADES PARK BORO
PASSAIC CITY
WALLINGTON BORO
MOONACHIE BORO
RIDGEFIELD BORO
RUTHERFORD BORO
CARLSTADT BORO
CLIFFSIDE PARK BORO
FAIRVIEW BORO
EAST RUTHERFORD BORO
EDGEWATER
GUTTENBERG TOWN
NUTLEY TWP
LYNDHURST TWP
BELLEVILLE TWP
NORTH ARLINGTON BORO
SECAUCUS TOWN
NORTH BERGEN TWP
WEEHAWKEN TWP
WEST NEW YORK TOWN
UNION CITY
HOBOKEN CITY
BLOOMFIELD TWP
KEARNY TOWN
EAST ORANGE CITY
EAST NEWARK BORO
HARRISON TOWN
JERSEY CITY
NEWARK CITY
BAYONNE CITY
ELIZABETH CITY
MONTCLAIR TWP
LIVINGSTON TWP
WEST ORANGE TWP
CITY OF ORANGE TWP
SOUTH ORANGE VILLAGE TWP
MILLBURN TWP
MAPLEWOOD TWP
IRVINGTON TWP
SUMMIT CITY
SPRINGFIELD TWP
UNION TWP
HILLSIDE TWP
MOUNTAINSIDE BORO
KENILWORTH BORO
ROSELLE PARK BORO
CRANFORD TWP
GARWOOD BORO
ROSELLE BORO
WESTFIELD TOWN
WINFIELD TWP
LINDEN CITY
SCOTCH PLAINS TWP
CLARK TOWNSHIP
RAHWAY CITY
CARTERET BORO
WOODBRIDGE TWP
EDISON TWP
PERTH AMBOY CITY
SOUTH AMBOY CITY
SAYREVILLE BORO
OLD BRIDGE TWP

LEGEND:

- UNITED STATES GEOLOGICAL SURVEY GAGE STATION LOCATION
- RIVER/BAY MILE
- NEWARK BAY STUDY AREA BOUNDARY (OU3)

NOTES:

1. BASEMAP INFORMATION FROM NOAA CHARTS 12331, 12333, AND 12337, DATED MAY 4, 1995.
2. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
3. REFERENCES:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

0 2.25 4.5 Miles
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

HYDROLOGICAL LANDMARKS IN THE NEWARK BAY REGION

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
3-2

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Newark Bay (B0009989.0058.00005)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig3-3_2013_Bathymetry.mxd 11/30/2020 2:52:47 PM

LEGEND:

TYPICAL SALTWATER FLOW DIRECTION DURING FLOOD TIDE

TYPICAL FRESHWATER FLOWING OVER SALTWATER

BATHYMETRY
(FT AMSL)

6
0
-6
-12
-18
-24
-30
-36
-42
-48
-54
-60

NOTES:

1. AERIAL PHOTOS DATED 2019 (ESRI CLOUD IMAGERY).
2. BATHYMETRY WAS MEASURED IN 2012/2013 (TIERRA 2013C).
3. NET CIRCULATION DIRECTION IN NEWARK BAY IS TYPICALLY COUNTERCLOCKWISE AROUND STATEN ISLAND (BLUMBERG ET AL. 1999).
4. REFERENCE:
BLUMBERG, A.F., L.A. KHAN, AND J.P. ST. JOHN. 1999. THREE-DIMENSIONAL HYDRODYNAMIC MODEL OF NEW YORK HARBOR REGION. J. HYDRAULIC ENGINEERING AUGUST 1999: 799-816.4

0 0.55 1.1 Miles

GRAPHIC SCALE

PASSAIC RIVER
HACKENSACK RIVER
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK BAY CDF
NAVIGATION CHANNEL
SUBTIDAL FLATS
NEWARK BAY
ARTHUR KILL
KILL VAN KULL
STATEN ISLAND

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

BATHYMETRY AND SALTWATER/FRESHWATER FLOW

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE 3-3

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: avi00815
Newark Bay (B0009989.0058.00005)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig3-4_D50Grain_Results_PhI_and_PhII_surface.mxd 7/22/2021 11:57:45 AM

LEGEND:

- PHASE I CORING LOCATION
- PHASE II CORING LOCATION

D_{50} GRAIN SIZE (µm)

- < 16 FINE SILT OR SMALLER
- 16 - 31 MEDIUM SILT
- 31 - 62 COARSE SILT
- 62 - 125 VERY FINE SAND
- > 125 SAND OR LARGER

- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- SHORELINE
- UNDERGROUND TRIBUTARY
- POTENTIAL HIGH NET DEPOSITION AREA

GEOMORPHIC AREAS:

- HISTORICALLY DISTURBED SUBTIDAL FLATS
- INDUSTRIAL WATERFRONT
- INTERTIDAL AREA
- NAVIGATION CHANNEL
- PORT CHANNEL
- SUBTIDAL FLATS
- TRANSITIONAL SLOPES

049 PHASE I CORE ID
102* PHASE II CORE ID

0 0.75 1.5 Miles
GRAPHIC SCALE

PASSAIC RIVER
HACKENSACK RIVER
CONRAIL BRIDGE
PIERSON'S CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
ARTHUR KILL
SHOOTERS ISLAND
GOETHALS BRIDGE
PRALL'S ISLAND
KILL VAN KULL

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. THE GEOMORPHIC AREAS SHOWN ARE CONSISTENT WITH THOSE PRESENTED IN THE PHASE II RIWP (TIERRA 2007).
4. DEPOSITIONAL INFORMATION WAS EXTRACTED FROM FIGURE 2 OF USACE GEOMORPHOLOGICAL REPORT DATED DECEMBER 31, 2006.
5. GRAIN SIZE MEASURED BY PARTICLE TECHNOLOGY LABS, LTD. AND TEST AMERICA, INC. (WITH LASER DIFFRACTION TECHNOLOGY) AS DESCRIBED IN THE PHASE I RIWP (TIERRA 2005) AND PHASE II RIWP (TIERRA 2007), RESPECTIVELY.
6. D_{50} = MEDIAN GRAIN SIZE; WENTWORTH SIZE CLASSES ARE INDICATED FOR GRAIN SIZE RANGE.
7. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
8. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
9. REFERENCES:

A. TIERRA. 2005. NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION WORK PLAN. SEDIMENT SAMPLING AND SOURCE IDENTIFICATION PROGRAM, NEWARK BAY, NEW JERSEY. REVISION 1. SEPTEMBER.
B. TIERRA 2007. NEWARK BAY STUDY AREA PHASE II REMEDIAL INVESTIGATION WORK PLAN. REVISION 2. AMENDMENT 1. NOVEMBER.
C. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

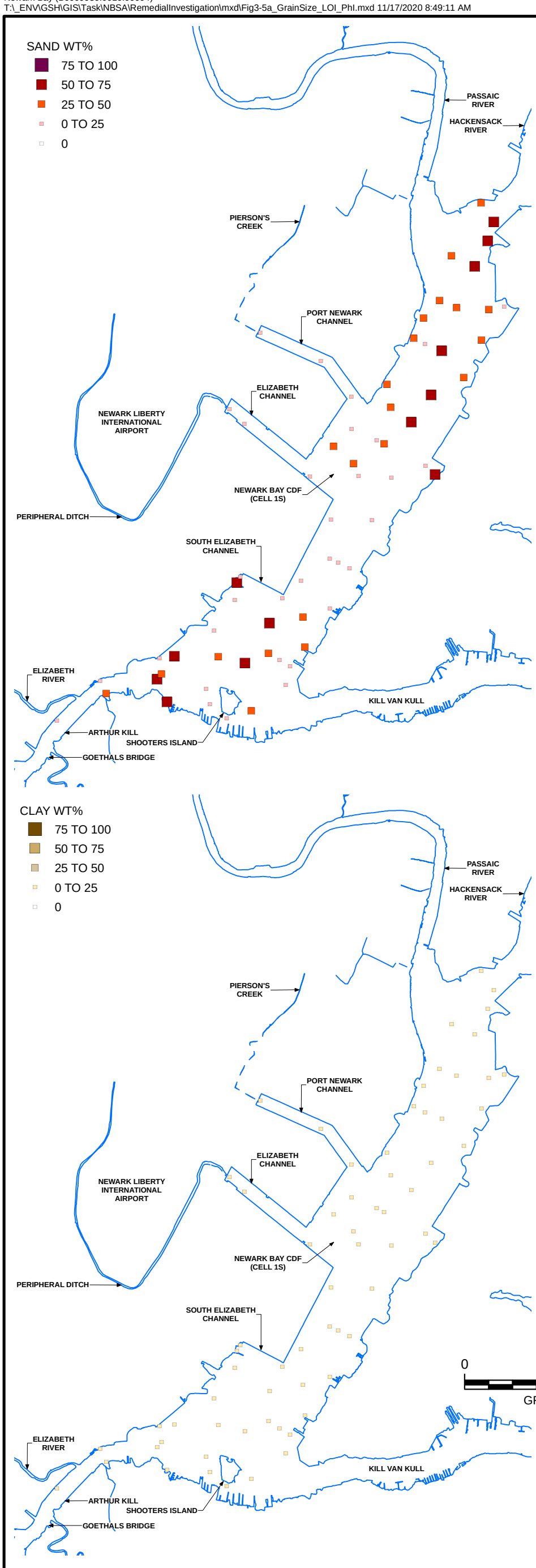
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

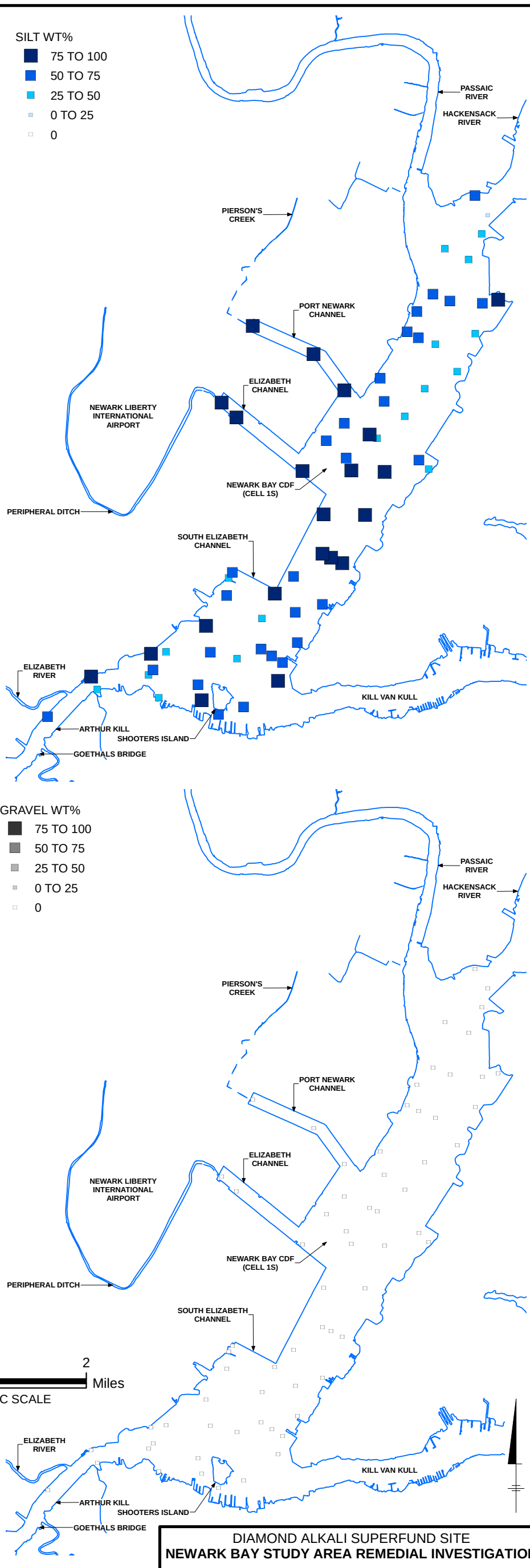
D_{50} GRAIN SIZE RESULTS - SURFACE (0 - 0.5 FEET)

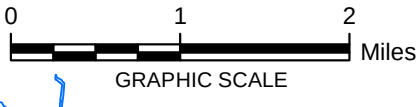
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
3-4

CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR:
Newark Bay (B0009989.0016.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig3-5a_GrainSize_LOI_PhI.mxd 11/17/2020 8:49:11 AM







NOTES:

1. GRAIN SIZE WAS COLLECTED AS PART OF THE THE SEDIMENT INVESTIGATION PROGRAM IN THE NEWARK BAY STUDY AREA AND REPORTED IN THE PHASE I AND PHASE II SEDIMENT INVESTIGATION FIELD AND DATA REPORT (TIERRA SOLUTIONS, INC. 2008).

2. REFERENCES:
   A. TIERRA SOLUTIONS, INC. 2008. PHASE I AND PHASE II SEDIMENT INVESTIGATION FIELD AND DATA REPORT. DECEMBER 2008.

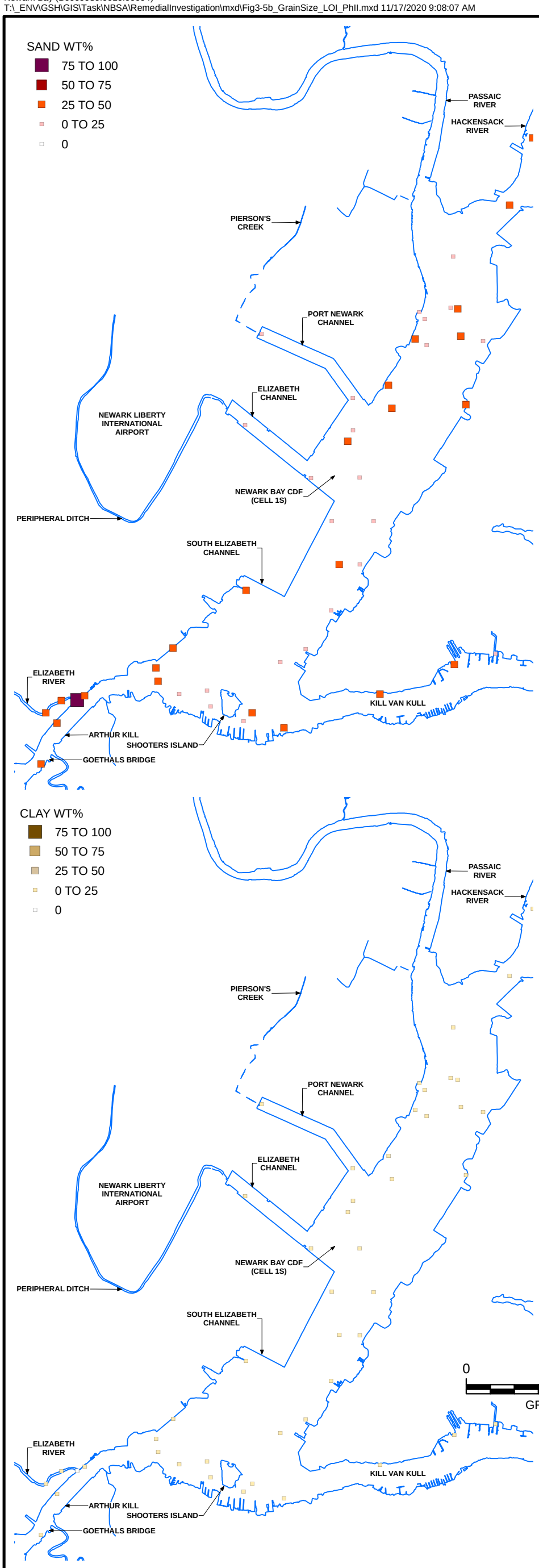
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

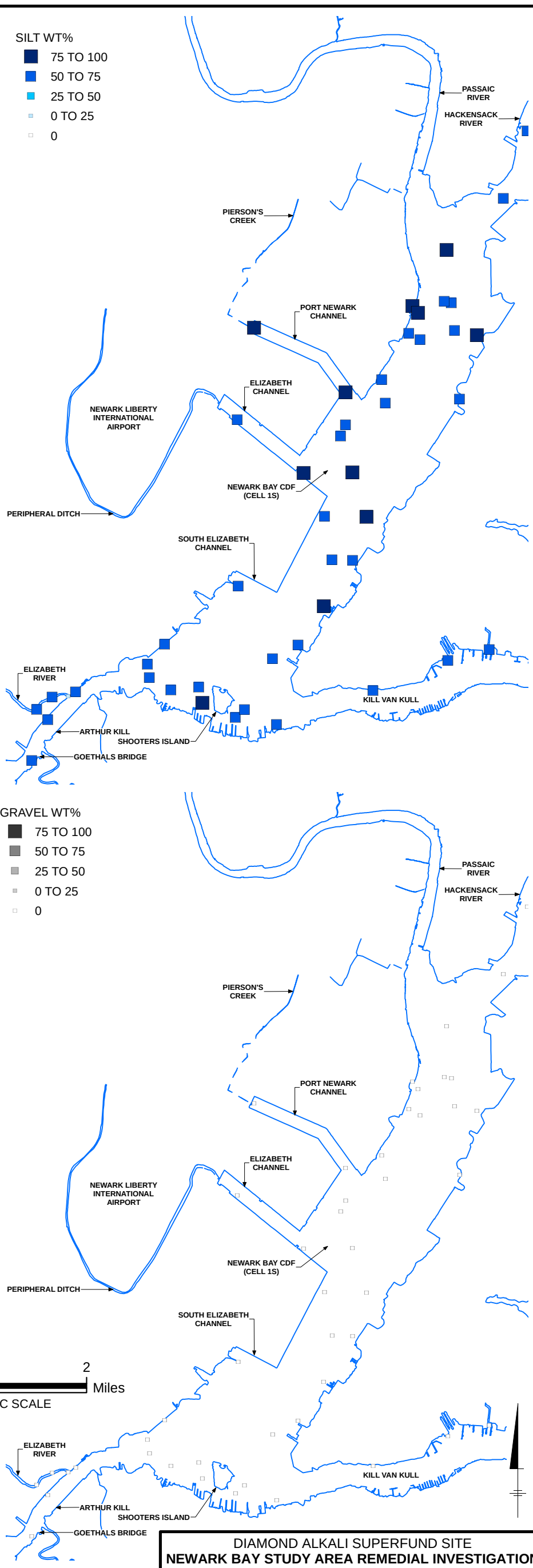
GRAIN SIZE FOR PHASE I BED SEDIMENTS IN THE NEWARK BAY STUDY AREA

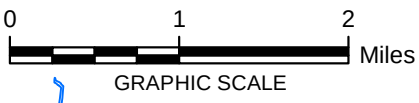
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
3-5a

CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR:
Newark Bay (B0009989.0016.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig3-5b_GrainSize_LOI_PhII.mxd 11/17/2020 9:08:07 AM







NOTES:

1. GRAIN SIZE WAS COLLECTED AS PART OF THE THE SEDIMENT INVESTIGATION PROGRAM IN THE NEWARK BAY STUDY AREA AND REPORTED IN THE PHASE I AND PHASE II SEDIMENT INVESTIGATION FIELD AND DATA REPORT (TIERRA SOLUTIONS, INC. 2008).

2. REFERENCES:
   A. TIERRA SOLUTIONS, INC. 2008. PHASE I AND PHASE II SEDIMENT INVESTIGATION FIELD AND DATA REPORT. DECEMBER 2008.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

GRAIN SIZE FOR PHASE II BED SEDIMENTS IN THE NEWARK BAY STUDY AREA

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
3-5b

CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR:
Newark Bay (B0009989.0016.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig3-5c_GrainSize_LOI_PhIII.mxd 12/1/2020 11:09:36 AM

SAND WT%
- 75 TO 100
- 50 TO 75
- 25 TO 50
- 0 TO 25
- 0

SILT WT%
- 75 TO 100
- 50 TO 75
- 25 TO 50
- 0 TO 25
- 0

CLAY WT%
- 75 TO 100
- 50 TO 75
- 25 TO 50
- 0 TO 25
- 0

GRAVEL WT%
- 75 TO 100
- 50 TO 75
- 25 TO 50
- 0 TO 25
- 0

PASSAIC RIVER
HACKENSACK RIVER
PIERSON'S CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
KILL VAN KULL
ARTHUR KILL
SHOOTERS ISLAND
GOETHALS BRIDGE

0 1 2 Miles
GRAPHIC SCALE

NOTES:

1. GRAIN SIZE WAS ANALYZED DURING PHASE III ACTIVITIES IN 2014 AS PART OF THE CRAB AND CLAM SAMPLING PROGRAM (GSH 2017A), IN 2015 AS PART OF THE SEDIMENT QUALITY TRIAD AND POREWATER SAMPLING PROGRAM (GSH 2017B), AND IN 2016 AS PART OF THE SURFACE SEDIMENT SAMPLING PROGRAM (TIERRA 2016; GSH 2018).

2. REFERENCES:

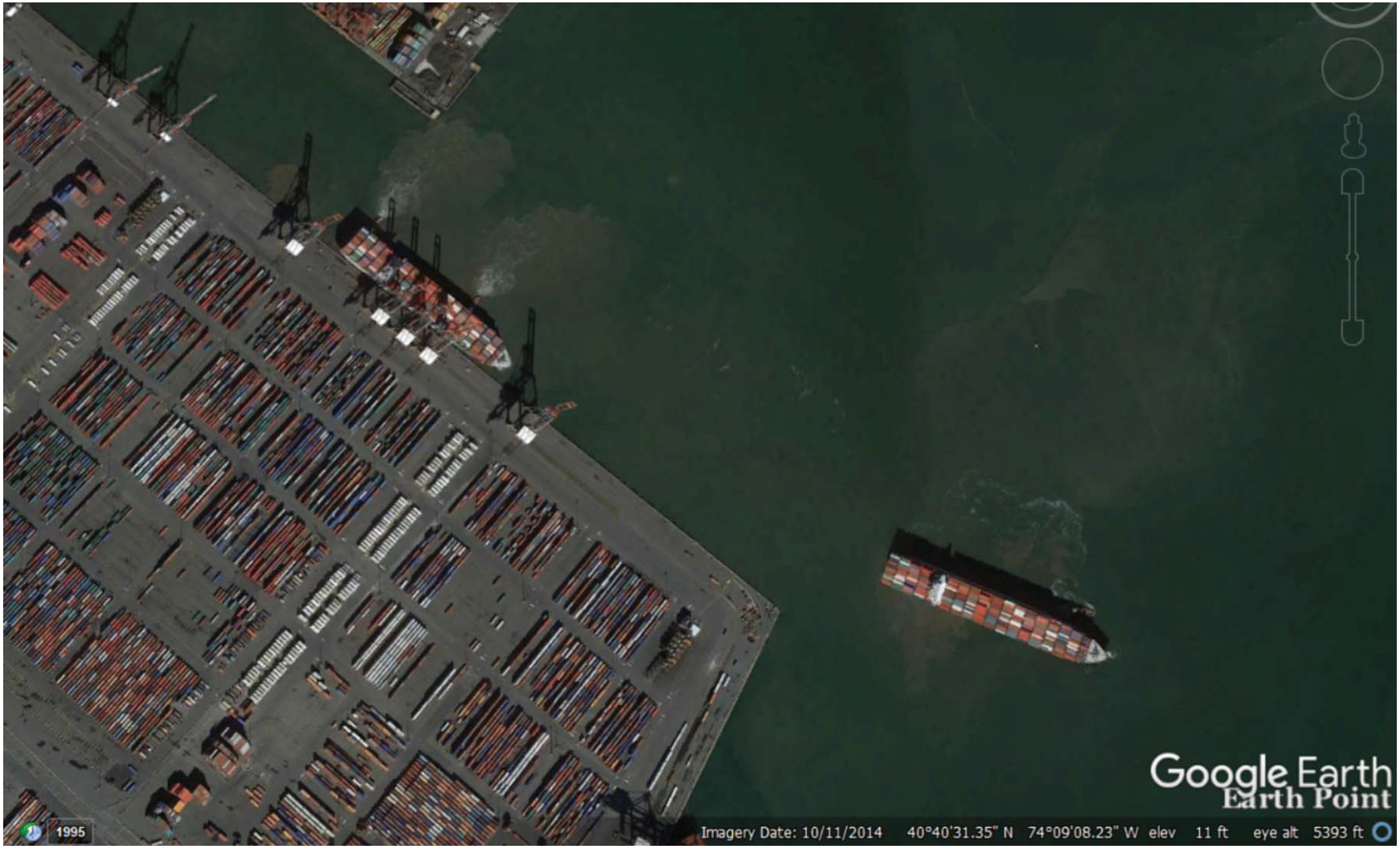
A. GSH. 2017A. NEWARK BAY STUDY AREA CRAB AND CLAM DATA REPORT. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. REVISION 1. MARCH.
B. GSH. 2017B. NEWARK BAY STUDY AREA SEDIMENT QUALITY TRIAD AND POREWATER DATA REPORT. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. REVISION 2. SEPTEMBER.
C. GSH. 2018. NEWARK BAY STUDY AREA CONCEPTUAL SITE MODEL, REVISION 2. AUGUST.
D. SOMMERFIELD, C.K. AND R.J. CHANT. 2010. MECHANISMS OF SEDIMENT TRAPPING AND ACCUMULATION IN NEWARK BAY, NEW JERSEY: AN ENGINEERED ESTUARINE BASIN (HRF 008/07A). FINAL REPORT TO THE HUDSON RIVER FOUNDATION. JULY.
E. TIERRA. 2016. NEWARK BAY STUDY AREA PHASE III SEDIMENT INVESTIGATION QUALITY ASSURANCE PROJECT PLAN AMENDMENT. REVISION 2. SEPTEMBER.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

GRAIN SIZE FOR PHASE III BED SEDIMENTS IN THE NEWARK BAY STUDY AREA

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
3-5c



DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

VESSEL-INDUCED SEDIMENT RESUSPENSION

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
3-6

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: avi00815
Newark Bay (B0009989.0061.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig3-7_B3-7ActivitySurfSed.mxd 5/19/2021 11:45:55 AM

LEGEND:

Be-7 BEARING LOCATION (pCl/g)
- 0.5 - 1.0
- 1.0 - 5.0
- > 5.0
- NON-Be-7 BEARING LOCATION
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- POTENTIAL HIGH NET DEPOSITION AREA
- 048 LOCATION ID
- *1.98* Be-7 RESULT

GEOMORPHIC AREAS:
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- INDUSTRIAL WATERFRONT
- INTERTIDAL AREA
- NAVIGATION CHANNEL
- PORT CHANNEL
- SUBTIDAL FLATS
- TRANSITIONAL SLOPES

0 3,000 6,000 Feet
GRAPHIC SCALE

CONRAIL BRIDGE REMNANTS
PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
GOETHALS BRIDGE
ARTHUR KILL
SHOOTERS ISLAND
BAYONNE BRIDGE

065 *0.11 U*; 066 *0.14 U*; 101 *0.26 U*; 064 *0.06 U*; 063 *1.05*; 062 *0.15 G*; 102 *0.91*; 094 *1.8*; 078 *0.41*; 061 *0.72*; 080 *1.2*; 058 *0.45*; 052 *0.57*; 060 *0.61*; 056 *0.27 G*; 059 *0.23 G*; 075 *3.8*; 079 *0.56*; 049 *3.595*; 077 *0.88*; 057 *1.18*; 104 *0.85*; 054 *0.18 U*; 048 *1.98*; 093 *0.34*; 076 *0.36 G,J*; 055 *2.525*; 053 *0.21*; 107 *0.93*; 051 *0.49*; 106 *0.695*; 050 *0.175*; 105 *0.20 G*; 047 *1.27*; 046 *1.42*; 036 *0.595*; 074 *0.26 G*; 045 *0.14 U*; 035A *1.42*; 044 *0.96*; 043 *0.3 G*; 110 *1.8*; 092 *0.36 G*; 042 *1.97*; 041 *0.49*; 040 *0.08 G,U*; 039 *0.47*; 034A *2.2*; 109 *1.25*; 038 *0.22 G*; 108 *2.1*; 033A *1.66*; 037 *1.14*; 073 *0.45*; 111 *0.66*; 032 *0.73*; 031 *1.69*; 112 *1.8*; 029 *1.7*; 030 *1.82*; 091 *0.75*; 026 *0.14 G*; 028 *1.71*; 027 *1.83*; 025 *0.15 U*; 098 *0.67*; 024 *0.835*; 023 *0.7*; 072 *0.58*; 021 *0.97*; 022 *0.91*; 012 *0.35*; 020 *0.5 G*; 019 *0.5*; 071 *0.84*; 114 *0.4*; 082 *0.98*; 007 *0.48*; 115 *0.8*; 013 *0.1 U*; 014 *0.43*; 018 *0.3*; 017 *1.55*; 010A *1.07*; 011 *0.44*; 097 *0.62*; 015 *0.105*; 016 *1.06*; 113 *1.2*; 068 *2.18*; 009 *0.575*; 006A *1.95*; 088 *0.20 G*; 002 *0.3 G*; 089 *1.4*; 008A *1.78*; 004 *0.24 G*; 003 *0.1 U*; 070 *0.11*; 120 *2.35*; 116 *0.11 U*; 005 *0.35*; 090 *0.26 G*; 001A *2.41*; 118 *0.28 G*

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002(INTRASEARCH, ENGLEWOOD, CO).
3. THE GEOMORPHIC AREAS SHOWN ARE CONSISTENT WITH THOSE PRESENTED IN THE PHASE II RIWP (TIERRA 2007).
4. THE BE-7 ACTIVITIES SHOWN WERE REPORTED IN THE DATA EVALUATION AND ANALYSIS REPORT (TIERRA 2014).
5. Be-7 BEARING LOCATIONS ARE DEFINED AS LOCATIONS WITH SURFACE SAMPLES ANALYZED FOR Be-7 AND RESULT CONCENTRATIONS GREATER THAN OR EQUAL TO 0.5 PICOCURIE PER GRAM (pCi/g). THESE LOCATIONS ARE CONSIDERED TO INDICATE RECENTLY DEPOSITED SEDIMENTS. NON-Be-7 BEARING LOCATIONS ARE LOCATIONS WITH SURFACE SAMPLES ANALYZED FOR Be-7, BUT WITH RESULT CONCENTRATIONS LESS THAN 0.5 pCi/g.
6. AT SOME CO-LOCATED LOCATIONS, ONE OF THE SURFACE SEDIMENT SAMPLES WAS Be-7 BEARING (INDICATING RECENTLY DEPOSITED SEDIMENTS), AND THE OTHER WAS NON-Be-7 BEARING. THESE LOCATIONS ARE INDICATED BY BOTH A TRIANGLE AND A PURPLE RING.
7. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
8. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
9. REFERENCES:
A. TIERRA. 2007. NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION WORK PLAN, SEDIMENT SAMPLING AND SOURCE IDENTIFICATION PROGRAM, NEWARK BAY, NEW JERSEY, PHASE II, REVISION 2, AMENDMENT 1. NOVEMBER.
B. TIERRA. 2008. NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION PHASE I AND PHASE II SEDIMENT INVESTIGATION FIELD AND DATA REPORT. REVISION 0. DECEMBER.
C. TIERRA. 2014. PHASE I AND PHASE II DATA EVALUATION AND ANALYSIS REPORT. NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION. REVISION 2. SEPTEMBER.
D. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

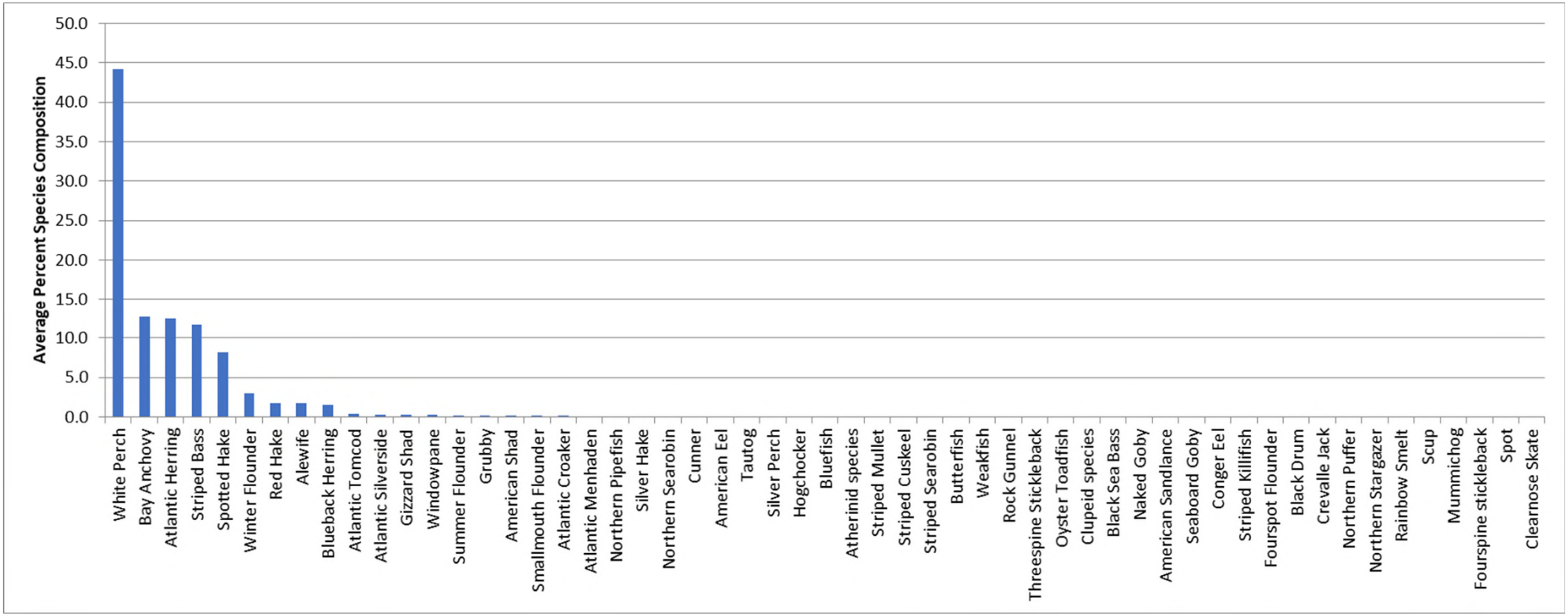
Geomorphic Unit	Average Be-7 Activity (pCi/g)
Historically Disturbed Subtidal Flats	0.49
Industrial Waterfront	0.91
Intertidal Area	0.24
Navigation Channel	1.17
Port Channel	1.69
Subtidal Flats	0.50
Transitional Slopes	1.03

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

Be-7 ACTIVITY IN SURFACE SEDIMENTS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
3-7



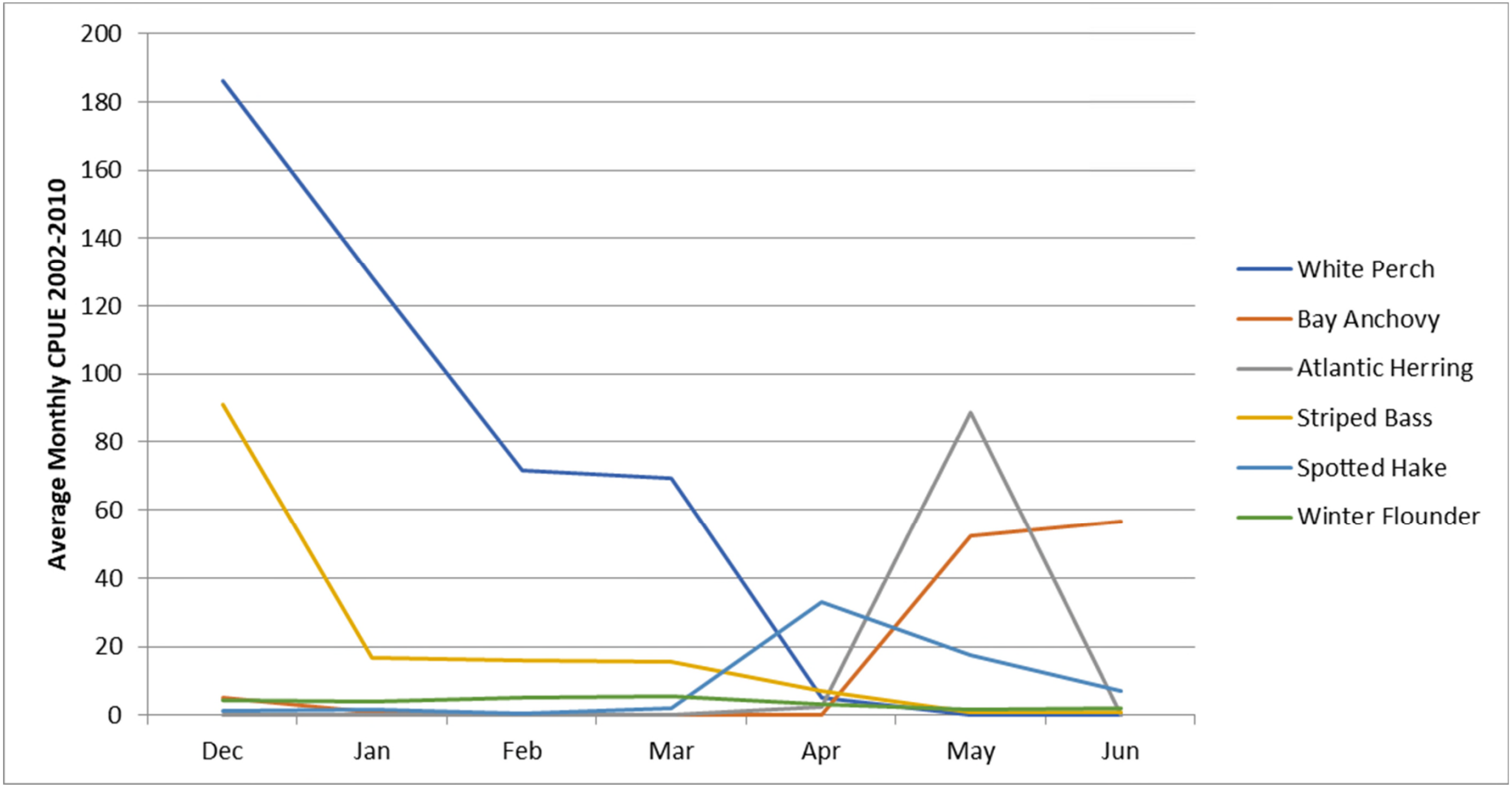
Notes:
CPUE = number of fish per 10-minute trawl
From the USACE Aquatic Biological Survey 2002-2010 bottom trawl/demersal fish surveys

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

AVERAGE PERCENT SPECIES CATCH PER UNIT EFFORT (CPUE) OF DEMERSAL FISH IN NEWARK BAY 2002-2010

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
3-8a



Notes:
CPUE = number of fish per 10-minute trawl
Six species are the predominant fish catch in terms of percent composition
From the USACE Aquatic Biological Survey 2002-2010 bottom trawl/demersal fish surveys

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

AVERAGE MONTHLY CATCH PER UNIT EFFORT (CPUE) OF DEMERSAL FISH IN NEWARK BAY 2002-2010

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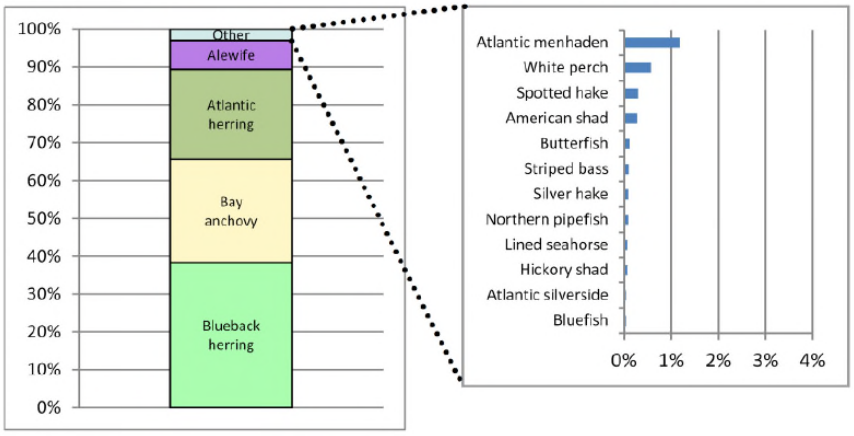
FIGURE
3-8b

MAJOR SPECIES (>= 5% of Total)

OTHER SPECIES >= 0.02% OF TOTAL

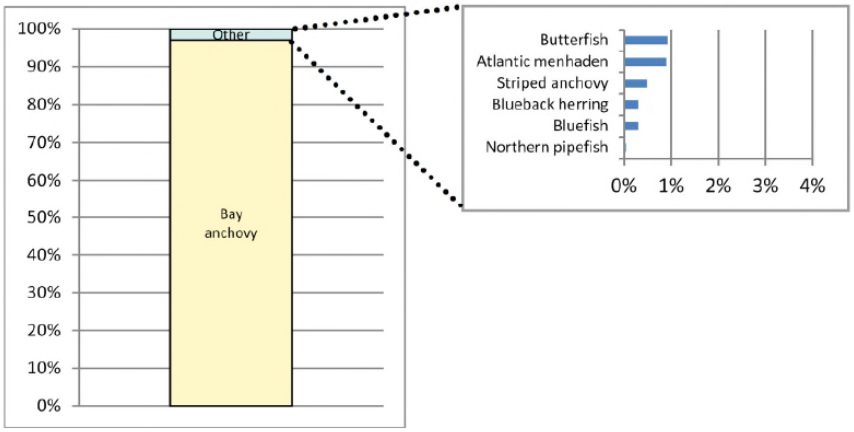
SPRING

Total Trawls: 131
Total Species Collected: 22
Total Fish Collected: 6,395



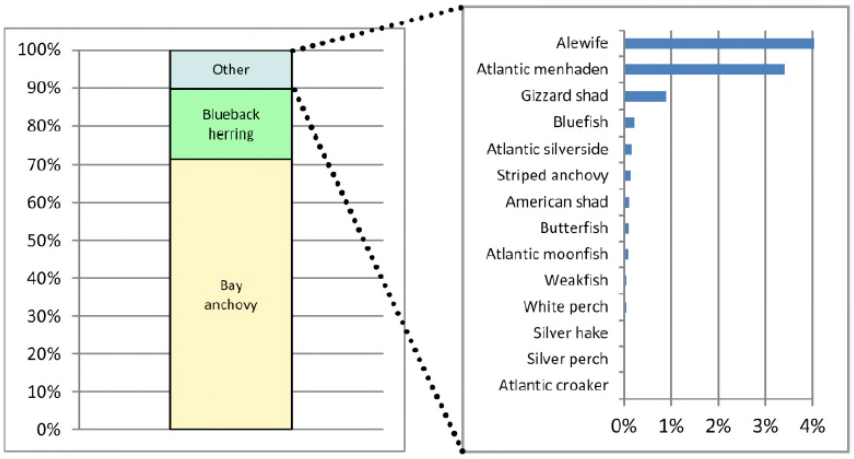
SUMMER

Total Trawls: 36
Total Species Collected: 8
Total Fish Collected: 6,099



FALL

Total Trawls: 170
Total Species Collected: 21
Total Fish Collected: 23,551



Note:
Mid-water fish collections from the USACE Migratory Finfish Surveys in Newark Bay during 2006 and 2011-2013 spring (March – May), summer (June to August), and fall (September to December) seasons.

Reference:
USACE. 2015. Migratory Finfish Summary Report. New York and New Jersey Harbor Deepening Project. U.S. Army Corps of Engineers, New York District. New York, New York.

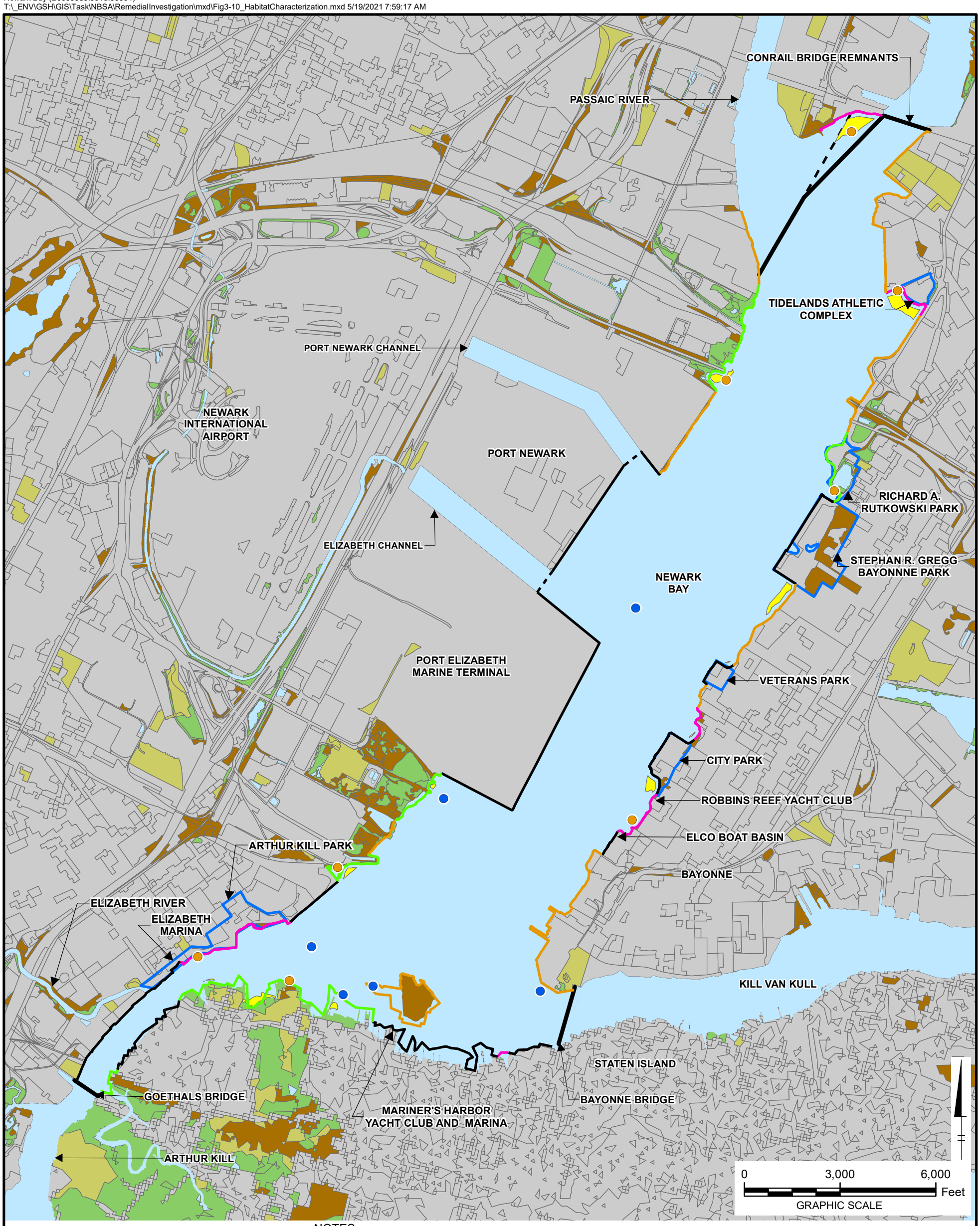
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SUMMARY OF SEASONAL CATCH IN MID-WATER TRAWLS IN NEWARK BAY, 2006 AND 2011-2013

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FIGURE
3-9

CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR:
Newark Bay (B0009989.0016.00004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig3-10_HabitatCharacterization.mxd 5/19/2021 7:59:17 AM



LEGEND:

- BIRD NEST LOCATION
- MAMMAL OBSERVATION
- FORMER OU2/OU3 BOUNDARY
- INTERTIDAL AREA
- PARKS AND RECREATIONAL AREAS
- NEWARK BAY STUDY AREA BOUNDARY

OBSERVED SHORELINE HABITAT:

- BULKHEAD
- MIXED INTERTIDAL
- RIPRAP
- VEGETATION

LANDCOVER:

- BARREN LAND
- FOREST
- URBAN
- WATER
- WETLANDS

NOTES:

1. 2012 NEW JERSEY LAND USE DATA (UPDATED IN 2015) DOWNLOADED FROM THE NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION GEOGRAPHIC INFORMATION SYSTEM WEBSITE AT www.state.nj.us/dep/gis.
2. 2011 NEW YORK NATIONAL LAND COVER DATA DOWNLOADED FROM THE NEW YORK STATE GEOGRAPHIC INFORMATION SYSTEMS CLEARINGHOUSE AT www.nysgis.state.ny.us.
3. THE INTERTIDAL AREAS SHOWN ARE CONSISTENT WITH THOSE PRESENTED IN THE PROBLEM FORMULATION TIERRA 2013) AND WERE VERIFIED DURING THE RECONNAISSANCE SURVEY. (TIERRA, 2015)
4. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
5. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
6. BIRD NESTS AND MAMMALS WERE OBSERVED SEPTEMBER 11 TO SEPTEMBER 15, 2013 (TIERRA 2015).
7. REFERENCES:
A. TIERRA. 2013. FINAL NEWARK BAY STUDY AREA PROBLEM FORMULATION. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. TIERRA SOLUTIONS, INC., EAST BRUNSWICK, N.J. JUNE.
B. TIERRA. 2015. NEWARK BAY STUDY AREA RECONNAISSANCE SURVEY REPORT. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. APRIL.
C. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

BIRD NEST AND MAMMAL OBSERVATION LOCATIONS

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FIGURE
3-10

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: MEstifanos
Project (B0009989.0045.00002)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\Figure_4-2_COLOC_Phase123ColocatedSedimentSamples.mxd 4/6/2021 4:49:09 PM

LEGEND:

- PHASE I CORE LOCATION
- PHASE II CORE LOCATION
- CO-LOCATED PHASE I/II CORE LOCATION
- 2016 PHASE III SEDIMENT SAMPLING LOCATION
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS

PROPOSED USEPA SUBUNIT

- 1
- 2
- 3
- 4
- 5
- 6

0 0.6 1.2 Miles

GRAPHIC SCALE

PASSAIC RIVER
HACKENSACK RIVER
PIERSONS CREEK
CONRAIL BRIDGE REMNANTS
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
PERIPHERAL DITCH
NEWARK BAY CDF (CELL 1S)
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
KILL VAN KULL
SHOOTERS ISLAND
BAYONNE BRIDGE
GOETHALS BRIDGE
ARTHUR KILL
PRALLS ISLAND

NOTES:

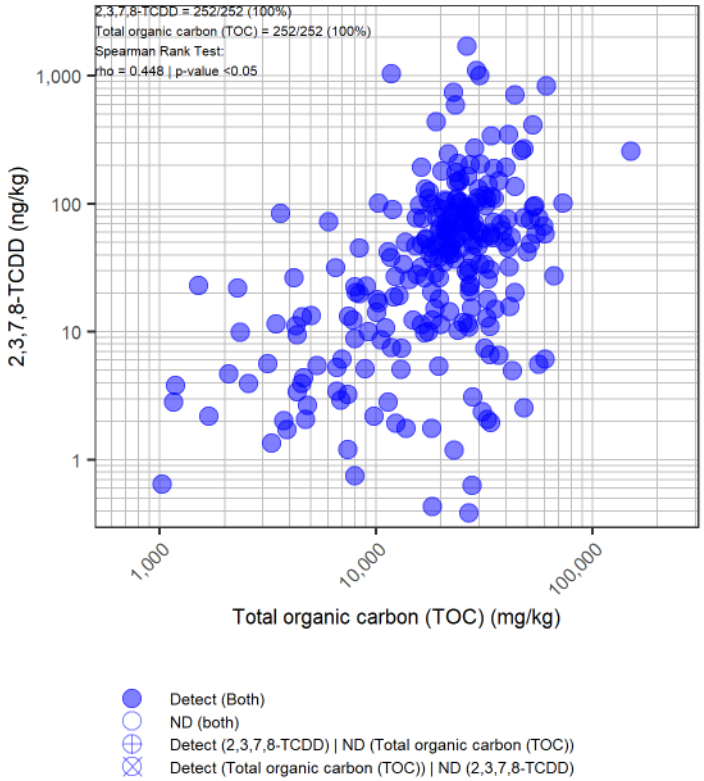
1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. BASE MAP INFORMATION AND NEWARK BAY NAVIGATION CHANNEL IS FROM NOAA CHARTS 12331, 12333, AND 12337, DATED MAY 4, 1995. PASSAIC NAVIGATION CHANNEL WAS PROVIDED BY THE USACE. ALL NAVIGATION CHANNEL BOUNDARIES SHOWN ARE APPROXIMATE. CHANNEL DREDGING AND DEEPENING AS PART OF THE HARBOR DEEPENING PROJECT (50-FOOT) IS COMPLETE; CONTACT USACE OPERATIONS DIVISION TO REFERENCE THE MOST CURRENT CHANNEL BOUNDARIES.
4. THE NEWARK BAY STUDY AREA BOUNDARY PRESENTED WAS USEPA-APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS, BUT MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
5. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA-APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
6. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
7. REFERENCE:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

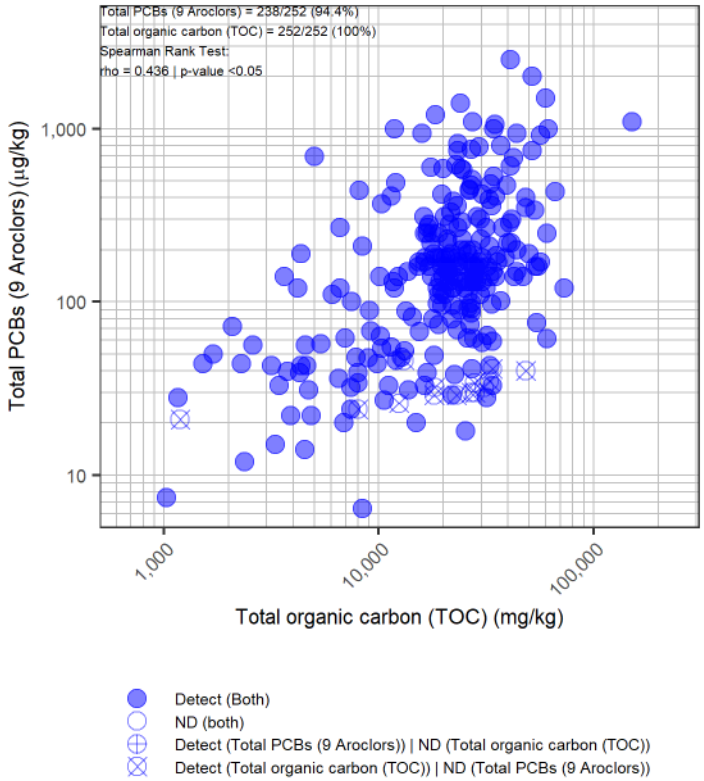
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

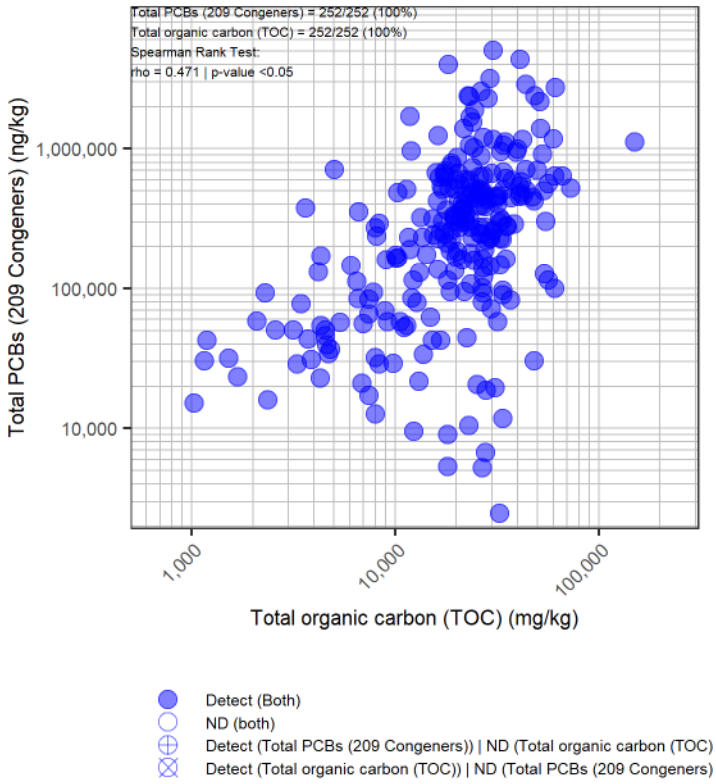
PHASE I/II/III CO-LOCATED SEDIMENT SAMPLES

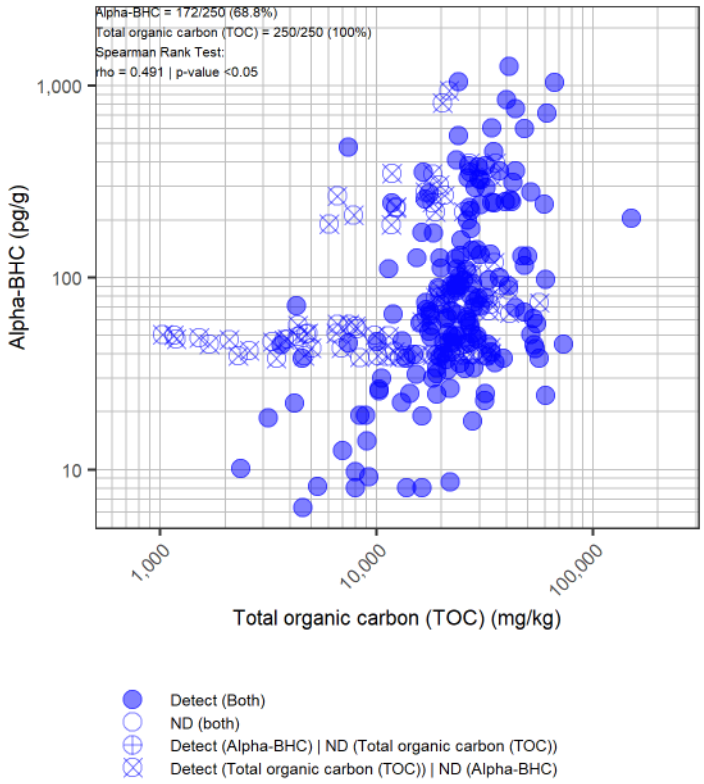
Glenn Springs Holdings, Inc.
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FIGURE 4-2









Notes:

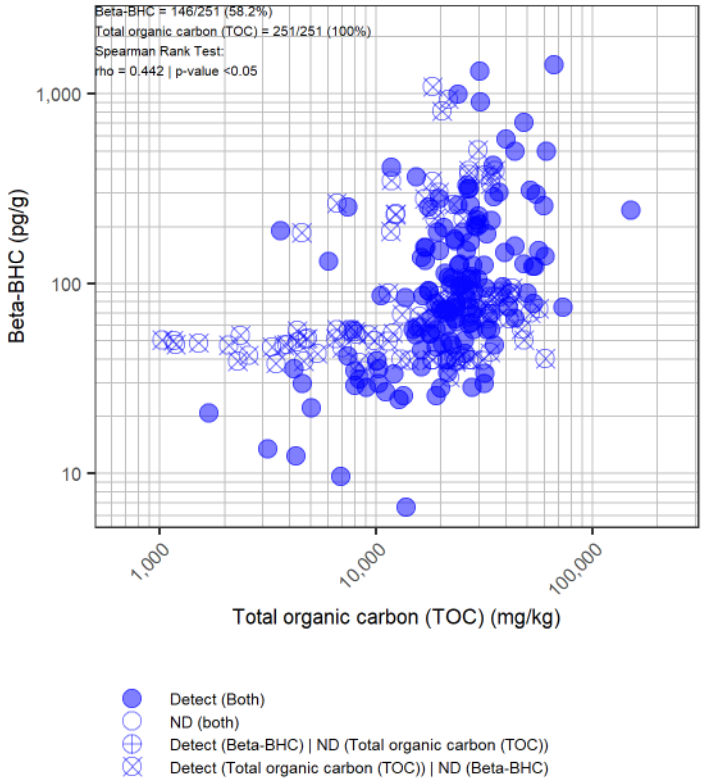
1. For correlation analysis, non-detects included at 1/2 the quantitation limit.
2. Non-detects plotted at the quantitation limit.
3. Includes Phase III surface sediment data collected from 2014 to 2016 (including the SQT and crab/clam sediment).

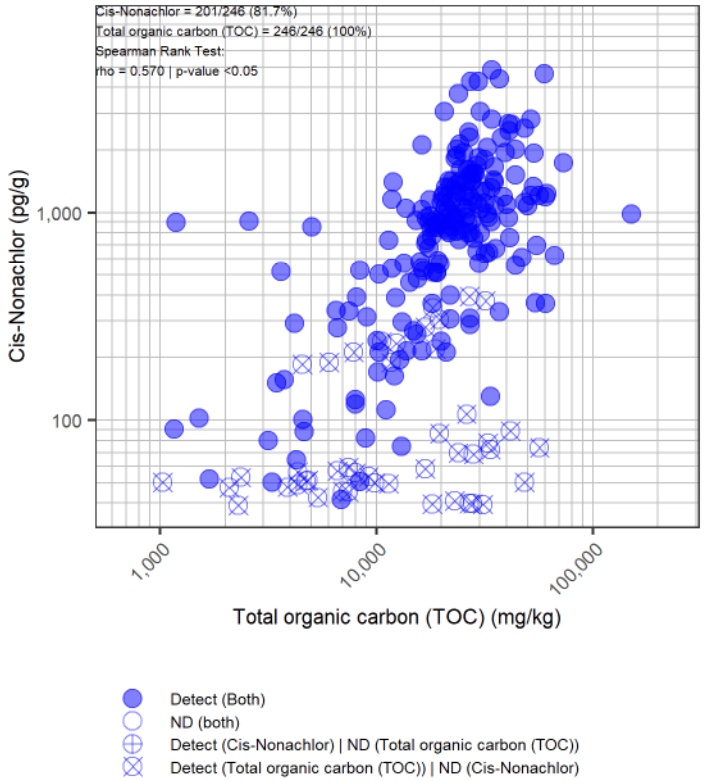
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

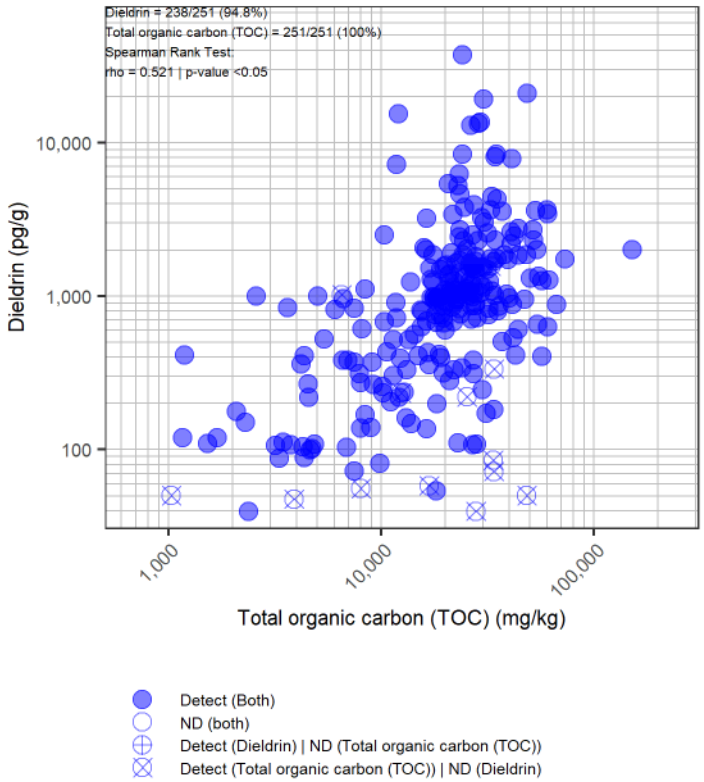
SEDIMENT CORRELATION – ORGANICS AND TOC

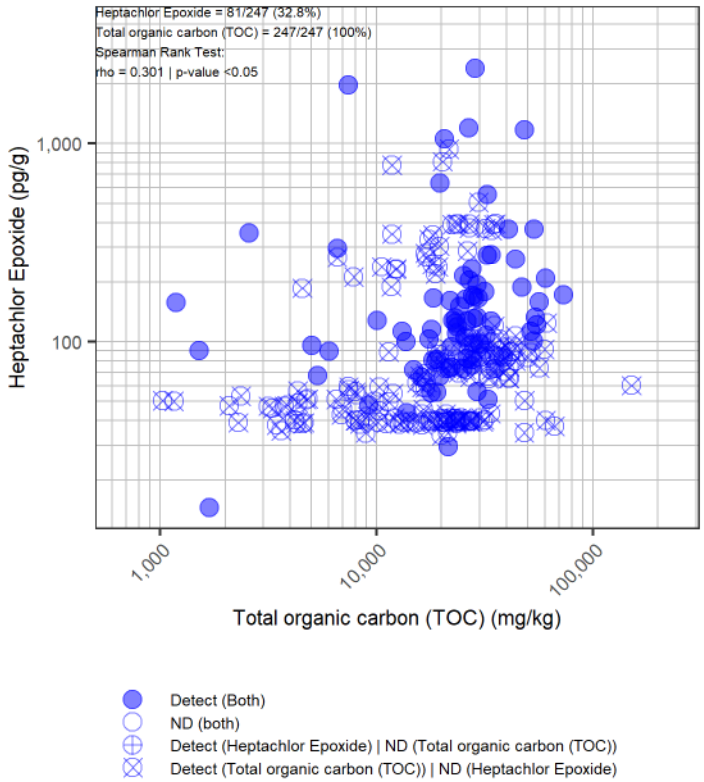
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FIGURE
4-3a









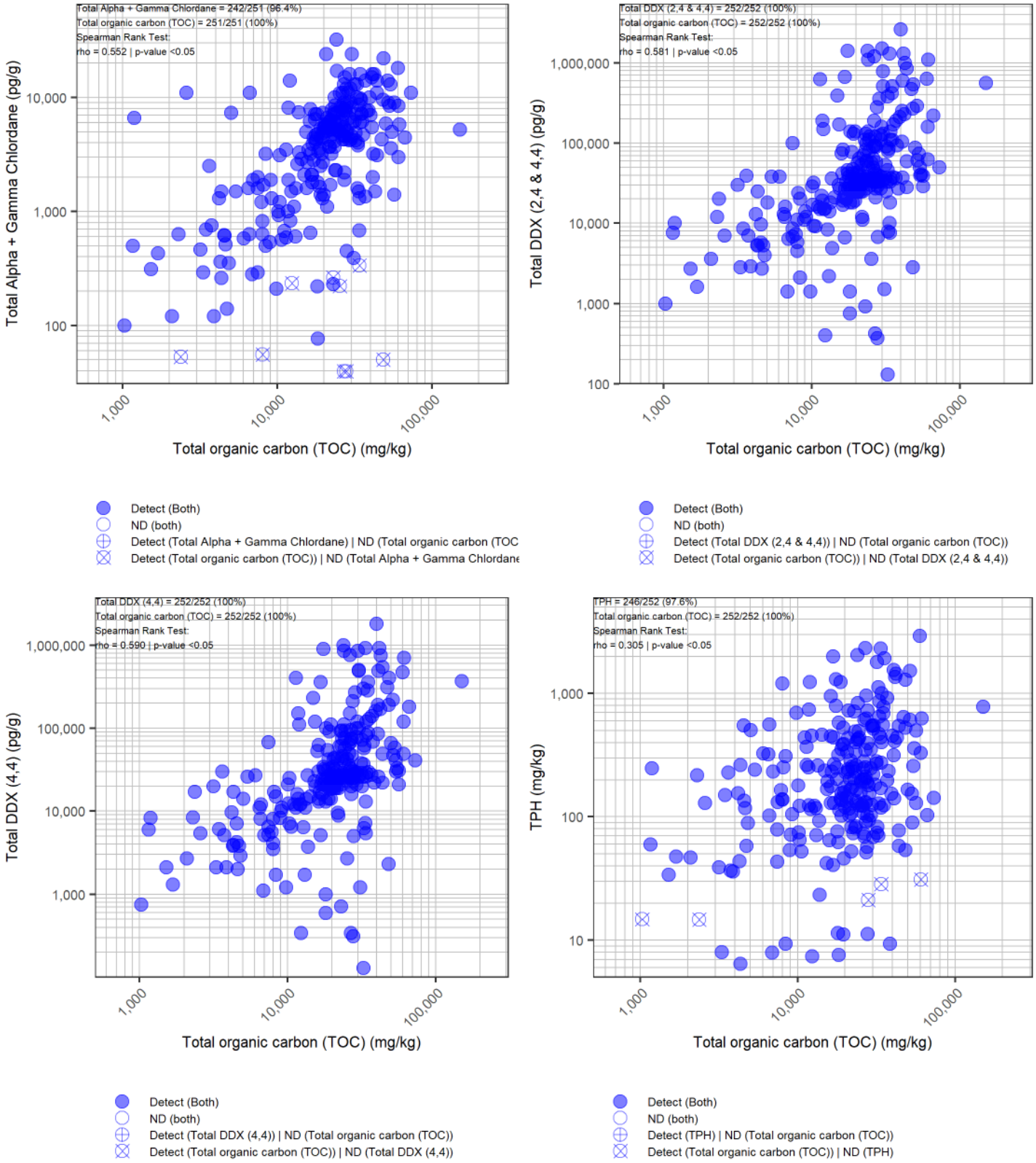
Notes:
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DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT CORRELATION – ORGANICS AND TOC

Glenn Springs Holdings, Inc.
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FIGURE
4-3b



Notes:

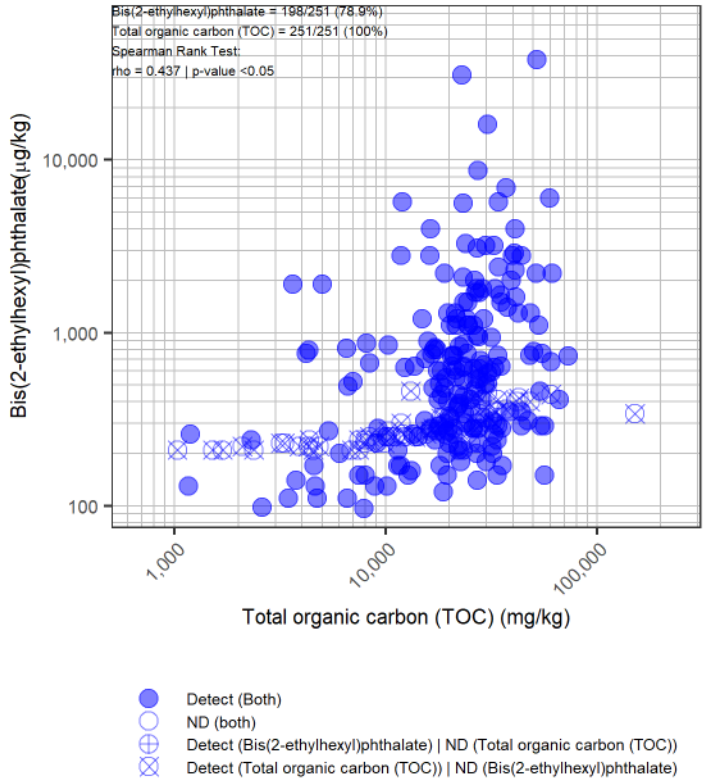
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2. Non-detects plotted at the quantitation limit.
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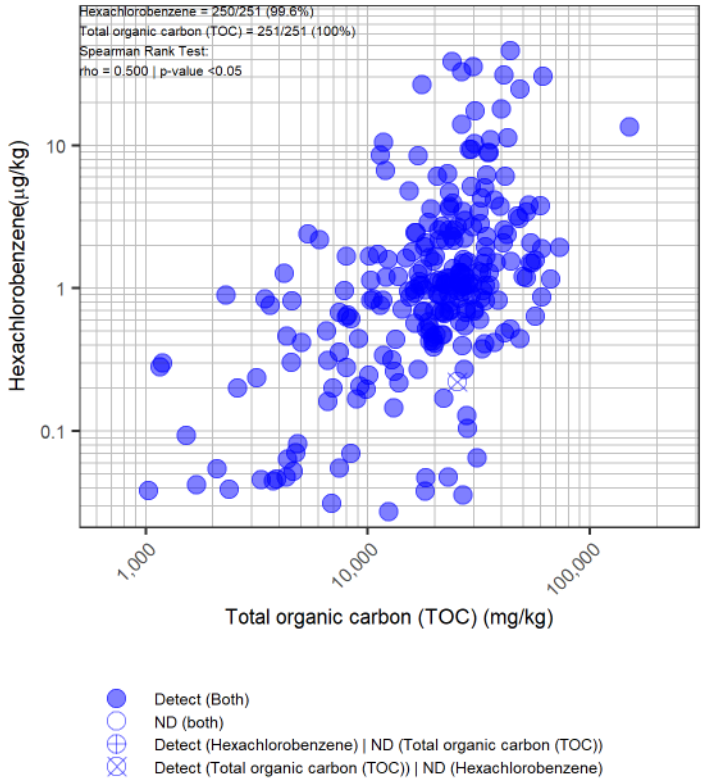
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

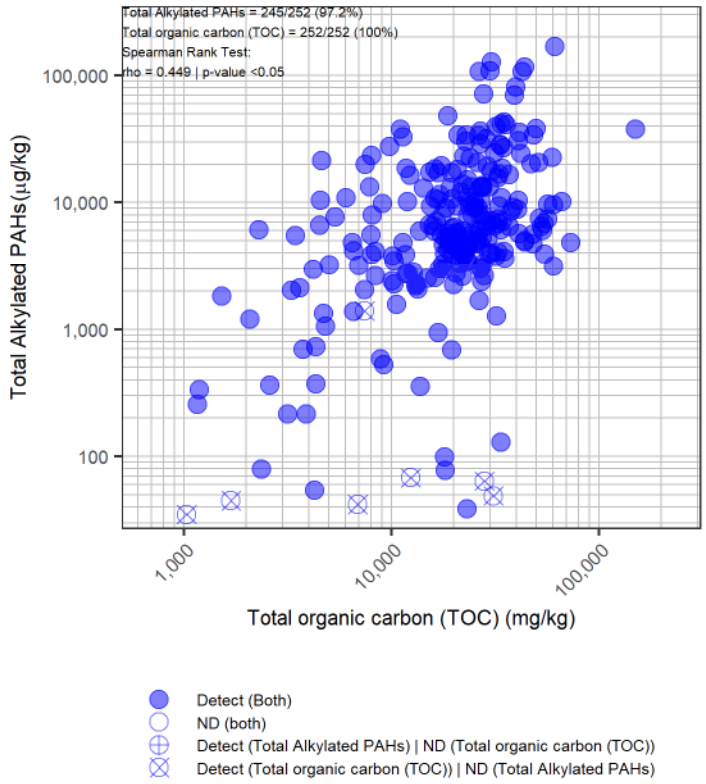
SEDIMENT CORRELATION – ORGANICS AND TOC

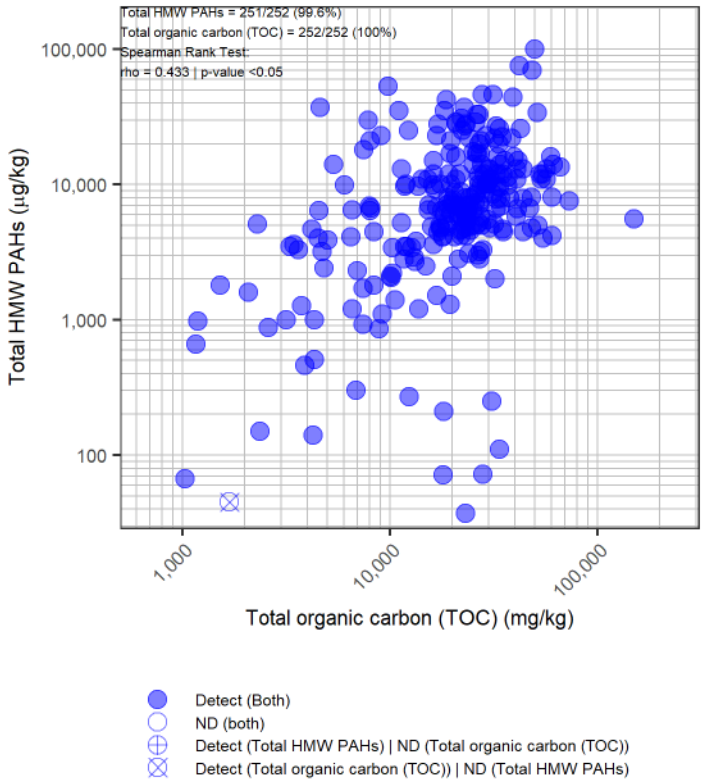
Glenn Springs Holdings, Inc.
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FIGURE
4-3c









Notes:

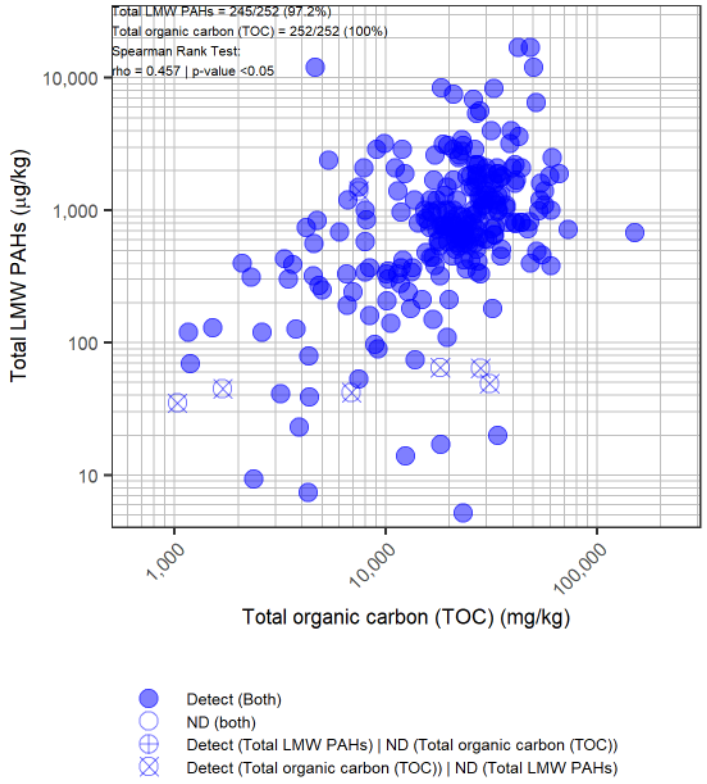
1. For correlation analysis, non-detects included at 1/2 the quantitation limit.
2. Non-detects plotted at the quantitation limit.
3. Includes Phase III surface sediment data collected from 2014 to 2016 (including the SQT and crab/clam sediment).

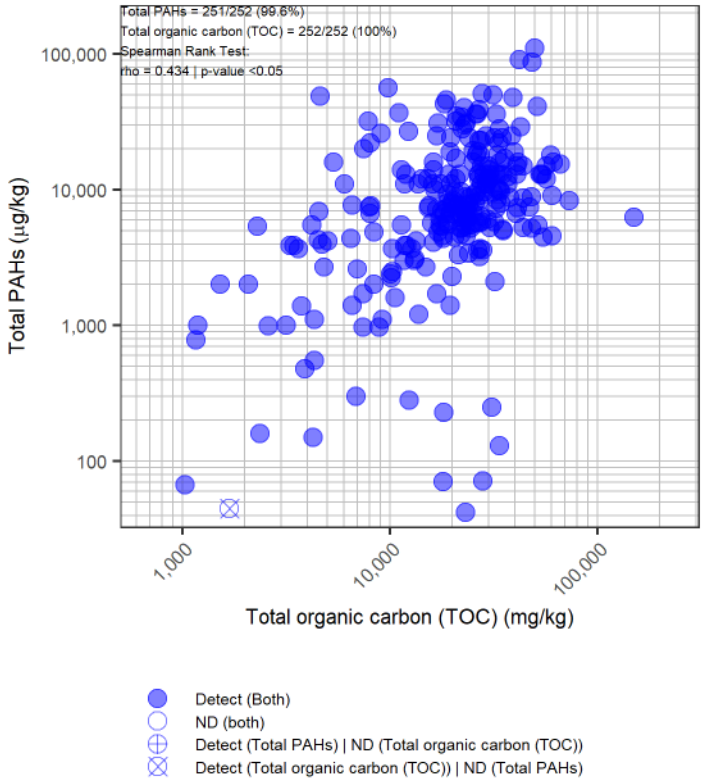
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT CORRELATION – ORGANICS AND TOC

OXY Glenn Springs Holdings, Inc.
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FIGURE
4-3d





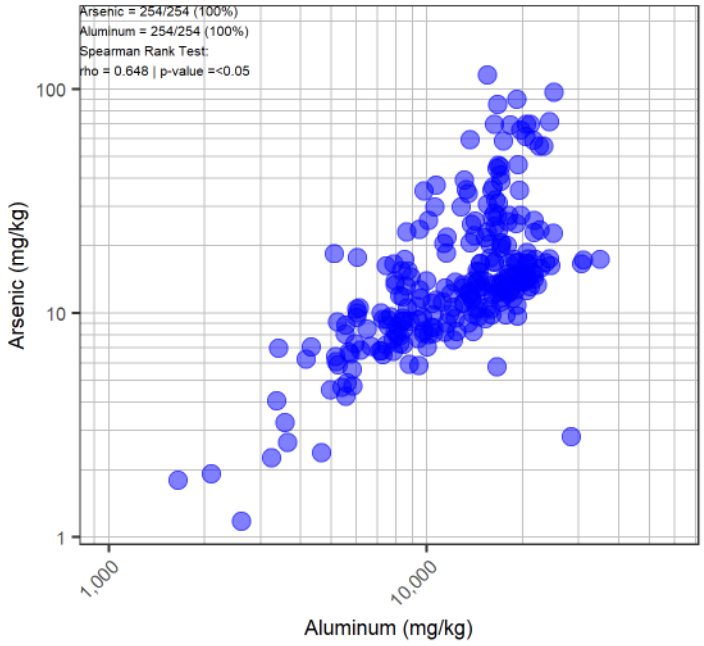
Notes:
1. For correlation analysis, non-detects included at 1/2 the quantitation limit.
2. Non-detects plotted at the quantitation limit.
3. Includes Phase III surface sediment data collected from 2014 to 2016 (including the SQT and crab/clam sediment).

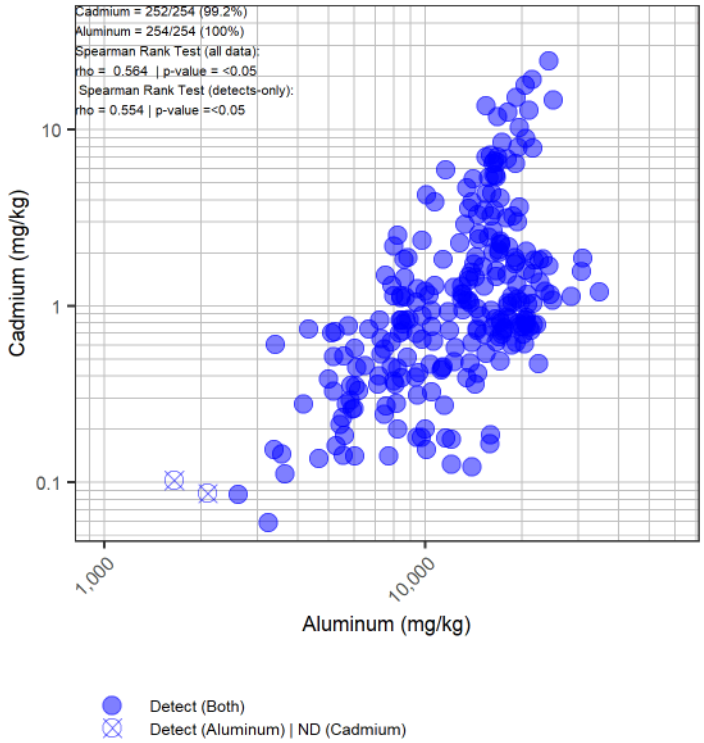
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

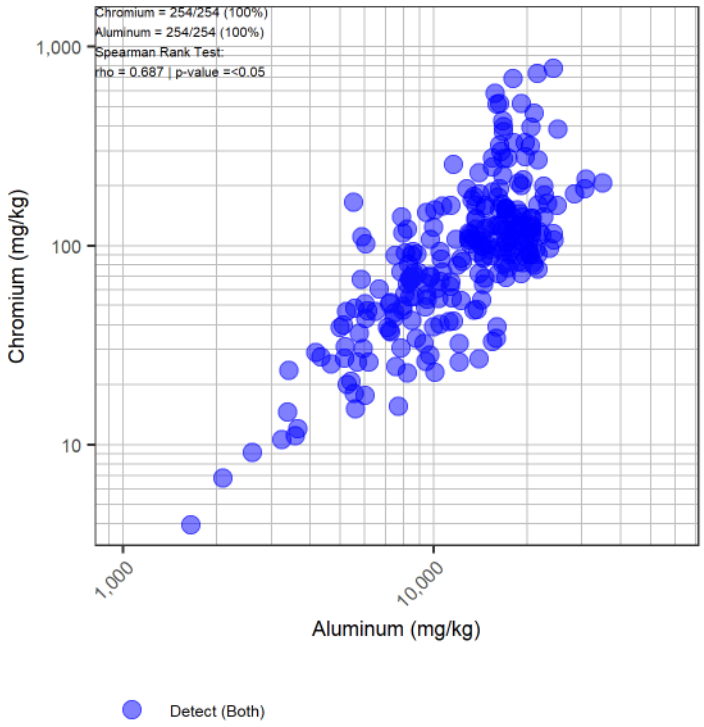
SEDIMENT CORRELATION – ORGANICS AND TOC

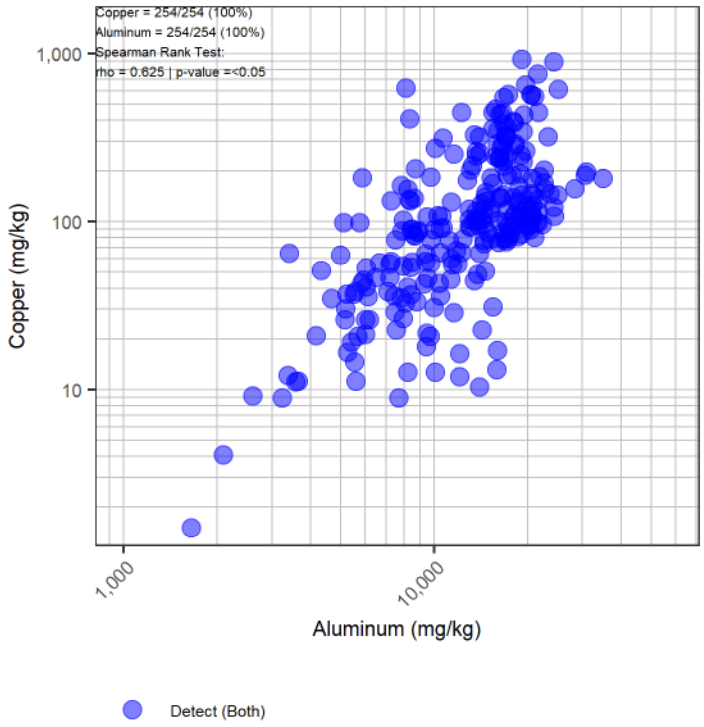
Glenn Springs Holdings, Inc.
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FIGURE
4-3e









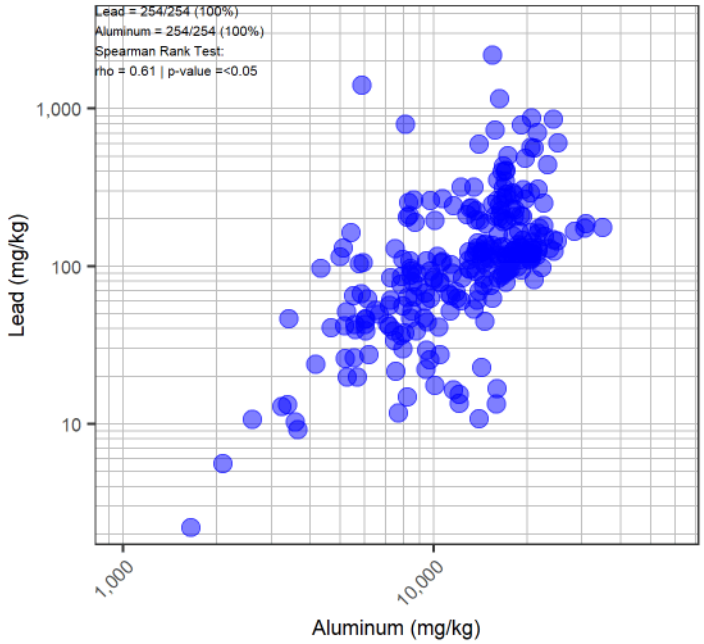
Notes:
1. For correlation analysis, non-detects included at 1/2 the quantitation limit.
2. Non-detects plotted at the quantitation limit.
3. Includes Phase III surface sediment data collected from 2014 to 2016 (including the SQT and crab/clam sediment).

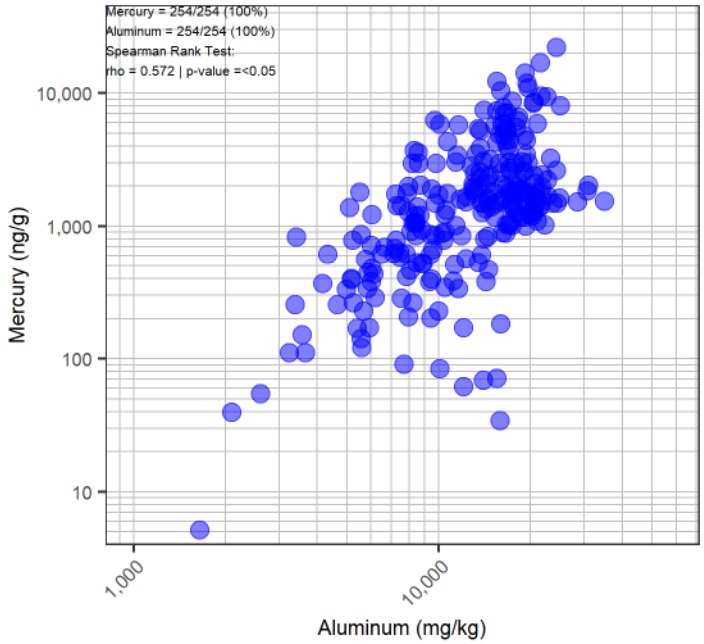
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

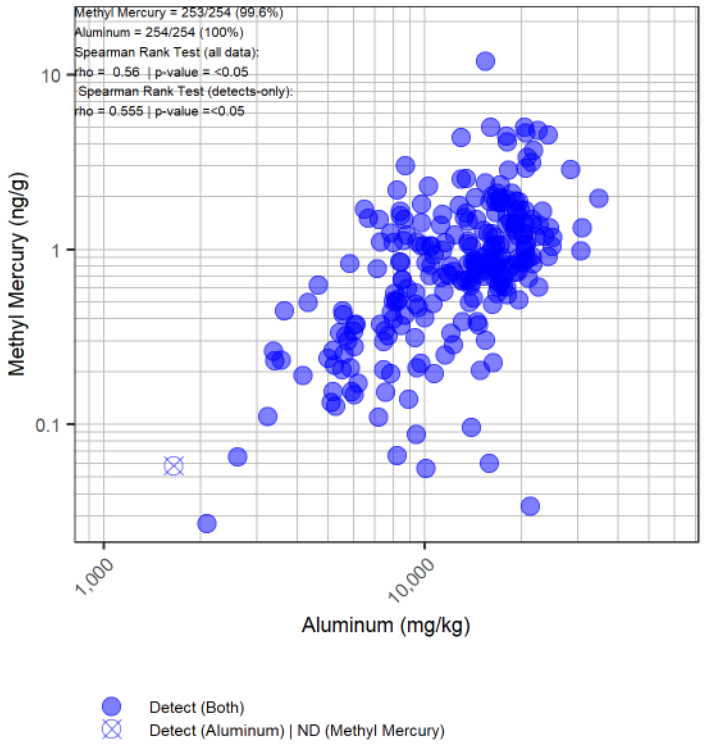
SEDIMENT CORRELATION - METALS AND ALUMINUM

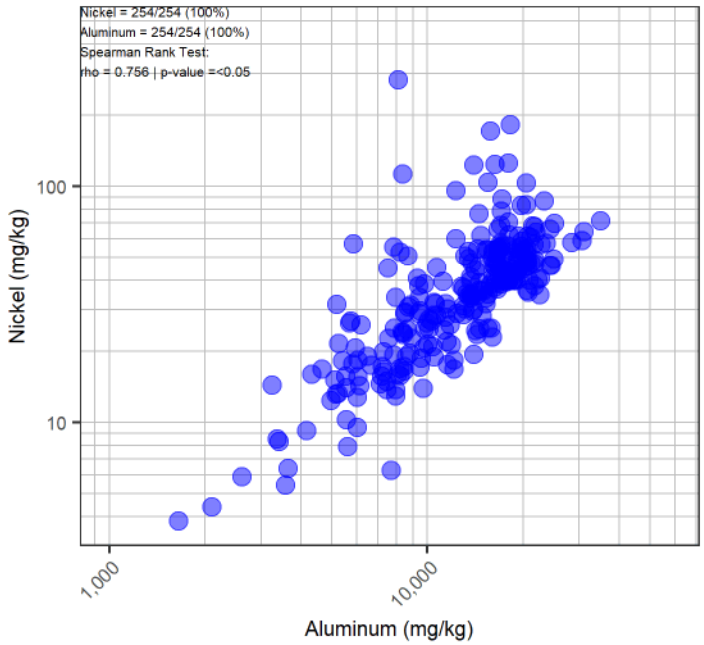
Glenn Springs Holdings, Inc.
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FIGURE
4-4a









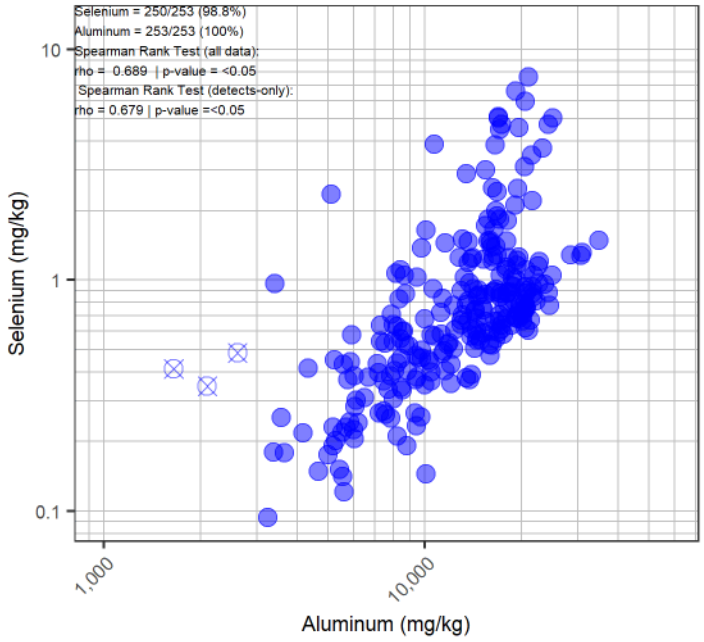
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DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

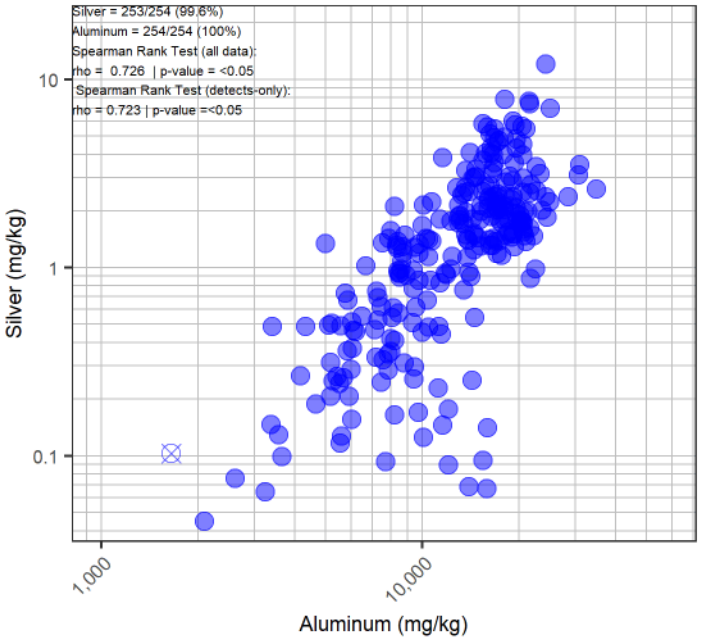
SEDIMENT CORRELATION - METALS AND ALUMINUM

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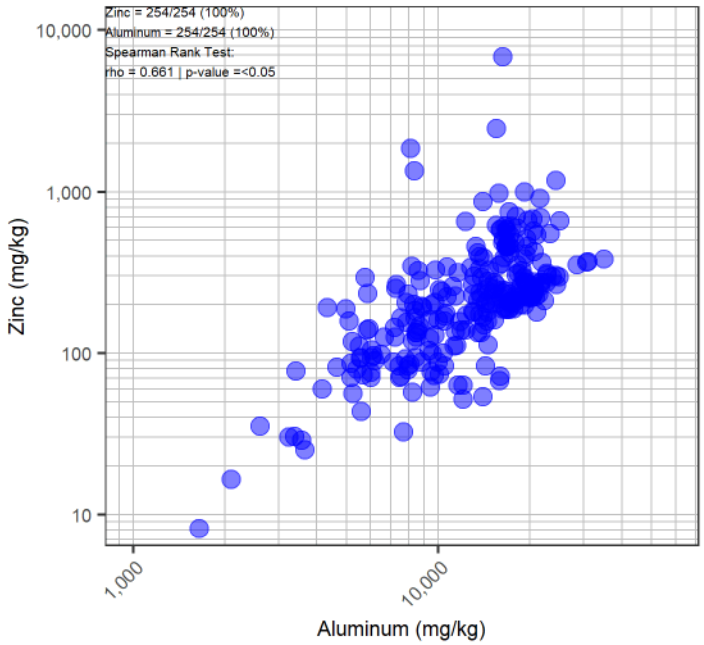
FIGURE
4-4b

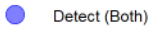












Notes:
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DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT CORRELATION - METALS AND ALUMINUM

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FIGURE
4-4c

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: MEstifanos
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T:\ ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\Figure 4-5 PotentialHighDepositionAreasUSACE.mxd 4/6/2021 4:58:00 PM

LEGEND:

- 2005 PHASE I CORE LOCATION
- 2007 PHASE II CORE LOCATION
- 2014 CRAB/CLAM SEDIMENT SAMPLING LOCATION
- 2015 SQT SEDIMENT SAMPLE LOCATION
- 2016 PHASE III SEDIMENT SAMPLING LOCATION
- CO-LOCATED 2005 PHASE I/2007 PHASE II CORE LOCATION
- SHORELINE
- UNDERGROUND TRIBUTARY
- NAVIGATION CHANNEL
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- USACE ACCUMULATION AREA

ESTIMATED DEPOSITION OVER TIME (1934 TO 2006; FEET):

- 0 -2
- 2 - 5
- 5 - 10
- 10 - 17
- 17 - 33

0 0.6 1.2 Miles

GRAPHIC SCALE

PASSAIC RIVER
HACKENSACK RIVER
CONRAIL BRIDGE REMNANTS
CONRAIL BRIDGE REMNANTS
PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
KILL VAN KULL
MORSES CREEK
BAYONNE BRIDGE
GOETHALS BRIDGE
ARTHUR KILL
PILES CREEK
PRALL'S ISLAND

NOTES:

1. DEPOSITIONAL INFORMATION (INCLUDING AREA DELINEATION) WAS EXTRACTED FROM THE USACE GEOMORPHOLOGICAL REPORT DATED DECEMBER 31, 2006.
2. AREAS WITH ESTIMATED NET DEPOSITION OF 5 FEET OR GREATER OVER TIME (1934 TO 2006) ARE CHARACTERIZED BY USACE (2006) AS AREAS OF "POTENTIAL HIGH NET DEPOSITION" AND WERE USED TO DEFINE THE BOUNDARIES FOR THE GEOMORPHIC AREA "HISTORICALLY DISTURBED SUBTIDAL FLATS", DISCUSSED IN SECTION 3.3 AND IS SHOWN ON FIGURE 2-1.
3. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
4. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
5. REFERENCES:

A. TIERRA. 2011. FINAL NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION PHASE I AND PHASE II SEDIMENT DEPOSITION REORT. REVISION 1. OCTOBER.

B. USACE. 2006. GEOMORPHOLOGICAL/GEOPHYSICAL CHARACTERIZATION OF THE NATURE AND DYNAMICS OF SEDIMENTATION AND SEDIMENT TRANSPORT IN NEWARK BAY FOCUSING THE EFFECTS RELATED TO CONTINUED AND FUTURE FEDERAL NAVIGATION CHANNEL DEEPENING AND MAINTENANCE. CONTRACT #W912DS-06-D-0001. DELIVERY ORDER #0004. U.S. ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT. DECEMBER 31.

C. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

DIAMOND ALKALI SUPERFUND SITE

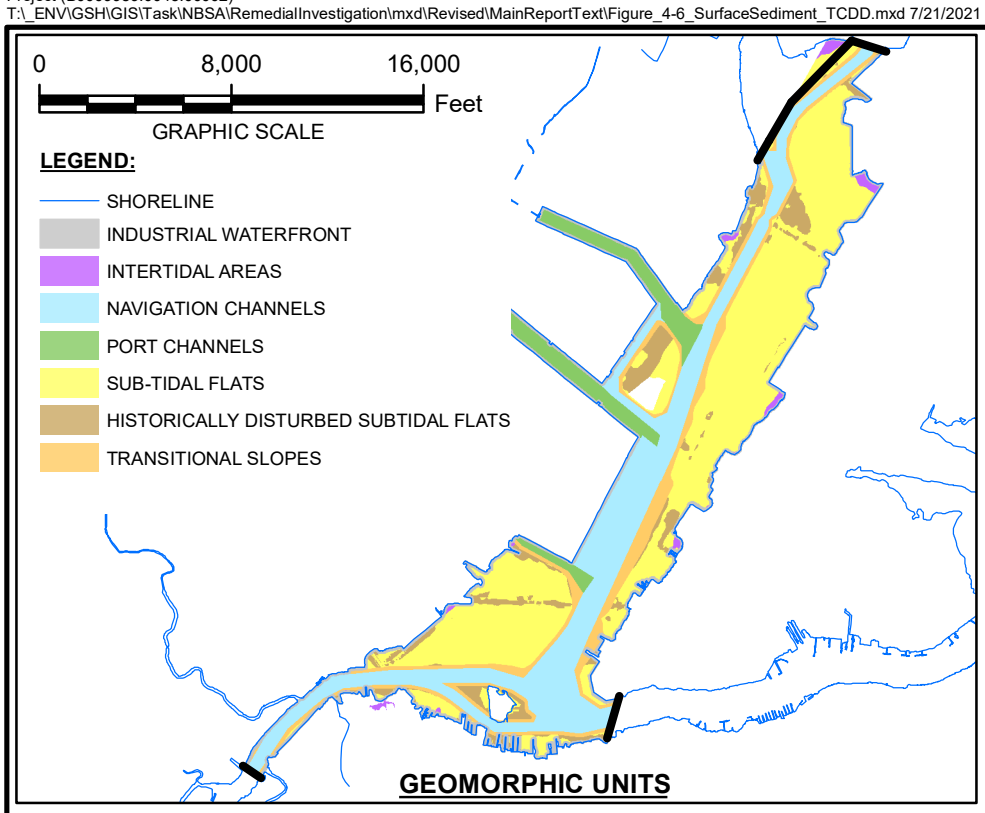
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION REMEDIAL INVESTIGATION REPORT

USACE SEDIMENT ACCUMULATION AREAS

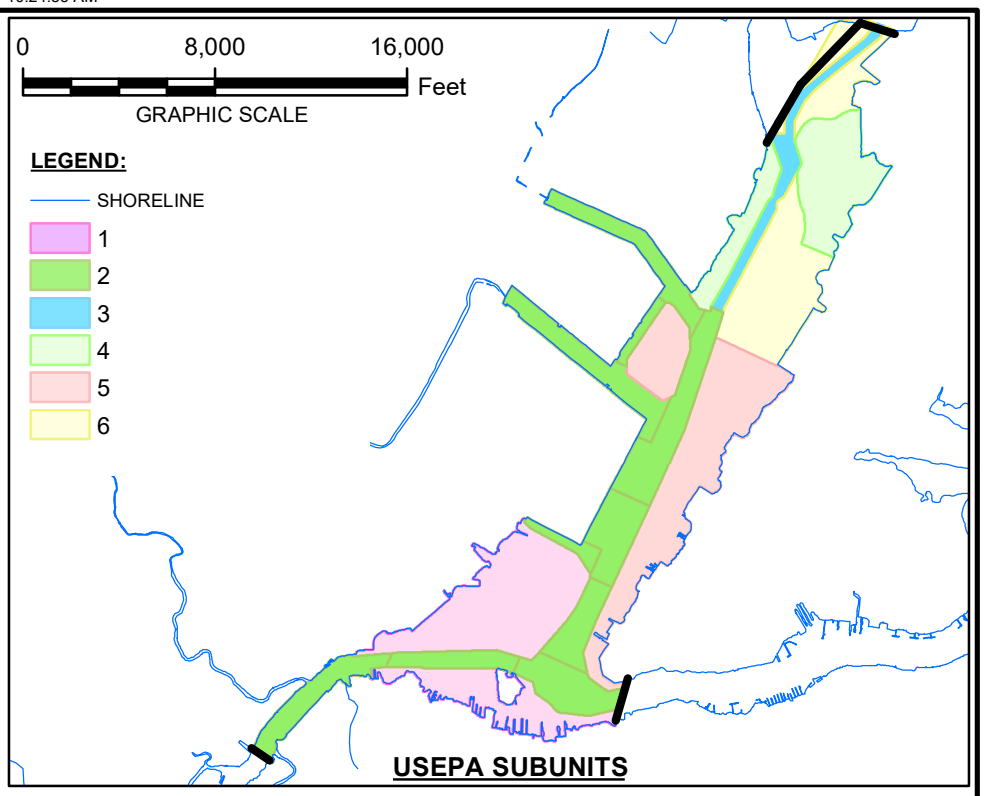
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
4-5

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: PJI01206
Project (B0009989.0045.00002)
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GEOMORPHIC UNITS



USEPA SUBUNITS

LEGEND:

- 2005 PHASE I CORE LOCATION
- 2007 PHASE II CORE LOCATION
- CO-LOCATED 2005 PHASE I / 2007 PHASE II CORE LOCATION
- 2014 CRAB/CLAM SEDIMENT SAMPLING LOCATION
- 2015 SQT SEDIMENT SAMPLE LOCATION
- 2016 PHASE III SEDIMENT SAMPLING LOCATION
- NON-DETECT RESULT. QUANTITATION LIMIT REPRESENTED BY SYMBOL COLOR
- Be-7 BEARING LOCATION

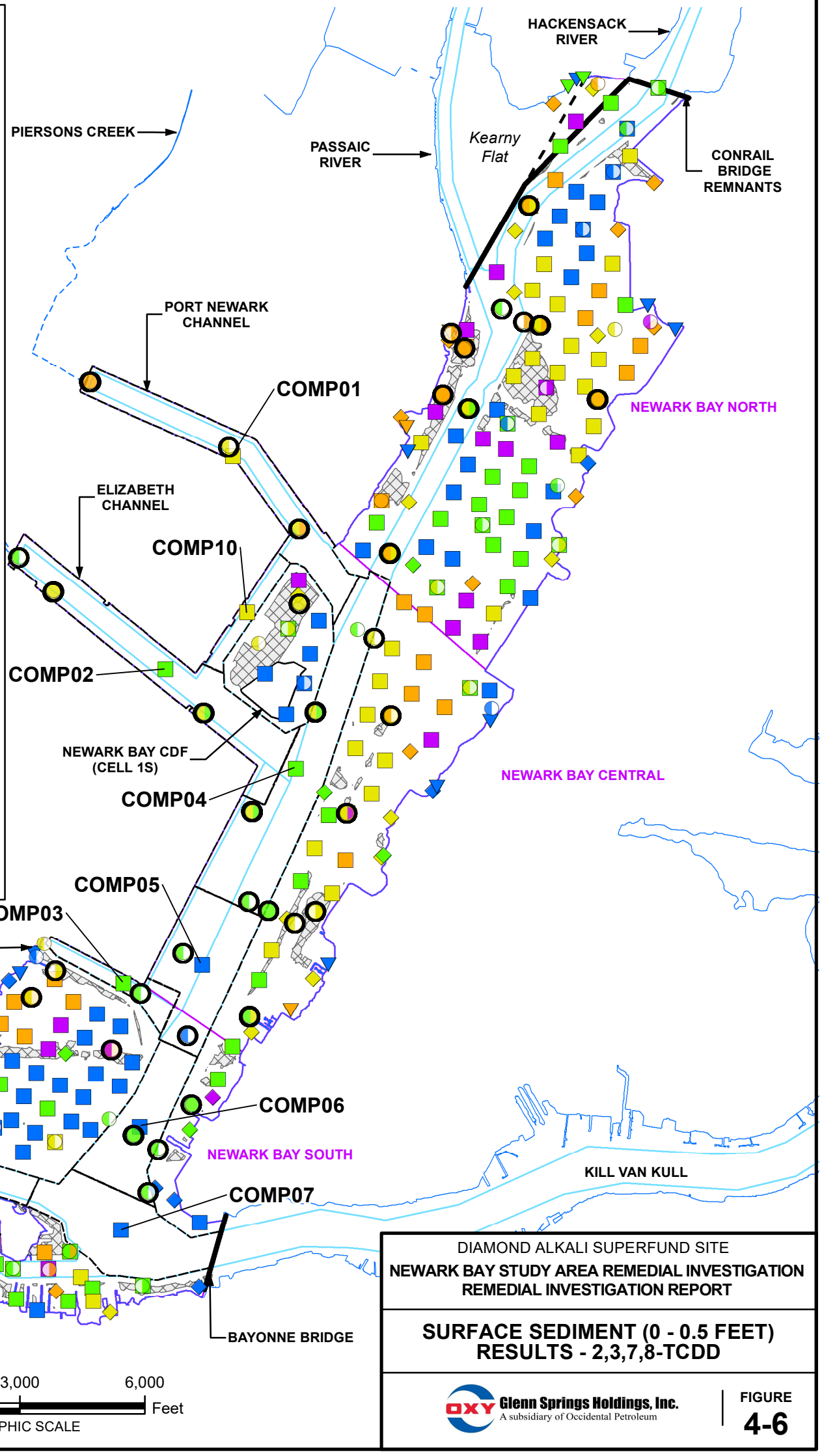
2,3,7,8-TCDD (ng/kg) (SEE NOTE 3)

- ≤ 14.7
- < 14.7 - 45
- < 45 - 83.3
- < 83.3 - 148
- > 148

- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- SHORELINE
- NORTH, CENTRAL & SOUTH GEOGRAPHIC ZONE BOUNDARY
- NAVIGATION CHANNEL
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREAS

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. RANGES PRESENTED FOR RESULTS ARE BASED ON THE 25TH, 50TH, 75TH, AND 90TH PERCENTILE OF THE SURFACE SEDIMENT DATA SET.
4. SAMPLING LOCATIONS COLLECTED DURING PHASE I/II FROM WITHIN THE NAVIGATION CHANNEL IN NEWARK BAY SOUTH AND NEWARK BAY CENTRAL MAY HAVE BEEN AFFECTED BY DREDGING ACTIVITIES CONDUCTED SINCE SAMPLE COLLECTION.
5. COMP01-COMP10 ARE COMPOSITE SAMPLES COLLECTED IN THE DREDGED PORTION OF THE NAVIGATION CHANNEL DURING THE 2016 PHASE III SAMPLING PROGRAM. A SYMBOL LOCATED CENTRALLY WITHIN EACH COMPOSITE AREA IS COLOR-CODED ACCORDING TO THE CONCENTRATION VALUES AS SHOWN IN THE LEGEND ABOVE.
6. LOCATIONS OUTSIDE THE STUDY AREA ARE SHOWN FOR CONSISTENCY BUT NOT INCLUDED IN STATISTICAL ANALYSIS.
7. GEOGRAPHIC ZONE BOUNDARIES ARE USED TO DIVIDE THE STUDY AREA INTO NORTH, CENTRAL, AND SOUTH ZONES.
8. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
9. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
10. BE-7 BEARING LOCATIONS ARE DEFINED AS LOCATIONS WITH SURFACE SAMPLES ANALYZED FOR BE-7 AND RESULT CONCENTRATIONS GREATER THAN OR EQUAL TO 0.5 PICOCURIE PER GRAM (PCI/G). THESE LOCATIONS ARE CONSIDERED TO INDICATE RECENTLY DEPOSITED SEDIMENTS. ONLY PHASE I/II SAMPLES WERE ANALYZED FOR BE-7.
11. REFERENCE:
    A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.



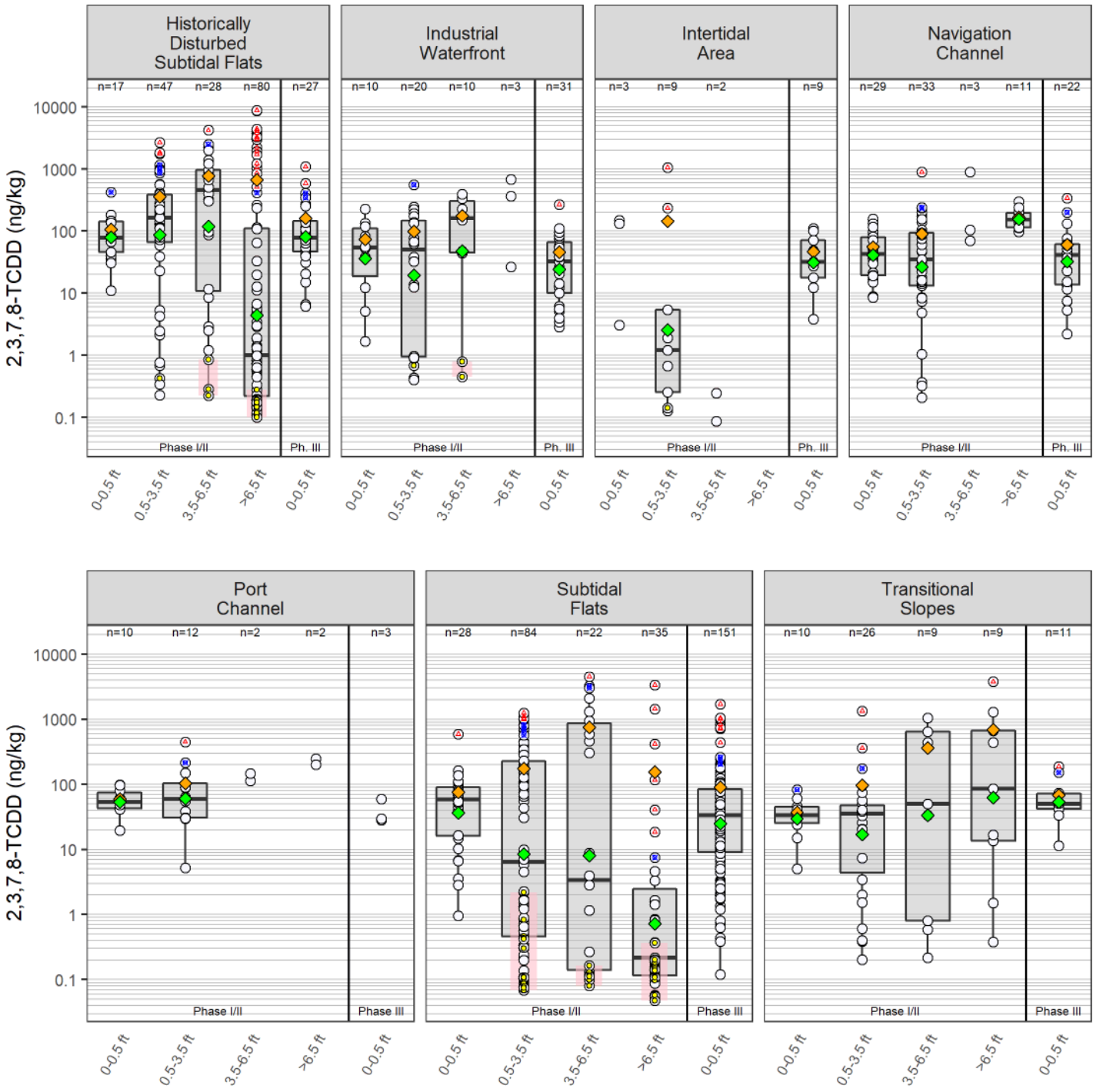
DIAMOND ALKALI SUPERFUND SITE

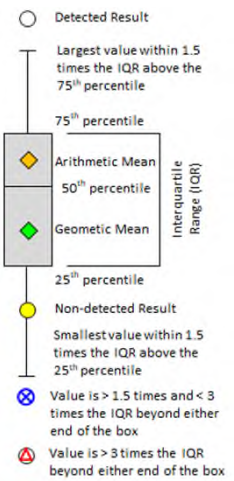
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT (0 - 0.5 FEET) RESULTS - 2,3,7,8-TCDD

Glenn Springs Holdings, Inc.
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FIGURE
4-6





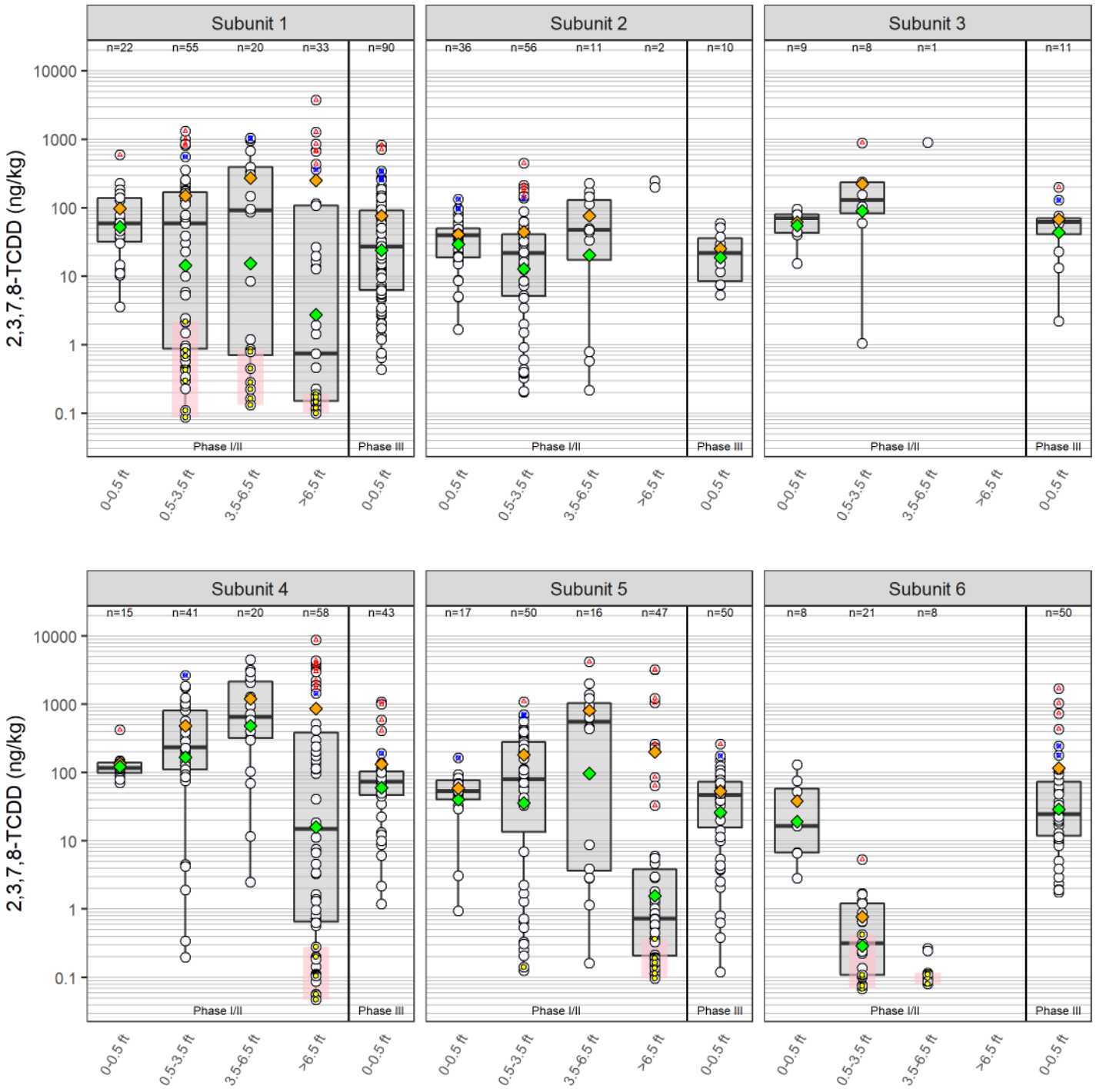
Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
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For percentiles, non-detects included at the quantitation limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the quantitation limit.
Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
Geomorphic areas shown on Figure 2-7.

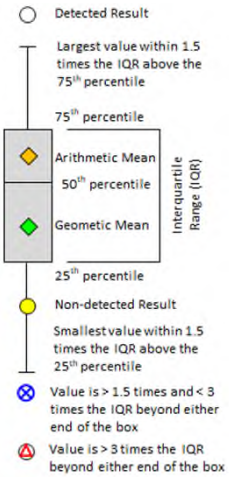
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT BY GEOMORPHIC AREA - 2,3,7,8-TCDD

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-7





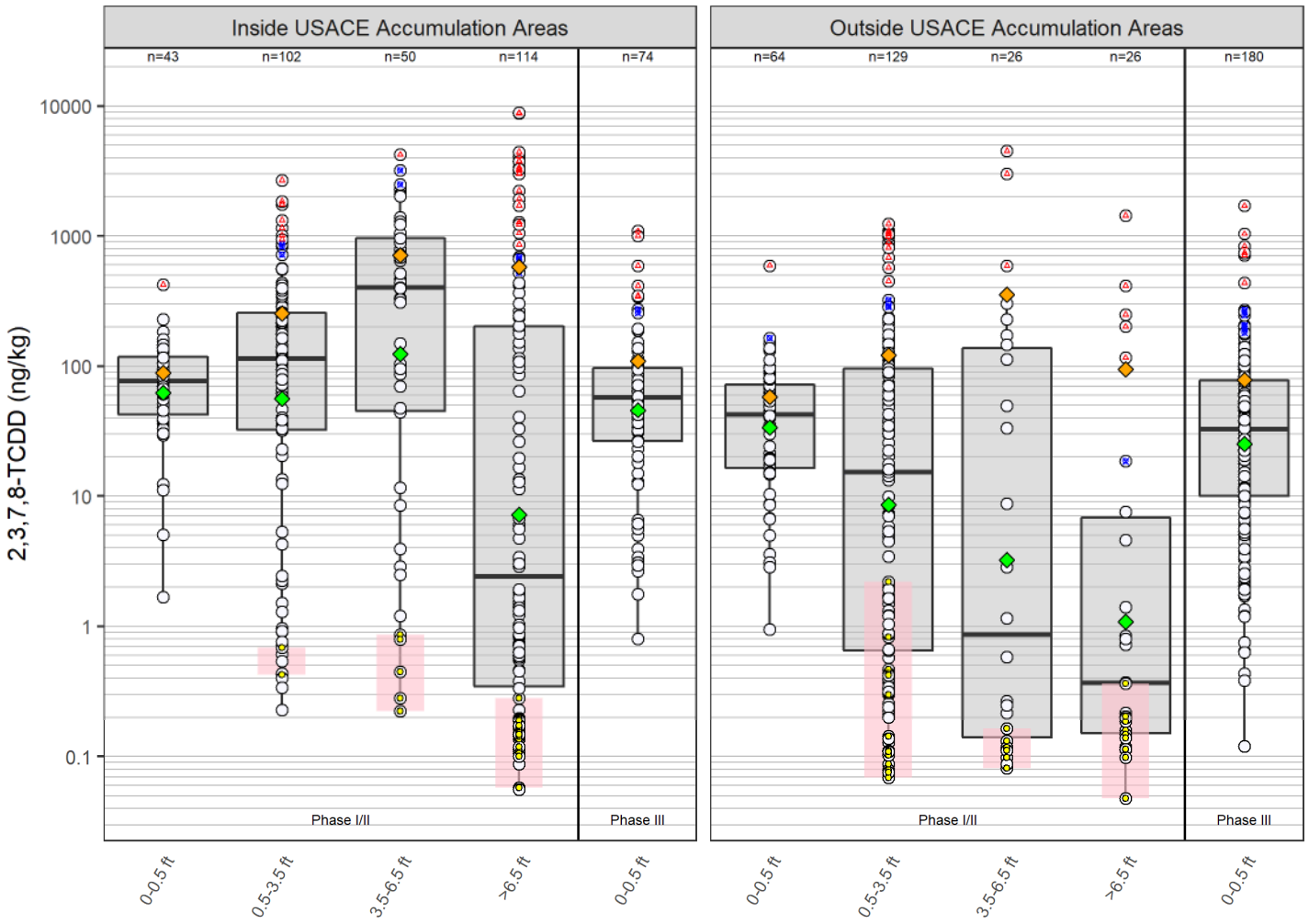
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Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
EPA subunits shown on Figure 2-8.

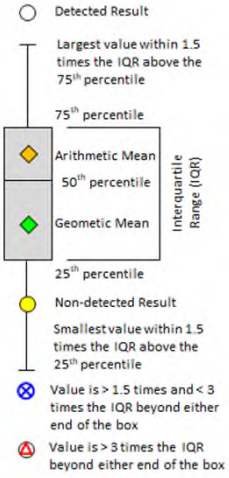
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT BY USEPA SUBUNIT - 2,3,7,8-TCDD

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-8





Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
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Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
United States Army Corps of Engineers (USACE) depositional areas shown on Figure 3-4.

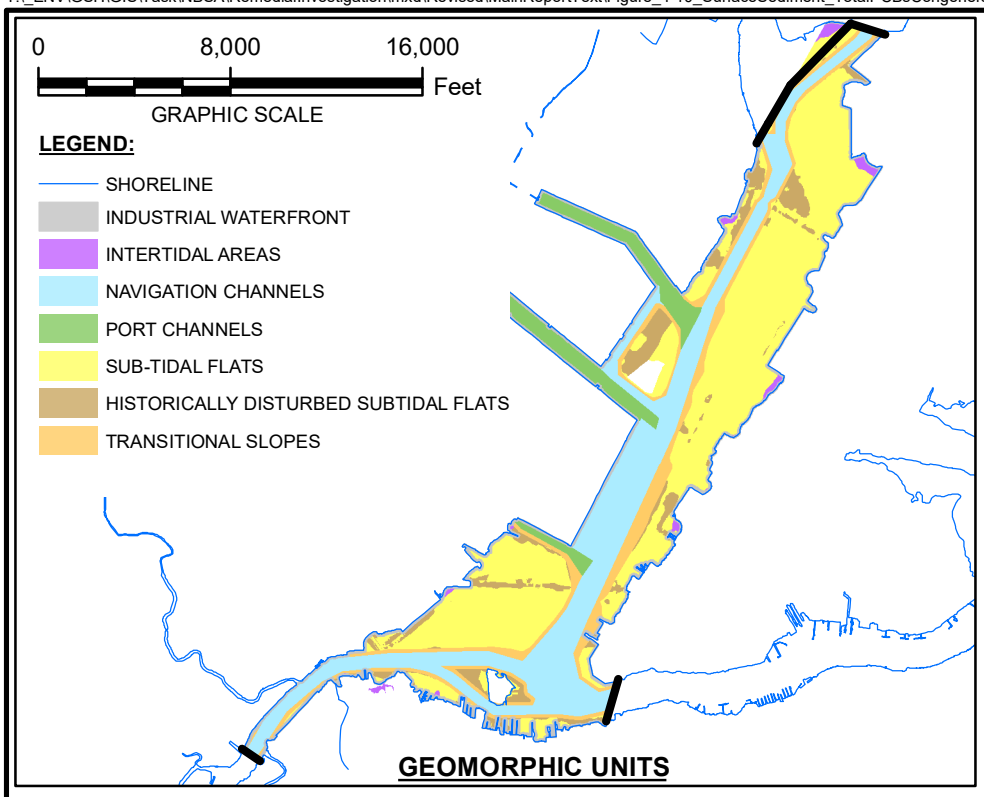
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT RESULTS BY ACCUMULATION AREA - 2,3,7,8-TCDD

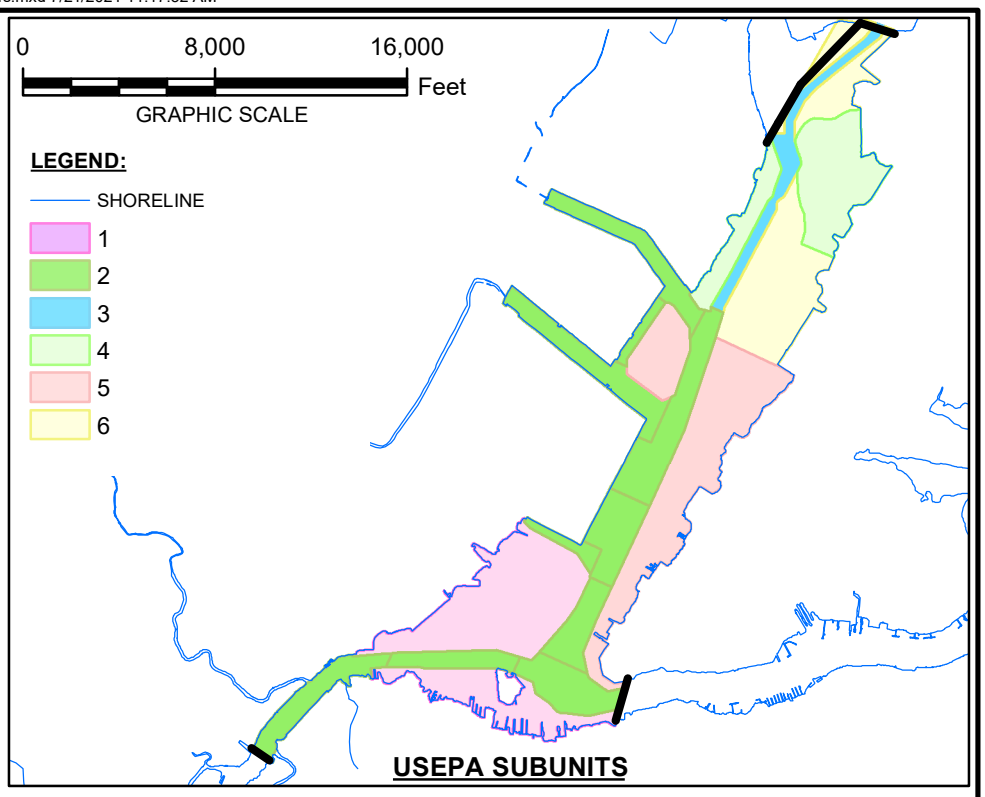
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-9

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: PJI01206
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GEOMORPHIC UNITS



USEPA SUBUNITS

LEGEND:

- 2005 PHASE I CORE LOCATION
- 2007 PHASE II CORE LOCATION
- CO-LOCATED 2005 PHASE I / 2007 PHASE II CORE LOCATION
- 2014 CRAB/CLAM SEDIMENT SAMPLING LOCATION
- 2015 SQT SEDIMENT SAMPLE LOCATION
- 2016 PHASE III SEDIMENT SAMPLING LOCATION
- NON-DETECT RESULT. QUANTITATION LIMIT REPRESENTED BY SYMBOL COLOR
- Be-7 BEARING LOCATION

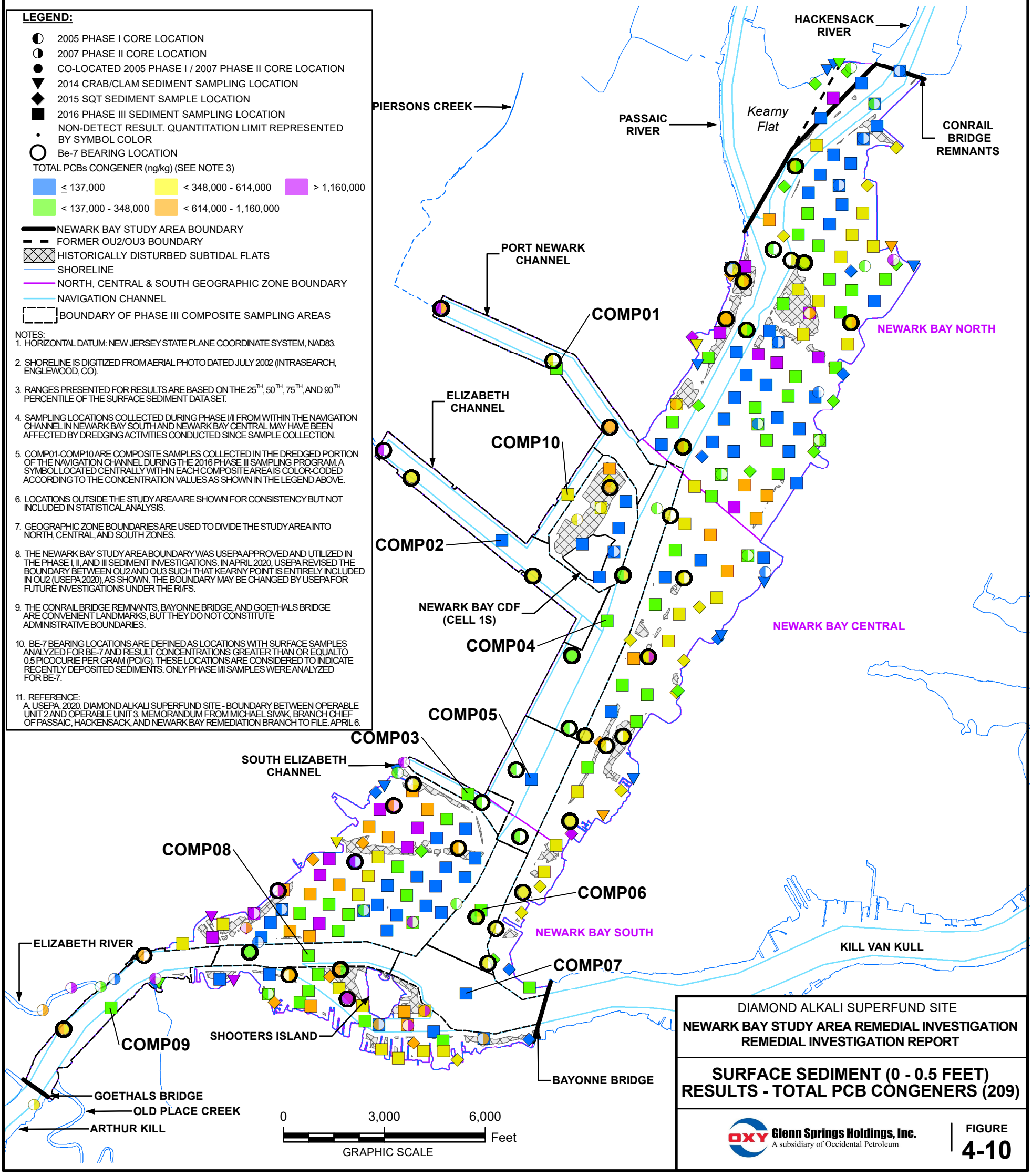
TOTAL PCBs CONGENER (ng/kg) (SEE NOTE 3)

- ≤ 137,000
- < 137,000 - 348,000
- < 348,000 - 614,000
- < 614,000 - 1,160,000
- > 1,160,000

- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- SHORELINE
- NORTH, CENTRAL & SOUTH GEOGRAPHIC ZONE BOUNDARY
- NAVIGATION CHANNEL
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREAS

NOTES:

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4. SAMPLING LOCATIONS COLLECTED DURING PHASE I/II FROM WITHIN THE NAVIGATION CHANNEL IN NEWARK BAY SOUTH AND NEWARK BAY CENTRAL MAY HAVE BEEN AFFECTED BY DREDGING ACTIVITIES CONDUCTED SINCE SAMPLE COLLECTION.
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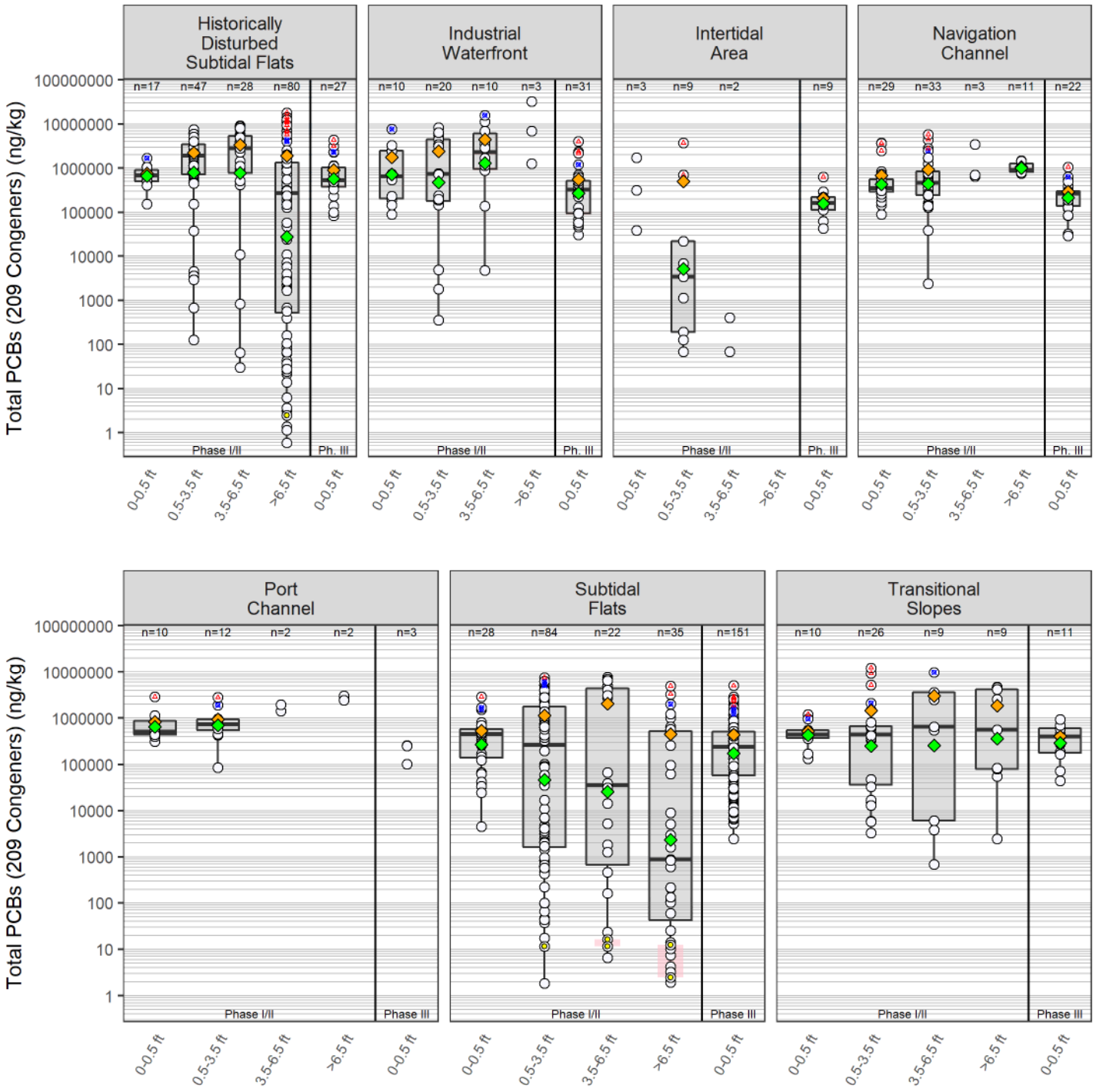
DIAMOND ALKALI SUPERFUND SITE

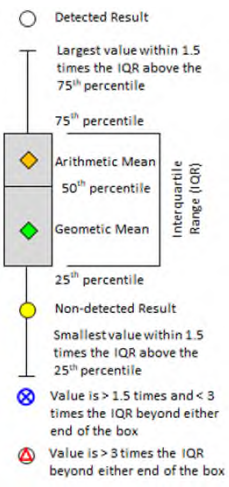
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT (0 - 0.5 FEET) RESULTS - TOTAL PCB CONGENERS (209)

Glenn Springs Holdings, Inc.
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FIGURE
4-10





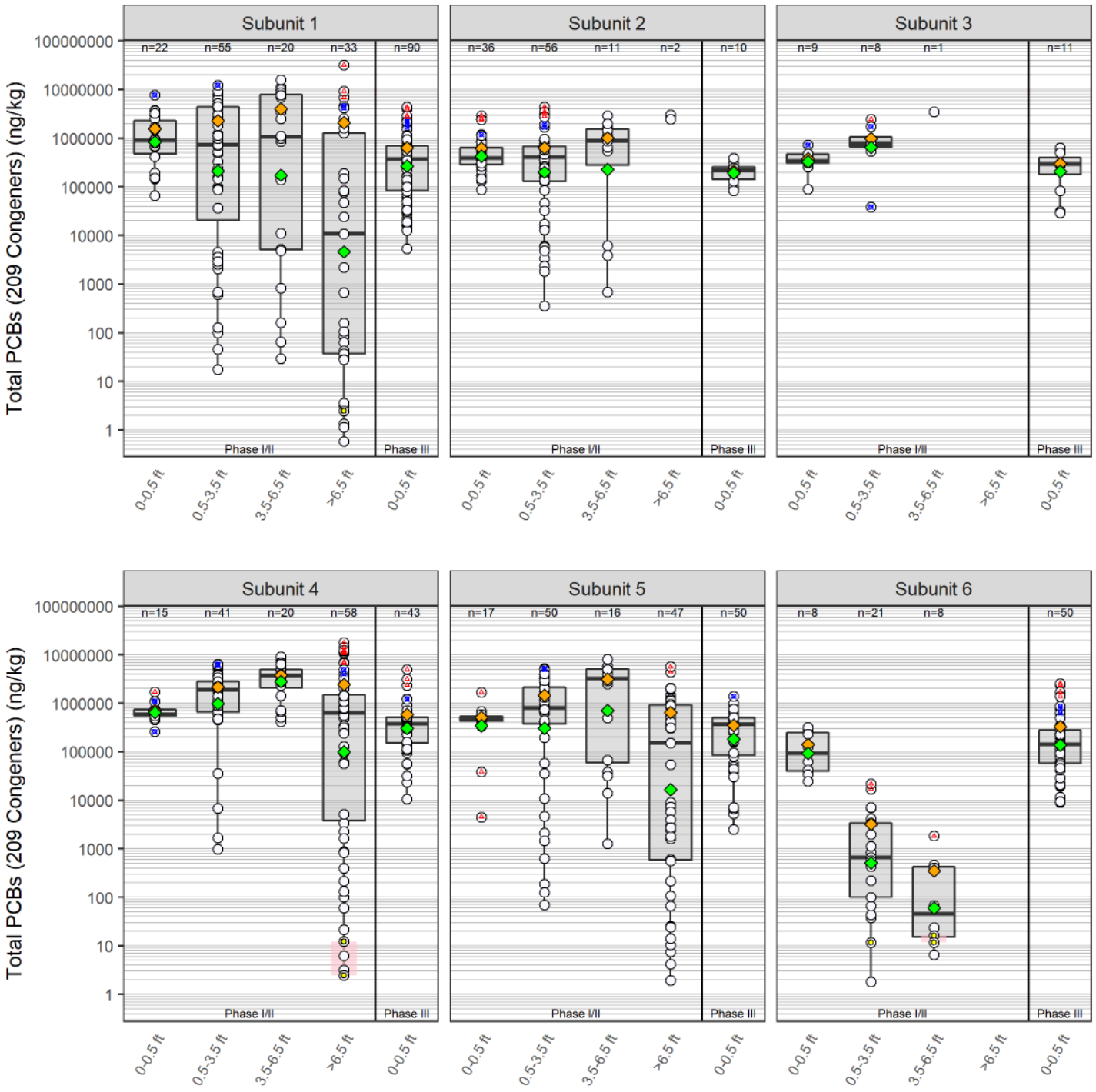
Notes:
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Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
Geomorphic areas shown on Figure 2-7.

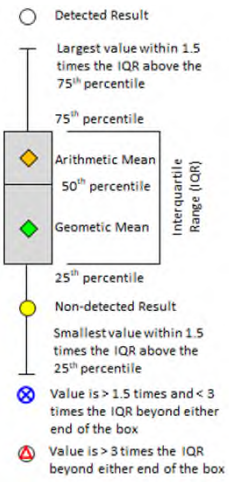
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT BY GEOMORPHIC AREA - TOTAL PCB (209 CONGENERS)

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-11





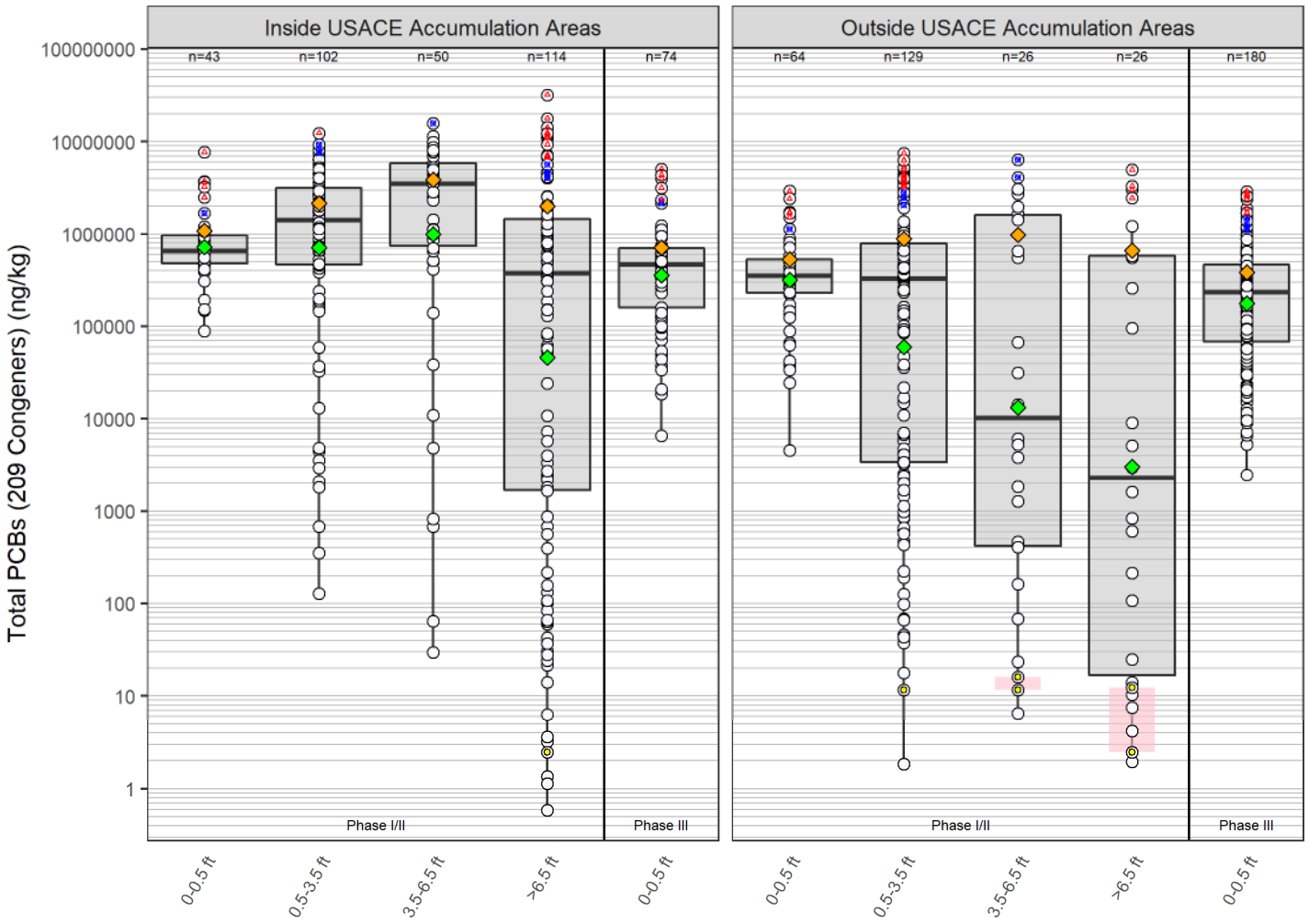
Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
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Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
EPA subunits shown on Figure 2-8.

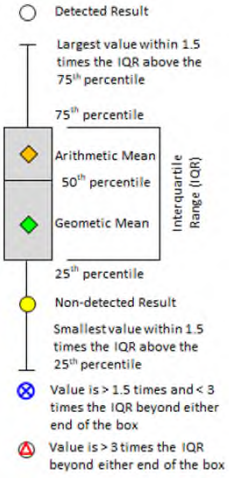
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT BY USEPA SUBUNIT - TOTAL PCB (209 CONGENERS)

OXY Glenn Springs Holdings, Inc.
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FIGURE
4-12





Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
Sample top depth used to assign depth category:
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For arithmetic mean and geometric mean, non-detects included at 1/2 the quantitation limit.
Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
United States Army Corps of Engineers (USACE) depositional areas shown on Figure 3-4.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT RESULTS BY ACCUMULATION AREA - TOTAL PCB (209 CONGENERS)

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-13

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: avi00815
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0 8,000 16,000 Feet
GRAPHIC SCALE

LEGEND:

- SHORELINE
- INDUSTRIAL WATERFRONT
- INTERTIDAL AREAS
- NAVIGATION CHANNELS
- PORT CHANNELS
- SUB-TIDAL FLATS
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- TRANSITIONAL SLOPES

GEOMORPHIC UNITS

0 8,000 16,000 Feet
GRAPHIC SCALE

LEGEND:

- SHORELINE
- 1
- 2
- 3
- 4
- 5
- 6

USEPA SUBUNITS

LEGEND:

- 2005 PHASE I CORE LOCATION
- 2007 PHASE II CORE LOCATION
- CO-LOCATED 2005 PHASE I / 2007 PHASE II CORE LOCATION
- 2014 CRAB/CLAM SEDIMENT SAMPLING LOCATION
- 2015 SQT SEDIMENT SAMPLE LOCATION
- 2016 PHASE III SEDIMENT SAMPLING LOCATION
- NON-DETECT RESULT. QUANTITATION LIMIT REPRESENTED BY SYMBOL COLOR
- Be-7 BEARING LOCATION

TOTAL DDx (pg/g) (SEE NOTE 3)

- ≤ 16,000
- < 16,000 - 27,000
- < 27,000 - 66,000
- < 66,000 - 210,000
- > 210,000

- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- SHORELINE
- NORTH, CENTRAL & SOUTH GEOGRAPHIC ZONE BOUNDARY
- NAVIGATION CHANNEL
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREAS

NOTES:
1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. RANGES PRESENTED FOR RESULTS ARE BASED ON THE 25TH, 50TH, 75TH, AND 90TH PERCENTILE OF THE SURFACE SEDIMENT DATA SET.
4. SAMPLING LOCATIONS COLLECTED DURING PHASE I/II FROM WITHIN THE NAVIGATION CHANNEL IN NEWARK BAY SOUTH AND NEWARK BAY CENTRAL MAY HAVE BEEN AFFECTED BY DREDGING ACTIVITIES CONDUCTED SINCE SAMPLE COLLECTION.
5. COMP01-COMP10 ARE COMPOSITE SAMPLES COLLECTED IN THE DREDGED PORTION OF THE NAVIGATION CHANNEL DURING THE 2016 PHASE III SAMPLING PROGRAM. A SYMBOL LOCATED CENTRALLY WITHIN EACH COMPOSITE AREA IS COLOR-CODED ACCORDING TO THE CONCENTRATION VALUES AS SHOWN IN THE LEGEND ABOVE.
6. LOCATIONS OUTSIDE THE STUDY AREA ARE SHOWN FOR CONSISTENCY BUT NOT INCLUDED IN STATISTICAL ANALYSIS.
7. GEOGRAPHIC ZONE BOUNDARIES ARE USED TO DIVIDE THE STUDY AREA INTO NORTH, CENTRAL, AND SOUTH ZONES.
8. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
9. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
10. BE-7 BEARING LOCATIONS ARE DEFINED AS LOCATIONS WITH SURFACE SAMPLES ANALYZED FOR BE-7 AND RESULT CONCENTRATIONS GREATER THAN OR EQUAL TO 0.5 PICOCURIE PER GRAM (PCI/G). THESE LOCATIONS ARE CONSIDERED TO INDICATE RECENTLY DEPOSITED SEDIMENTS. ONLY PHASE I/II SAMPLES WERE ANALYZED FOR BE-7.
11. REFERENCE:
A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

HACKENSACK RIVER
PIERSONS CREEK
PASSAIC RIVER
Kearny Flat
CONRAIL BRIDGE REMNANTS
PORT NEWARK CHANNEL
COMP01
NEWARK BAY NORTH
ELIZABETH CHANNEL
COMP10
COMP02
NEWARK BAY CDF (CELL 1S)
COMP04
NEWARK BAY CENTRAL
COMP05
COMP03
SOUTH ELIZABETH CHANNEL
COMP08
COMP06
NEWARK BAY SOUTH
KILL VAN KULL
ELIZABETH RIVER
COMP07
COMP09
SHOOTERS ISLAND
BAYONNE BRIDGE
GOETHALS BRIDGE
OLD PLACE CREEK
ARTHUR KILL

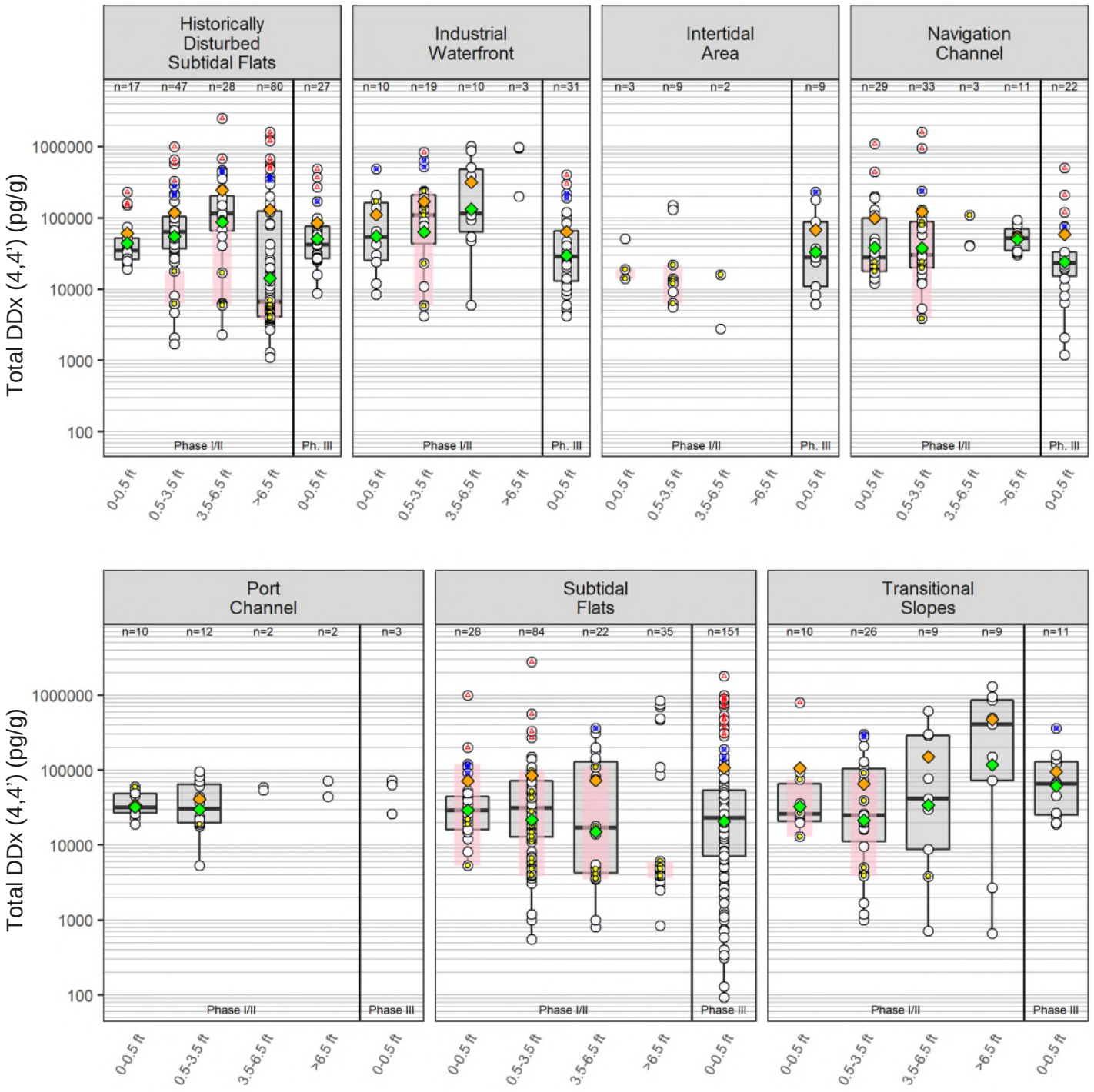
0 3,000 6,000 Feet
GRAPHIC SCALE

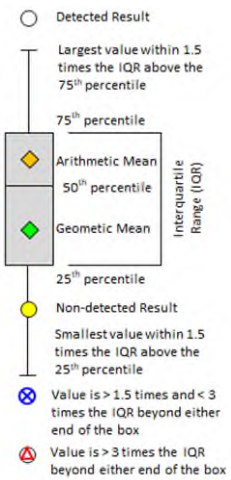
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT (0 - 0.5 FEET) RESULTS - TOTAL DDx (4,4')

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
4-14





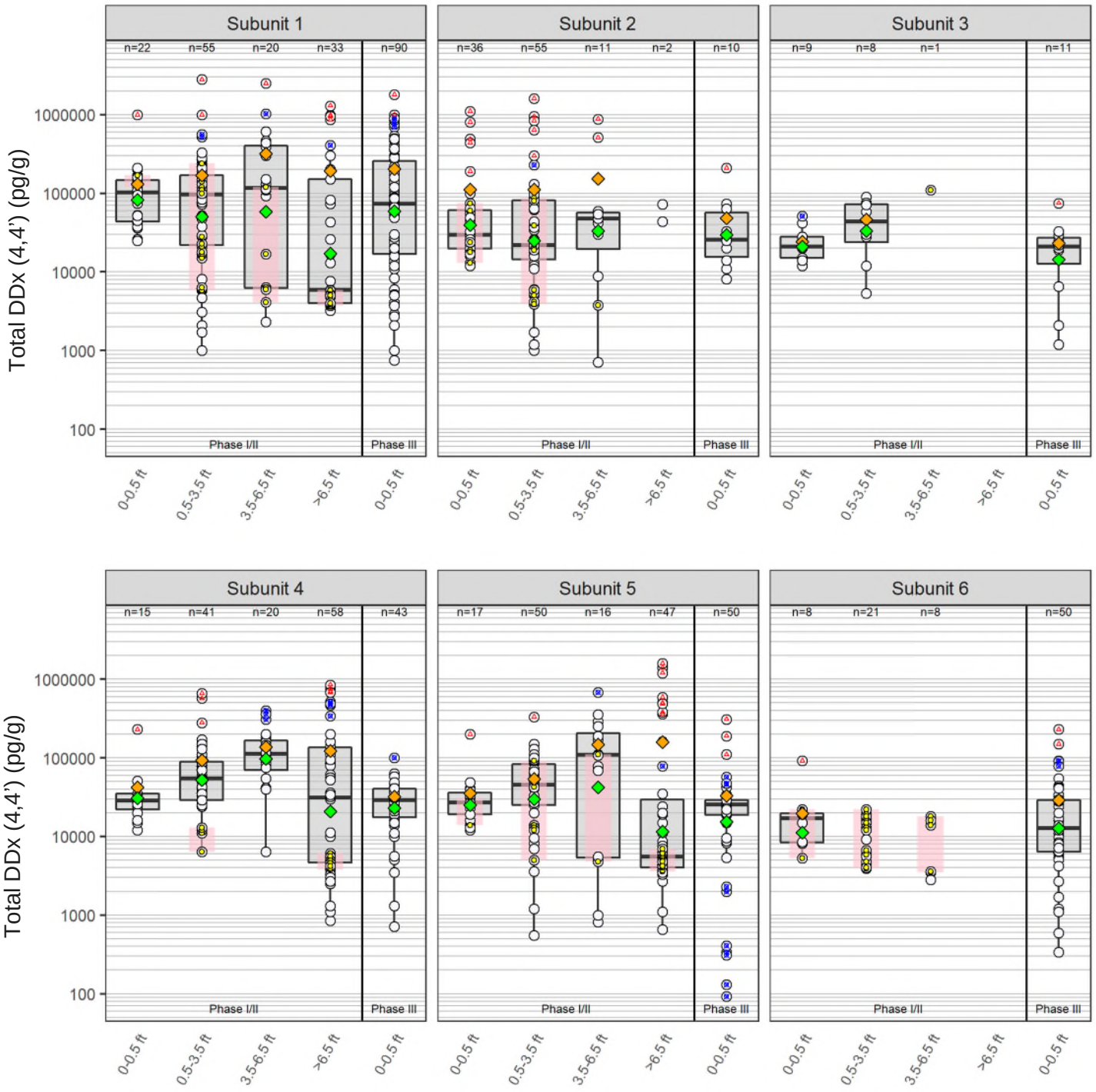
Notes:
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Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
Sample top depth used to assign depth category:
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Top depth >= 6.5 ft = >6.5 ft
Non-detects plotted at the quantitation limit.
For percentiles, non-detects included at the quantitation limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the quantitation limit.
Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
Geomorphic areas shown on Figure 2-7.

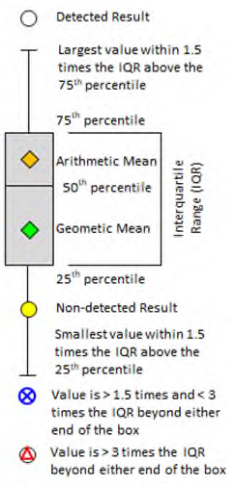
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT BY GEOMORPHIC AREA - TOTAL DDX (4,4')

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-15





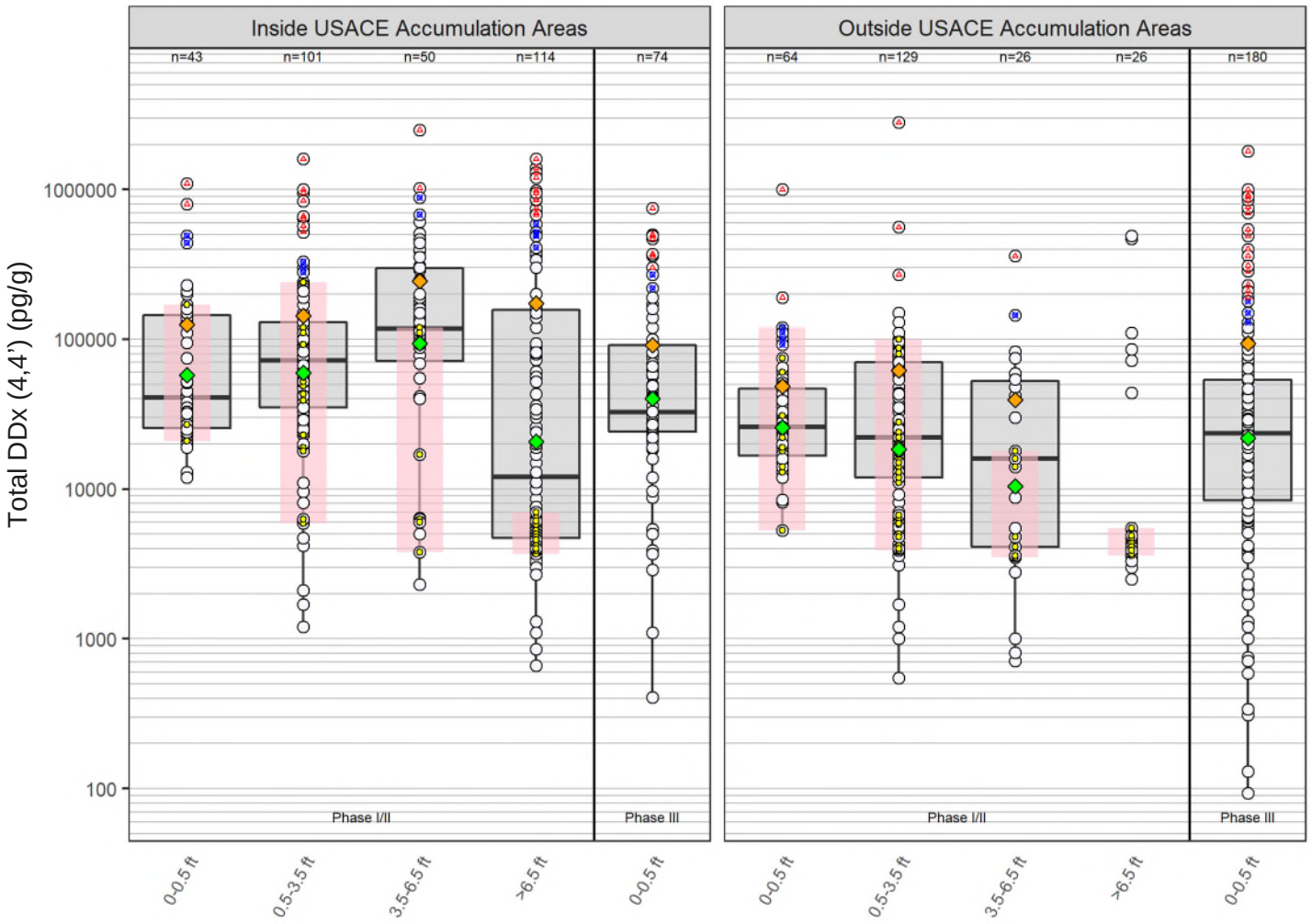
Notes:
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For percentiles, non-detects included at the quantitation limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the quantitation limit.
Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
EPA subunits shown on Figure 2-8.

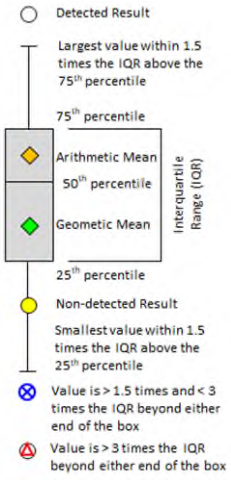
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT BY USEPA SUBUNIT - TOTAL DDX (4,4')

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-16





Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
Sample top depth used to assign depth category:
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For percentiles, non-detects included at the quantitation limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the quantitation limit.
Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
United States Army Corps of Engineers (USACE) depositional areas shown on Figure 3-4.

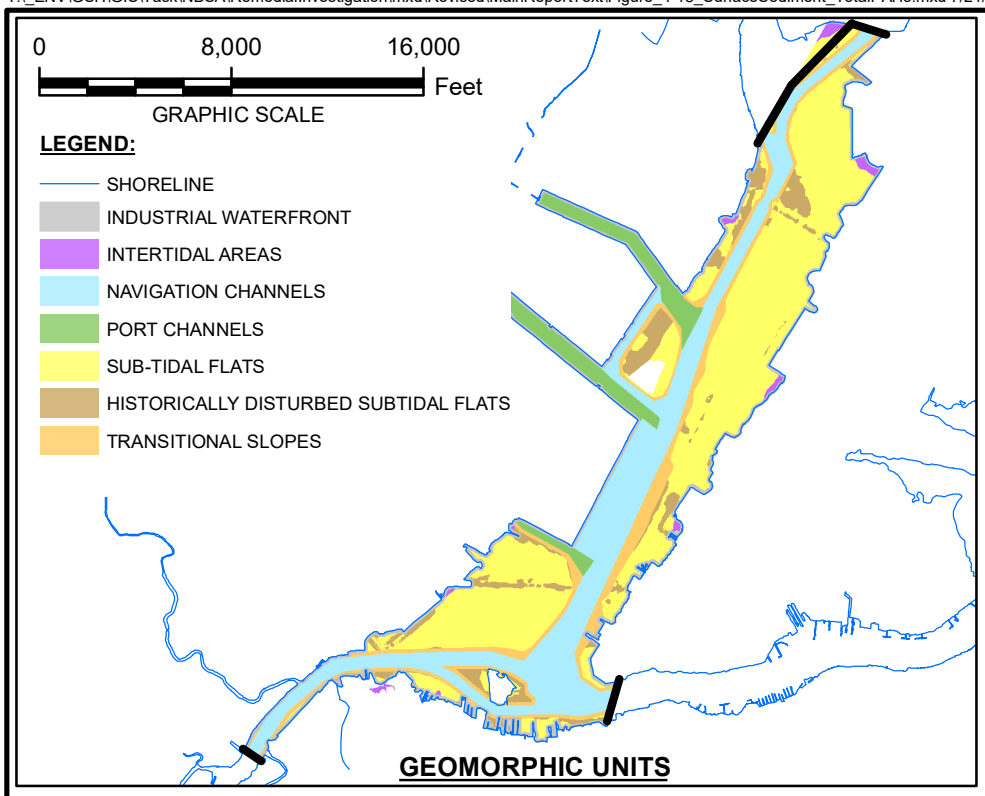
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT RESULTS BY ACCUMULATION AREA - TOTAL DDX (4,4')

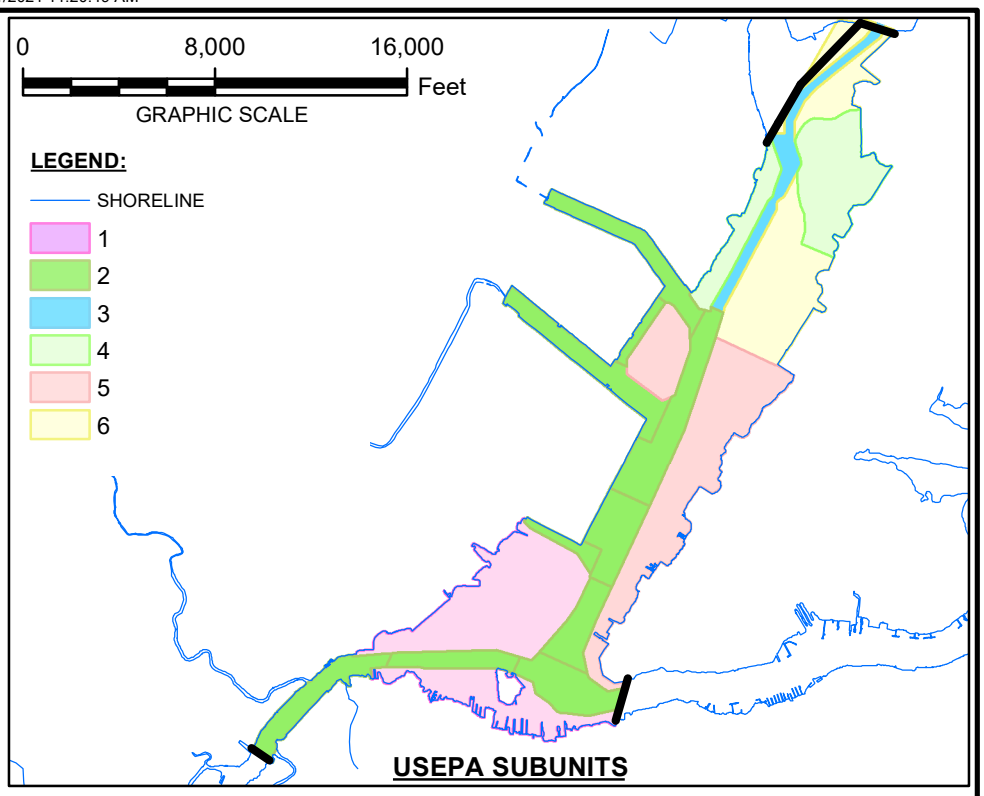
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-17

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: PJI01206
Project (B0009989.0045.00002)
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GEOMORPHIC UNITS



USEPA SUBUNITS

LEGEND:

- 2005 PHASE I CORE LOCATION
- 2007 PHASE II CORE LOCATION
- CO-LOCATED 2005 PHASE I / 2007 PHASE II CORE LOCATION
- 2014 CRAB/CLAM SEDIMENT SAMPLING LOCATION
- 2015 SQT SEDIMENT SAMPLE LOCATION
- 2016 PHASE III SEDIMENT SAMPLING LOCATION
- NON-DETECT RESULT. QUANTITATION LIMIT REPRESENTED BY SYMBOL COLOR
- Be-7 BEARING LOCATION

TOTAL PAH (ug/kg) (SEE NOTE 3)

- ≤ 5100
- < 5100 - 8400
- < 8400 - 16,000
- < 16,000 - 30,000
- > 30,000

- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- SHORELINE
- NORTH, CENTRAL & SOUTH GEOGRAPHIC ZONE BOUNDARY
- NAVIGATION CHANNEL
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREAS

NOTES:
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HACKENSACK RIVER
PIERSONS CREEK
PASSAIC RIVER
Kearny Flat
CONRAIL BRIDGE REMNANTS
PORT NEWARK CHANNEL
COMP01
NEWARK BAY NORTH
ELIZABETH CHANNEL
COMP10
COMP02
NEWARK BAY CDF (CELL 1S)
NEWARK BAY CENTRAL
COMP04
COMP05
COMP03
SOUTH ELIZABETH CHANNEL
COMP08
COMP06
NEWARK BAY SOUTH
KILL VAN KULL
ELIZABETH RIVER
COMP07
COMP09
SHOOTERS ISLAND
BAYONNE BRIDGE
GOETHALS BRIDGE
OLD PLACE CREEK
ARTHUR KILL
0
3,000
6,000
Feet
GRAPHIC SCALE

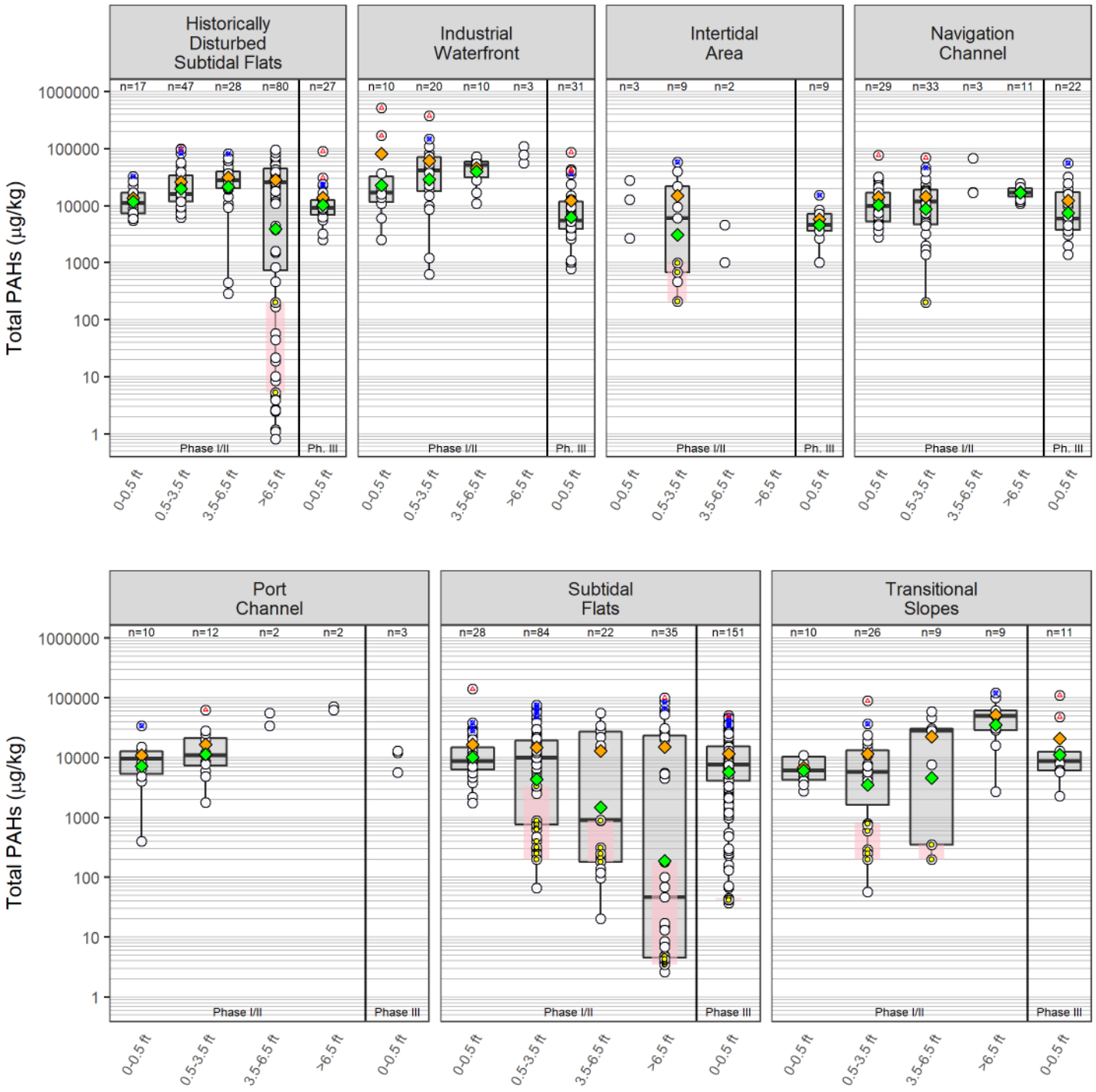
DIAMOND ALKALI SUPERFUND SITE

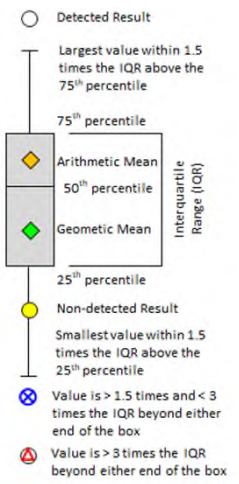
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT (0 - 0.5 FEET) RESULTS - TOTAL PAHs

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
4-18





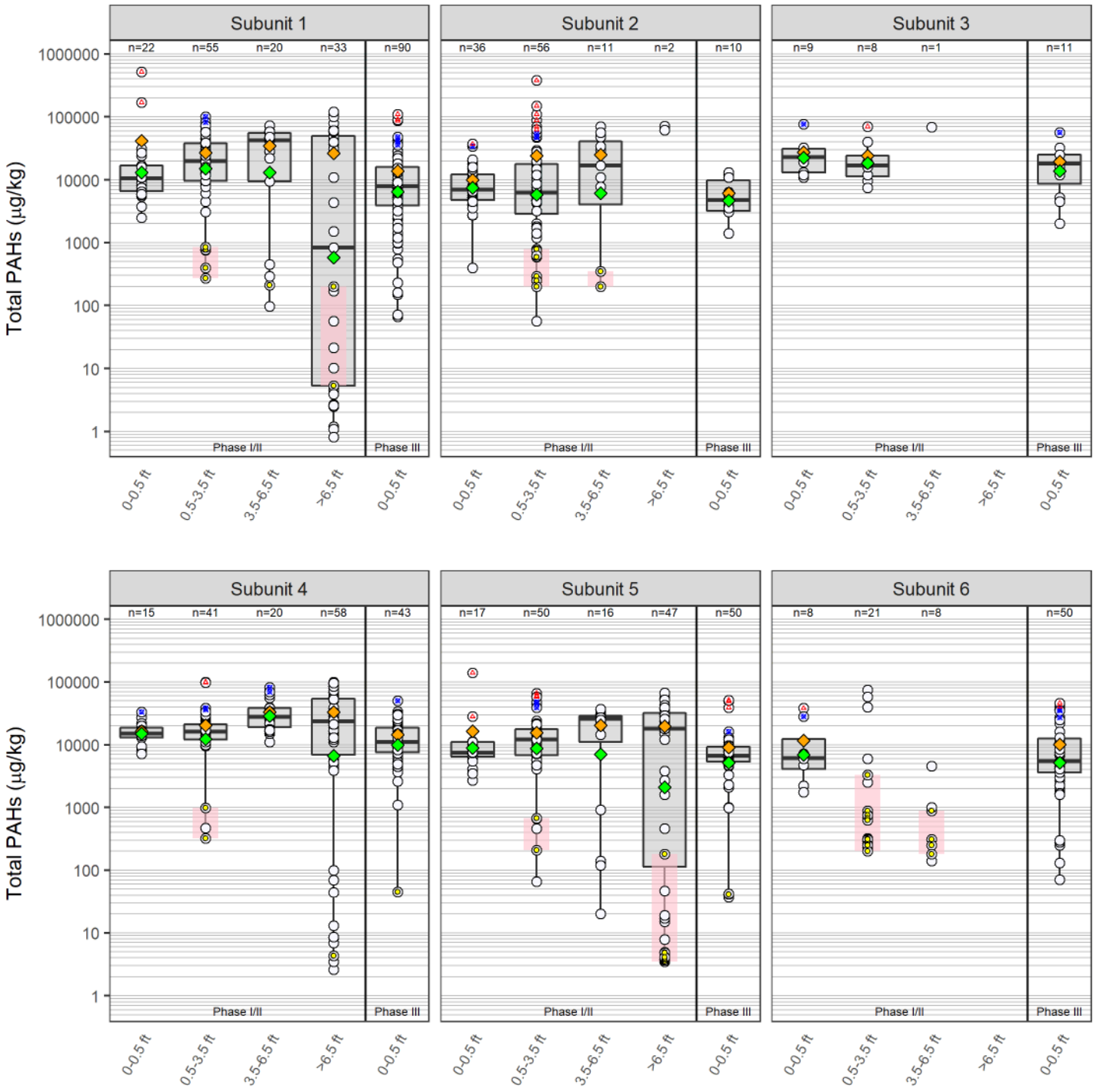
Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
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Top depth >= 3.5 and < 6.5 ft = 3.5-6.5 ft
Top depth >= 6.5 ft = >6.5 ft
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For arithmetic mean and geometric mean, non-detects included at 1/2 the quantitation limit.
Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
Geomorphic areas shown on Figure 2-7.

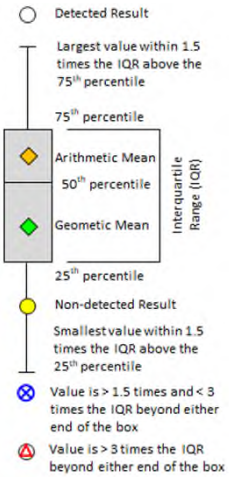
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT BY GEOMORPHIC AREA - TOTAL PAHS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-19





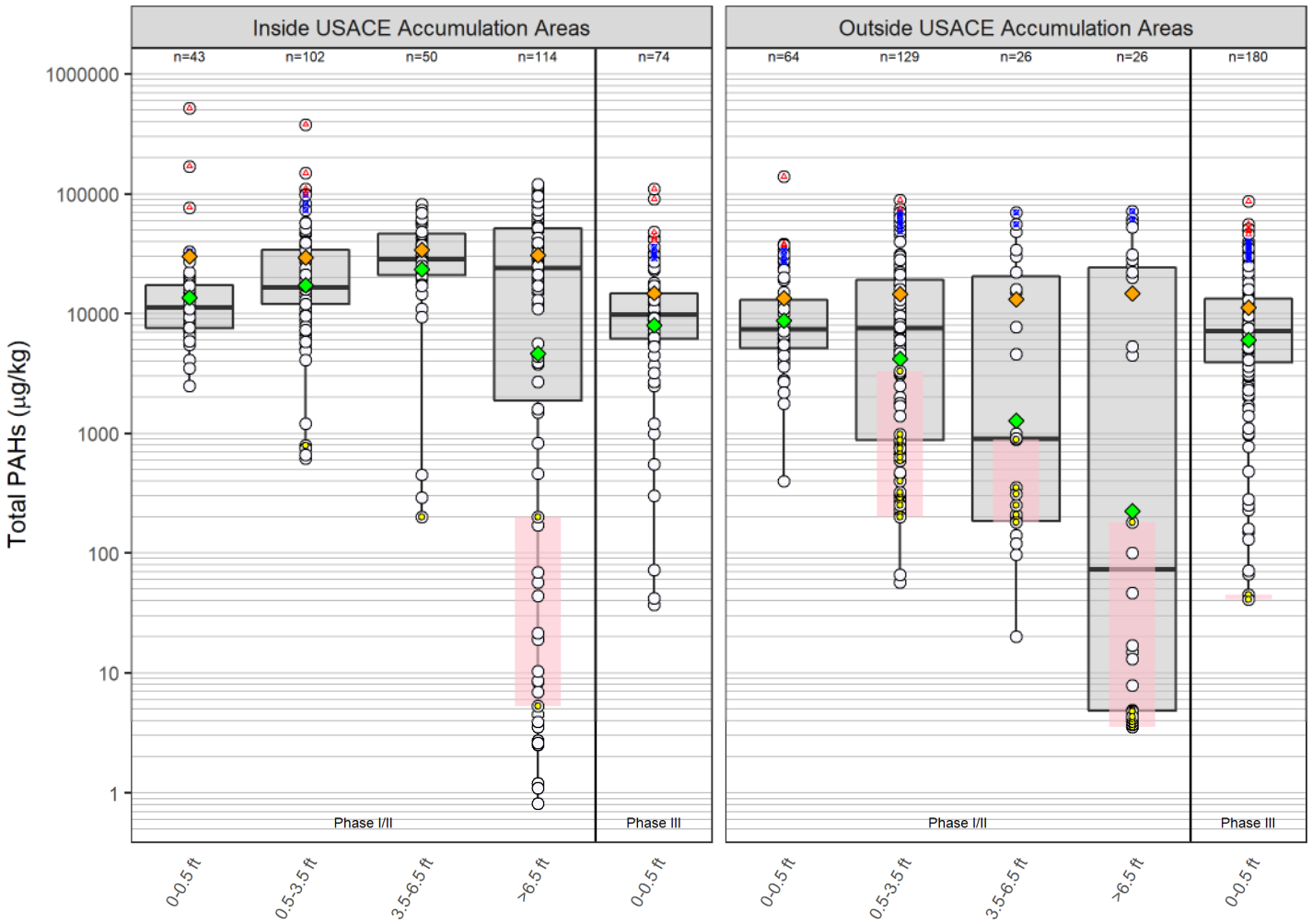
Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
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For percentiles, non-detects included at the quantitation limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the quantitation limit.
Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
EPA subunits shown on Figure 2-8.

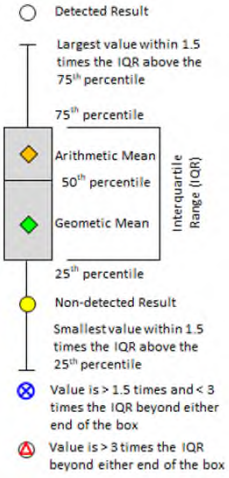
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT BY USEPA SUBUNIT - TOTAL PAHS

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-20





Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
Sample top depth used to assign depth category:
Top depth < 0.5 ft = 0-0.5 ft
Top depth >= 0.5 and < 3.5 ft = 0.5-3.5 ft
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United States Army Corps of Engineers (USACE) depositional areas shown on Figure 3-4.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT RESULTS BY ACCUMULATION AREA - TOTAL PAHS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-21

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: PJI01206
Project (B0009989.0045.00002)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\MainReportText\Figure_4-22_SurfaceSediment_TotalAlkylatedPAHs.mxd 7/21/2021 11:21:55 AM

0 8,000 16,000 Feet
GRAPHIC SCALE

LEGEND:
- SHORELINE
- INDUSTRIAL WATERFRONT
- INTERTIDAL AREAS
- NAVIGATION CHANNELS
- PORT CHANNELS
- SUB-TIDAL FLATS
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- TRANSITIONAL SLOPES

GEOMORPHIC UNITS

0 8,000 16,000 Feet
GRAPHIC SCALE

LEGEND:
- SHORELINE
- 1
- 2
- 3
- 4
- 5
- 6

USEPA SUBUNITS

LEGEND:
- 2005 PHASE I CORE LOCATION
- 2007 PHASE II CORE LOCATION
- CO-LOCATED 2005 PHASE I / 2007 PHASE II CORE LOCATION
- 2014 CRAB/CLAM SEDIMENT SAMPLING LOCATION
- 2015 SQT SEDIMENT SAMPLE LOCATION
- 2016 PHASE III SEDIMENT SAMPLING LOCATION
- NON-DETECT RESULT. QUANTITATION LIMIT REPRESENTED BY SYMBOL COLOR
- Be-7 BEARING LOCATION

TOTAL ALKYLATED PAHs (ug/kg) (SEE NOTE 3)
- ≤ 3239
- < 3239 - 5985.5
- < 5985.5 - 13,246
- < 13,246 - 30,422
- > 30,422

- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- SHORELINE
- NORTH, CENTRAL & SOUTH GEOGRAPHIC ZONE BOUNDARY
- NAVIGATION CHANNEL
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREAS

NOTES:
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9. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
10. BE-7 BEARING LOCATIONS ARE DEFINED AS LOCATIONS WITH SURFACE SAMPLES ANALYZED FOR BE-7 AND RESULT CONCENTRATIONS GREATER THAN OR EQUAL TO 0.5 PICOCURIE PER GRAM (PCI/G). THESE LOCATIONS ARE CONSIDERED TO INDICATE RECENTLY DEPOSITED SEDIMENTS. ONLY PHASE I/II SAMPLES WERE ANALYZED FOR BE-7.
11. REFERENCE:
A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

HACKENSACK RIVER
PIERSONS CREEK
PASSAIC RIVER
Kearny Flat
CONRAIL BRIDGE REMNANTS
PORT NEWARK CHANNEL
COMP01
NEWARK BAY NORTH
ELIZABETH CHANNEL
COMP10
COMP02
NEWARK BAY CDF (CELL 1S)
COMP04
NEWARK BAY CENTRAL
COMP05
COMP03
SOUTH ELIZABETH CHANNEL
COMP08
COMP06
NEWARK BAY SOUTH
KILL VAN KULL
ELIZABETH RIVER
COMP07
COMP09
SHOOTERS ISLAND
BAYONNE BRIDGE
GOETHALS BRIDGE
OLD PLACE CREEK
ARTHUR KILL

0 3,000 6,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT (0 - 0.5 FEET) RESULTS - TOTAL ALKYLATED PAHs

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
4-22

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: PJI01206
Project (B0009989.0045.00002)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\MainReportText\Figure_4-23_SurfaceSediment_Mercury.mxd 7/21/2021 11:22:55 AM

0 8,000 16,000 Feet
GRAPHIC SCALE

LEGEND:

- SHORELINE
- INDUSTRIAL WATERFRONT
- INTERTIDAL AREAS
- NAVIGATION CHANNELS
- PORT CHANNELS
- SUB-TIDAL FLATS
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- TRANSITIONAL SLOPES

GEOMORPHIC UNITS

0 8,000 16,000 Feet
GRAPHIC SCALE

LEGEND:

- SHORELINE
- 1
- 2
- 3
- 4
- 5
- 6

USEPA SUBUNITS

LEGEND:

- 2005 PHASE I CORE LOCATION
- 2007 PHASE II CORE LOCATION
- CO-LOCATED 2005 PHASE I / 2007 PHASE II CORE LOCATION
- 2014 CRAB/CLAM SEDIMENT SAMPLING LOCATION
- 2015 SQT SEDIMENT SAMPLE LOCATION
- 2016 PHASE III SEDIMENT SAMPLING LOCATION
- NON-DETECT RESULT. QUANTITATION LIMIT REPRESENTED BY SYMBOL COLOR
- Be-7 BEARING LOCATION

MERCURY (ng/g) (SEE NOTE 3)

- ≤ 881
- < 881 - 1580
- < 1580 - 2970
- < 2970 - 5730
- > 5730

- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- SHORELINE
- NORTH, CENTRAL & SOUTH GEOGRAPHIC ZONE BOUNDARY
- NAVIGATION CHANNEL
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREAS

NOTES:
1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. RANGES PRESENTED FOR RESULTS ARE BASED ON THE 25TH, 50TH, 75TH, AND 90TH PERCENTILE OF THE SURFACE SEDIMENT DATA SET.
4. SAMPLING LOCATIONS COLLECTED DURING PHASE I/II FROM WITHIN THE NAVIGATION CHANNEL IN NEWARK BAY SOUTH AND NEWARK BAY CENTRAL MAY HAVE BEEN AFFECTED BY DREDGING ACTIVITIES CONDUCTED SINCE SAMPLE COLLECTION.
5. COMP01-COMP10 ARE COMPOSITE SAMPLES COLLECTED IN THE DREDGED PORTION OF THE NAVIGATION CHANNEL DURING THE 2016 PHASE III SAMPLING PROGRAM. A SYMBOL LOCATED CENTRALLY WITHIN EACH COMPOSITE AREA IS COLOR-CODED ACCORDING TO THE CONCENTRATION VALUES AS SHOWN IN THE LEGEND ABOVE.
6. LOCATIONS OUTSIDE THE STUDY AREAARE SHOWN FOR CONSISTENCY BUT NOT INCLUDED IN STATISTICAL ANALYSIS.
7. GEOGRAPHIC ZONE BOUNDARIES ARE USED TO DIVIDE THE STUDY AREA INTO NORTH, CENTRAL, AND SOUTH ZONES.
8. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
9. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
10. BE-7 BEARING LOCATIONS ARE DEFINED AS LOCATIONS WITH SURFACE SAMPLES ANALYZED FOR BE-7 AND RESULT CONCENTRATIONS GREATER THAN OR EQUALTO 0.5 PICOCURIE PER GRAM (PCI/G). THESE LOCATIONS ARE CONSIDERED TO INDICATE RECENTLY DEPOSITED SEDIMENTS. ONLY PHASE I/II SAMPLES WERE ANALYZED FOR BE-7.
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A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

HACKENSACK RIVER
PIERSONS CREEK
PASSAIC RIVER
Kearny Flat
CONRAIL BRIDGE REMNANTS
PORT NEWARK CHANNEL
COMP01
NEWARK BAY NORTH
ELIZABETH CHANNEL
COMP10
COMP02
NEWARK BAY CDF (CELL 1S)
COMP04
NEWARK BAY CENTRAL
COMP05
COMP03
SOUTH ELIZABETH CHANNEL
COMP08
COMP06
NEWARK BAY SOUTH
KILL VAN KULL
ELIZABETH RIVER
COMP07
COMP09
SHOOTERS ISLAND
BAYONNE BRIDGE
GOETHALS BRIDGE
OLD PLACE CREEK
ARTHUR KILL

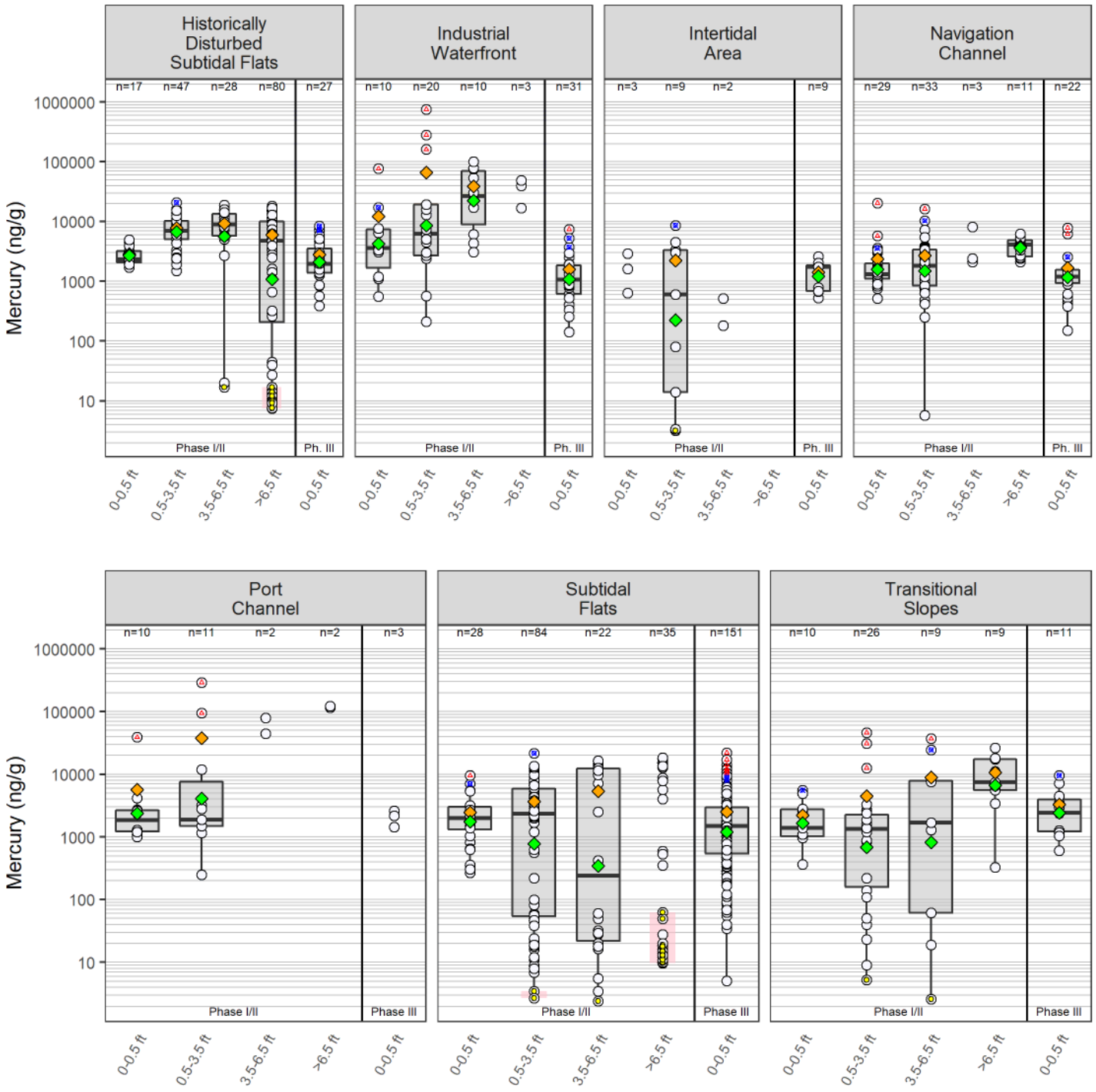
0 3,000 6,000 Feet
GRAPHIC SCALE

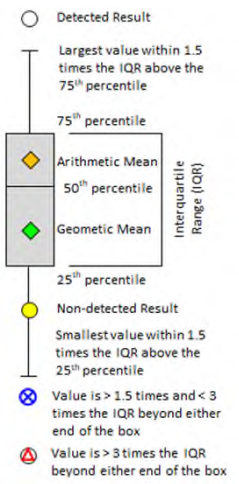
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT (0 - 0.5 FEET) RESULTS - MERCURY

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
4-23





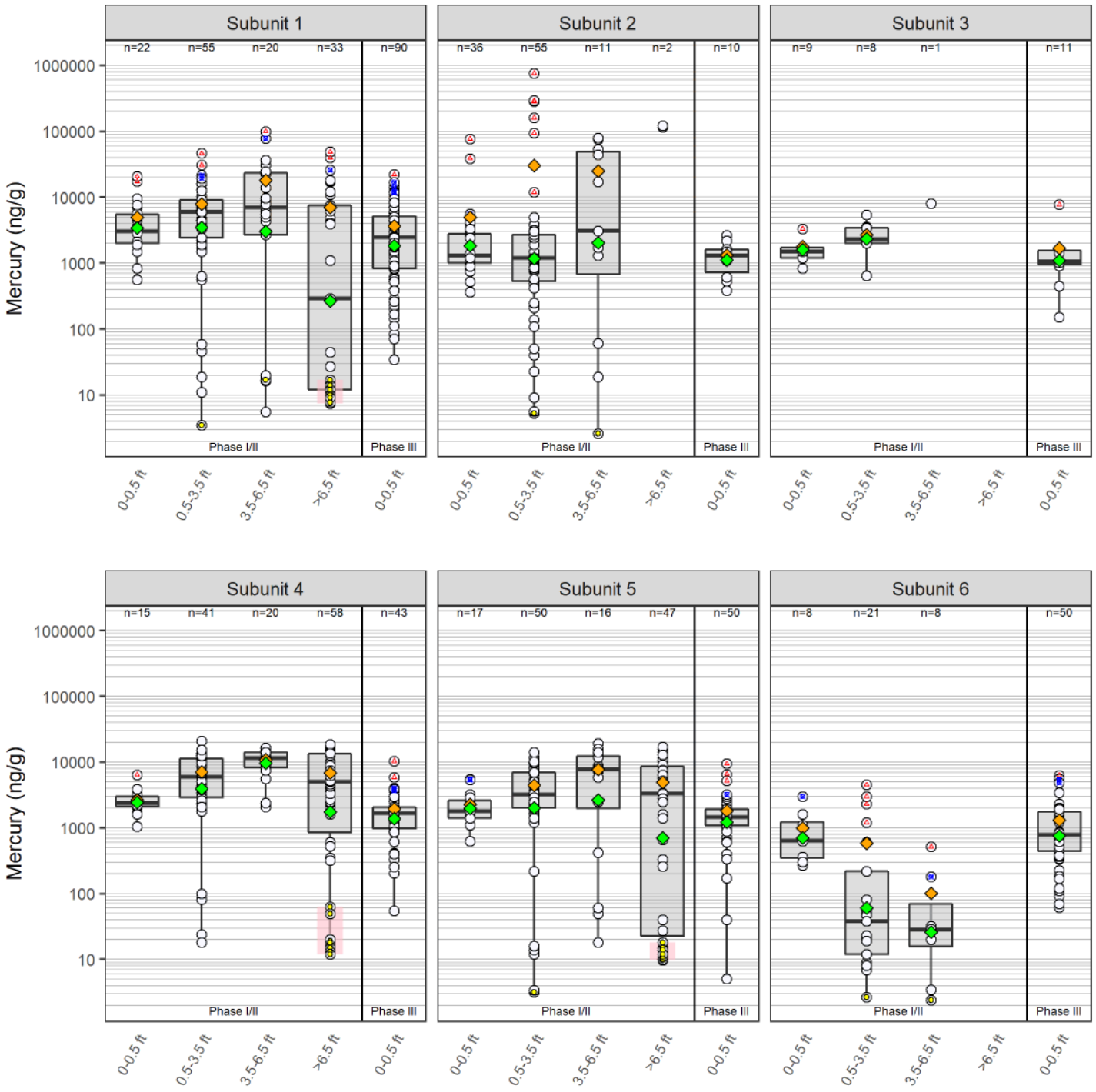
Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
Sample top depth used to assign depth category:
Top depth < 0.5 ft = 0-0.5 ft
Top depth >= 0.5 and < 3.5 ft = 0.5-3.5 ft
Top depth >= 3.5 and < 6.5 ft = 3.5-6.5 ft
Top depth >= 6.5 ft = >6.5 ft
Non-detects plotted at the quantitation limit.
For percentiles, non-detects included at the quantitation limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the quantitation limit.
Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
Geomorphic areas shown on Figure 2-7.

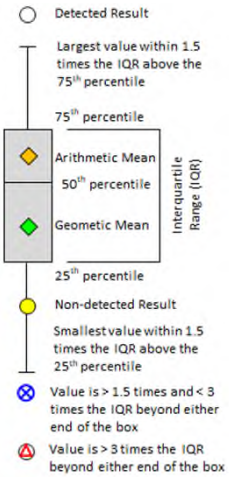
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT BY GEOMORPHIC AREA - MERCURY

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-24





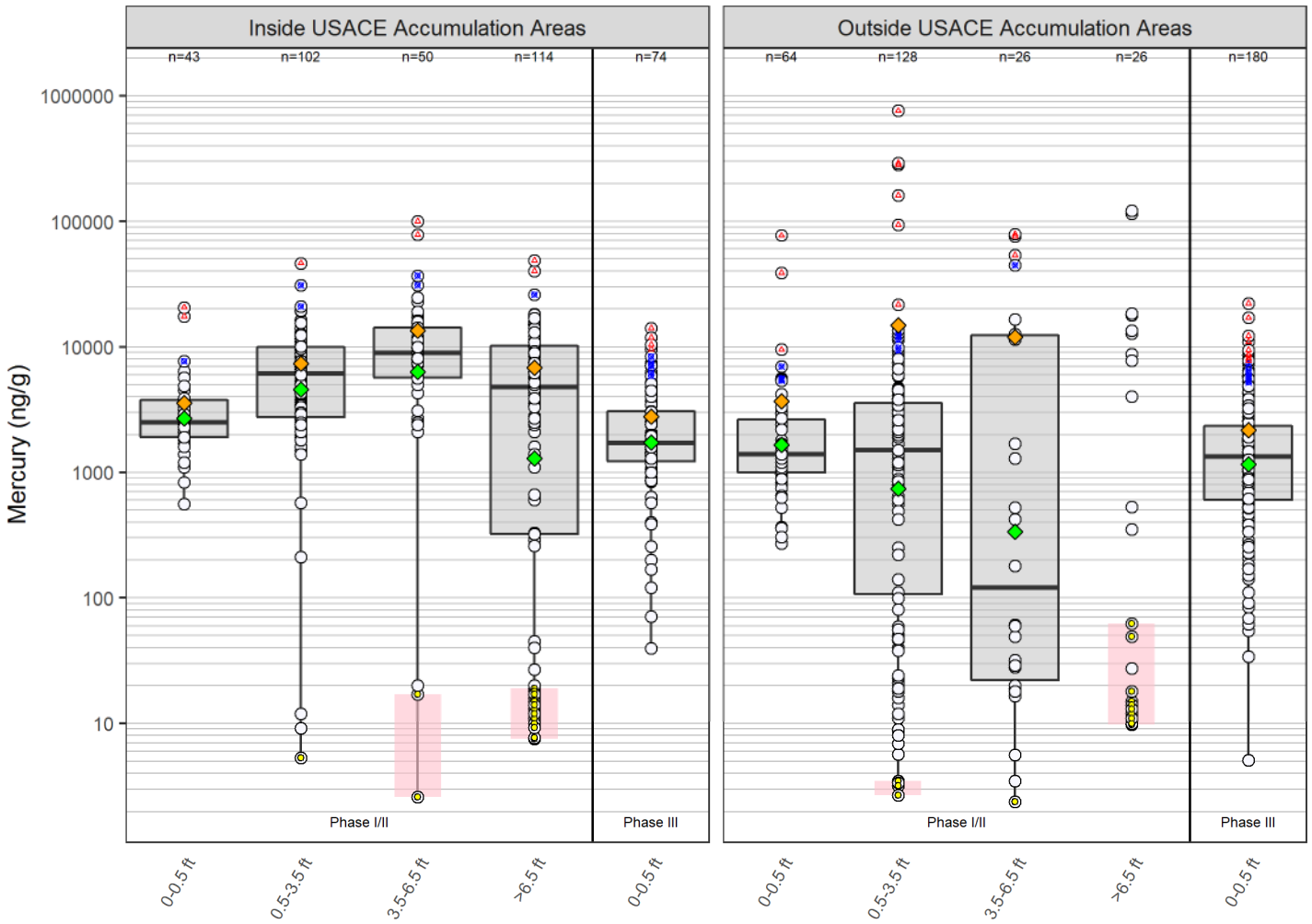
Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
Sample top depth used to assign depth category:
Top depth < 0.5 ft = 0-0.5 ft
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Top depth >= 3.5 and < 6.5 ft = 3.5-6.5 ft
Top depth >= 6.5 ft = >6.5 ft
Non-detects plotted at the quantitation limit.
For percentiles, non-detects included at the quantitation limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the quantitation limit.
Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
EPA subunits shown on Figure 2-8.

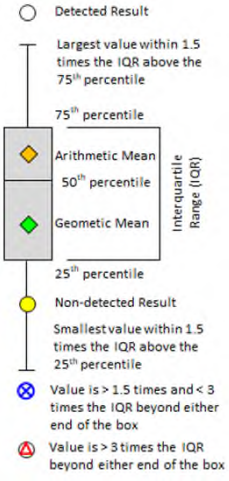
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT BY USEPA SUBUNIT - MERCURY

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-25





Notes:
Phase I/II = 2005 Phase I & 2007 Phase II
Phase III = 2014 Crab/Clam, 2015 SQT, & 2016 Phase III
n = number of samples
Sample top depth used to assign depth category:
Top depth < 0.5 ft = 0-0.5 ft
Top depth >= 0.5 and < 3.5 ft = 0.5-3.5 ft
Top depth >= 3.5 and < 6.5 ft = 3.5-6.5 ft
Top depth >= 6.5 ft = >6.5 ft
Non-detects plotted at the quantitation limit.
For percentiles, non-detects included at the quantitation limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the quantitation limit.
Pink shaded area represents range of non-detect quantitation limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.
United States Army Corps of Engineers (USACE) depositional areas shown on Figure 3-4.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT RESULTS BY ACCUMULATION AREA - MERCURY

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-26

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: avi00815
Project (B0009989.0061.0004)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\MainReportText\Figure_4-27 Sediment Chem Principal Component Scores.mxd 7/28/2021 1:30:12 PM

LEGEND:

- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- NAVIGATION CHANNEL
- HISTORICALLY DISTURBED SUBTIDAL FLATS

SEDIMENT CHEMISTRY PRINCIPAL COMPONENT SCORE

- < -2
- -2 TO 0
- 0 TO 2
- 2 TO 5
- > 5

0 3,000 6,000 Feet

GRAPHIC SCALE

FIGURE SHOWS SCORES FOR THE FIRST PRINCIPAL COMPONENT FROM THE PRINCIPAL COMPONENT ANALYSIS OF PHASE III SEDIMENT CHEMISTRY DATA PRESENTED IN THE BERA. THE STATIONS WITH LABELS ARE THOSE LISTED IN TABLE 4-17 THAT HAVE AT LEAST TEN CONTAMINANT CONCENTRATIONS IN THE UPPER TENTH PERCENTILE.

PASSAIC RIVER
PIERSONS CREEK
CONRAIL BRIDGE REMNANTS
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
PERIPHERAL DITCH
NEWARK BAY CDF (CELL 1S)
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
KILL VAN KULL
SHOOTERS ISLAND
BAYONNE BRIDGE
GOETHALS BRIDGE
ARTHUR KILL
PRALLS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. BASE MAP INFORMATION AND NEWARK BAY NAVIGATION CHANNEL IS FROM NOAA CHARTS 12331, 12333, AND 12337, DATED MAY 4, 1995. PASSAIC NAVIGATION CHANNEL WAS PROVIDED BY THE USACE. ALL NAVIGATION CHANNEL BOUNDARIES SHOWN ARE APPROXIMATE. CHANNEL DREDGING AND DEEPENING AS PART OF THE HARBOR DEEPENING PROJECT (50-FOOT) IS COMPLETE; CONTACT USACE OPERATIONS DIVISION TO REFERENCE THE MOST CURRENT CHANNEL BOUNDARIES.
4. THE NEWARK BAY STUDY AREA BOUNDARY WAS USE PAAPPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
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DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT CHEMISTRY PRINCIPAL COMPONENT SCORES

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
4-27

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: MEstifanos
GSH (B0009989.0061.00013)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\Figure_4-28_SedimentToxicityResults.mxd 4/6/2021 6:37:41 PM

LEGEND:

- 10-DAY SURVIVAL FOR *LEPTOCHEIRUS PLUMULOSUS*
- 28-DAY SURVIVAL FOR *LEPTOCHEIRUS PLUMULOSUS*
- SURVIVAL STATISTICALLY DIFFERENT THAN CONTROLS
- SURVIVAL NOT STATISTICALLY DIFFERENT THAN CONTROLS
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- GEOGRAPHIC ZONE BOUNDARY

PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
SHOOTERS ISLAND
NEWARK BAY NORTH
NEWARK BAY CENTRAL
NEWARK BAY SOUTH
NEWARK BAY
KILL VAN KULL

140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 136 137 138 139

NOTES:

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2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
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0 2,500 5,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SEDIMENT TOXICITY RESULTS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
4-28

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: MEstifanos
GSH (B0009989.0061.00013)
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\Figure_4-29_BenthicIndexBioticIntegrity.mxd 4/12/2021 3:30:19 PM

LEGEND:

B-IBI SCORE

- IMPACTED (1 TO <2)
- SLIGHTLY IMPACTED (2 TO <3)
- NON-IMPACTED (3 TO 5)
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- GEOGRAPHIC ZONE BOUNDARY

PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
SHOOTERS ISLAND
NEWARK BAY
KILL VAN KULL
NEWARK BAY NORTH
NEWARK BAY CENTRAL
NEWARK BAY SOUTH

140 164 163 165 162 161 137 136 138 160 159 158 139 157 141 156 142 143 144 145 155 154 153 152 151 146 149 150 148 147

NOTES:

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0 2,500 5,000 Feet
GRAPHIC SCALE

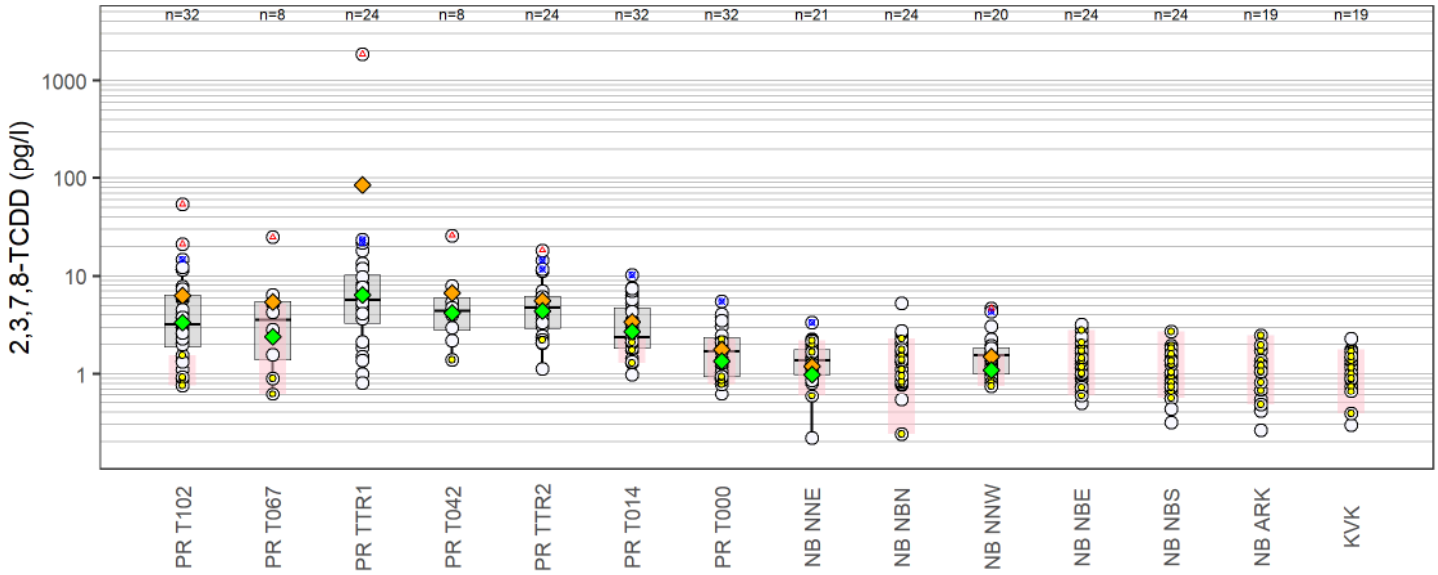
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

NY/NJ BENTHIC INDEX OF BIOTIC INTEGRITY

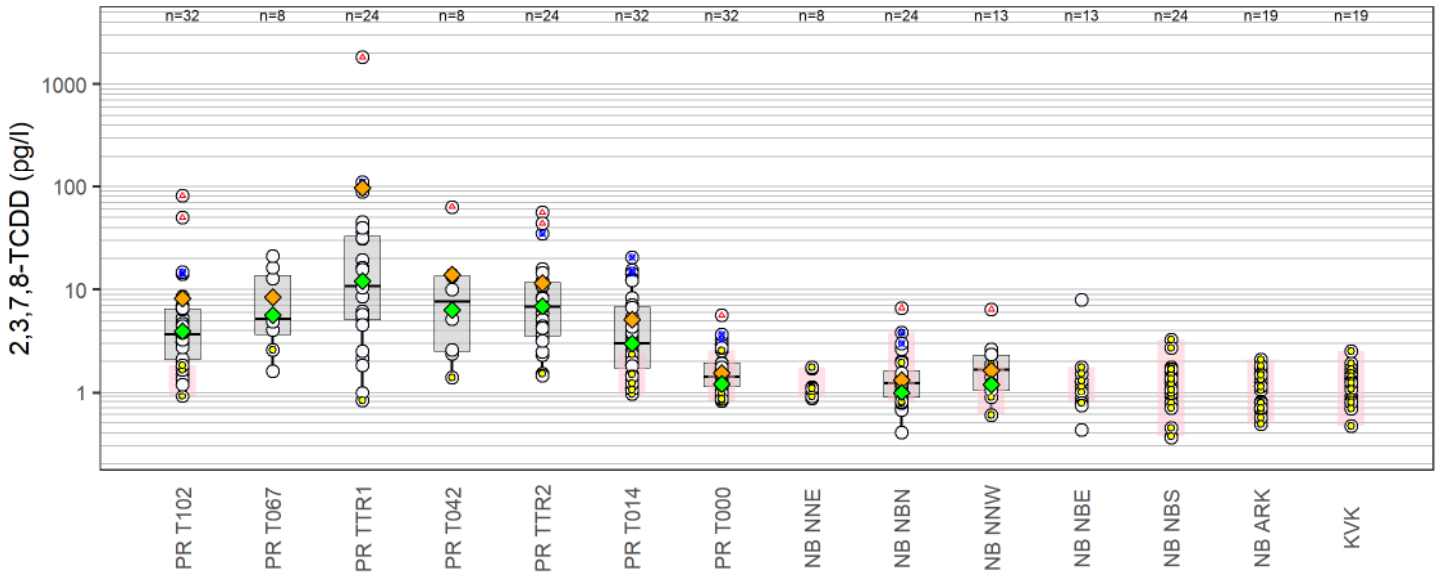
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

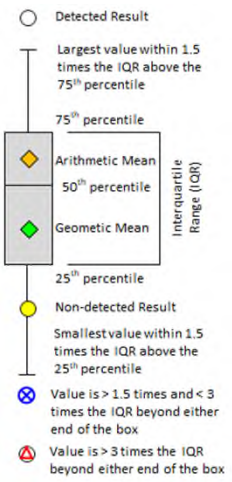
FIGURE
4-29

At Surface



Below Surface





Notes:
Surface water sampling conducted under the Chemical Water Column Monitoring Program (2011-2013). Data were downloaded from ourpassaic.org.
At Surface samples were collected at a depth of 3 feet below the water surface. Below Surface samples were collected at a depth 3 feet above the sediment surface.
Six sampling stations located in the Newark Bay Study Area (NNE, NBN, NNW, NBE, NBS, ARK).
Seven sampling stations located in the Lower Passaic River Study Area (T102, T067, TTR1, T042, TTR2, T014, T000).
One sampling station located in the Kill Van Kull (KVK).
See Figure 2-10 for locations.
n = number of samples
Non-detects plotted at the reporting limit.
For percentiles, non-detects included at the reporting limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the reporting limit.
Pink shaded area represents range of non-detect reporting limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.

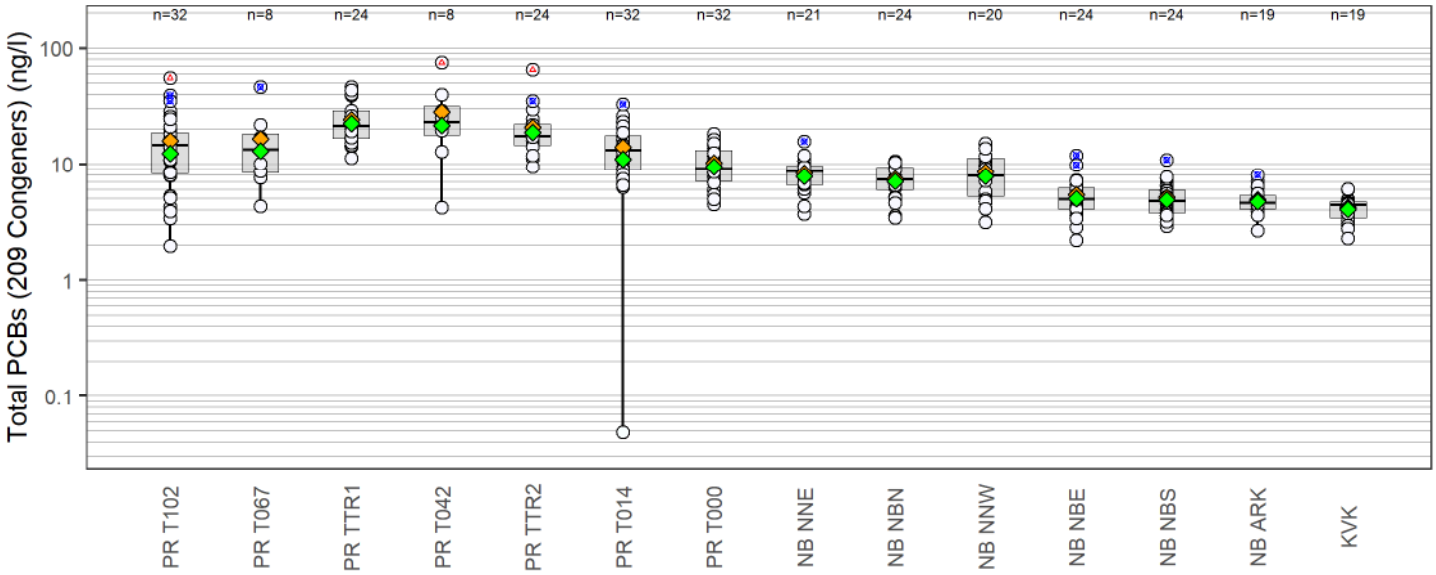
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE WATER RESULTS - 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN

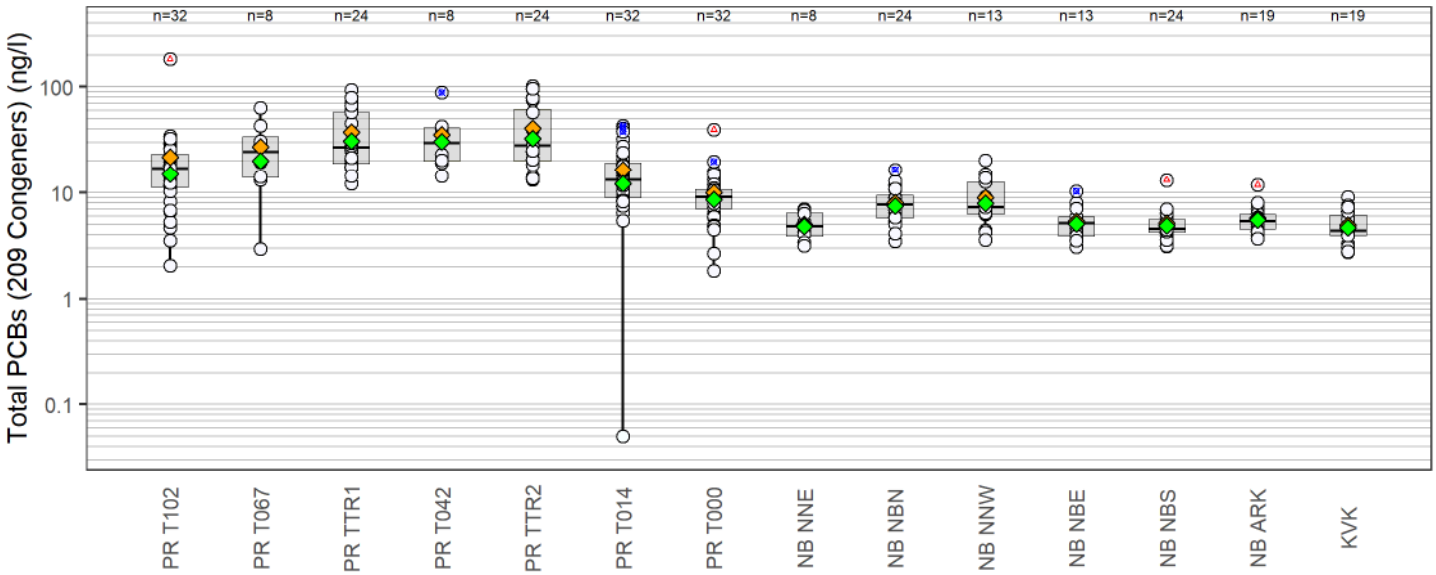
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

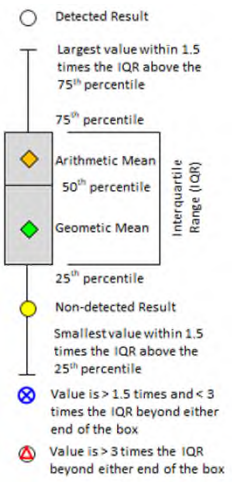
FIGURE
4-30

At Surface



Below Surface





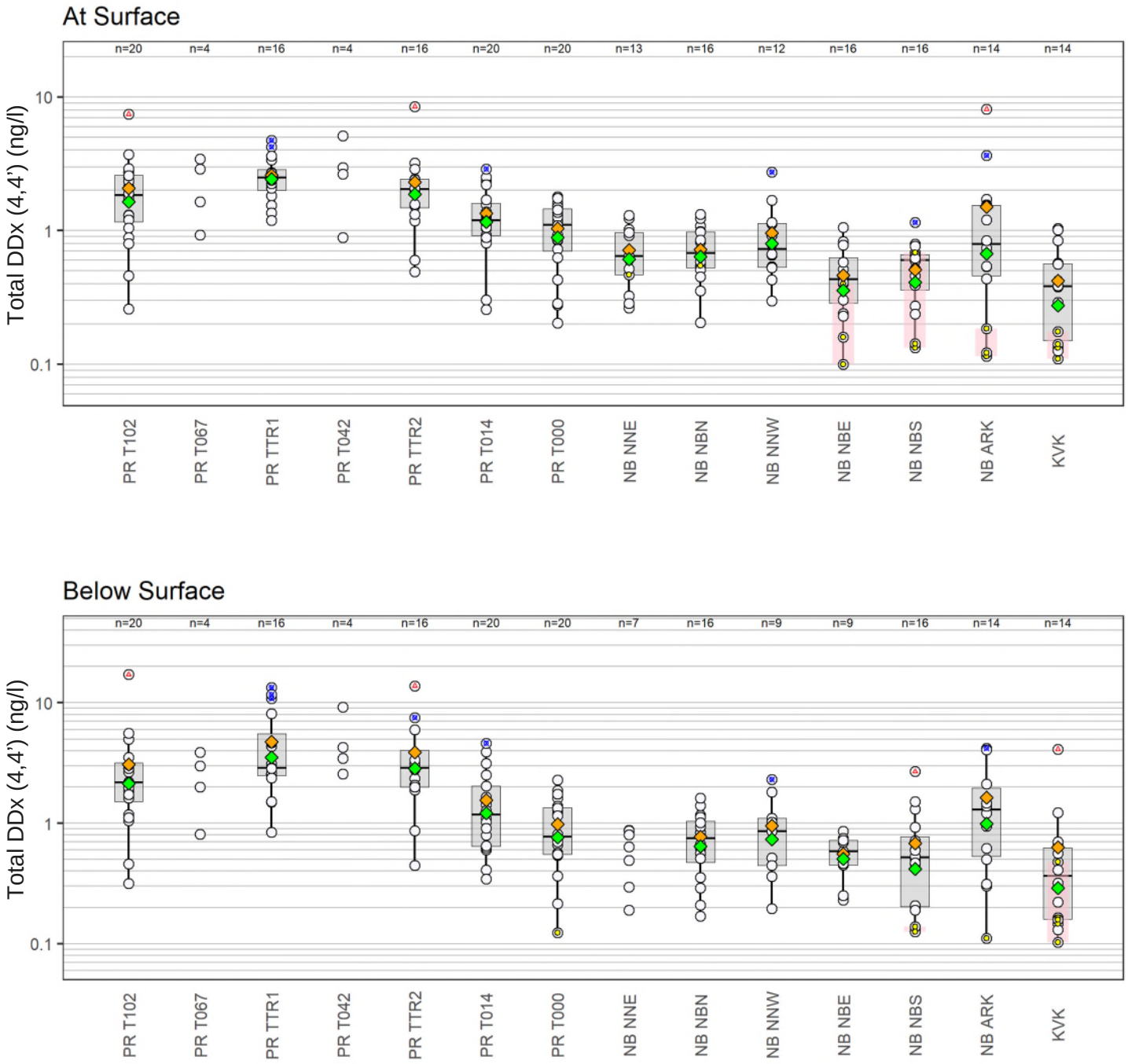
Notes:
Surface water sampling conducted under the Chemical Water Column Monitoring Program (2011-2013). Data were downloaded from ourpassaic.org.
At Surface samples were collected at a depth of 3 feet below the water surface. Below Surface samples were collected at a depth 3 feet above the sediment surface.
Six sampling stations located in the Newark Bay Study Area (NNE, NBN, NNW, NBE, NBS, ARK).
Seven sampling stations located in the Lower Passaic River Study Area (T102, T067, TTR1, T042, TTR2, T014, T000).
One sampling station located in the Kill Van Kull (KVK).
See Figure 2-10 for locations.
n = number of samples
Non-detects plotted at the reporting limit.
For percentiles, non-detects included at the reporting limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the reporting limit.
Pink shaded area represents range of non-detect reporting limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.

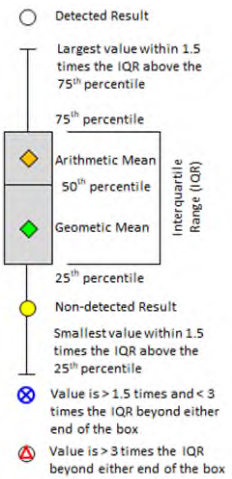
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE WATER RESULTS - TOTAL PCB CONGENERS (209)

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
4-31





Notes:
Surface water sampling conducted under the Chemical Water Column Monitoring Program (2011-2013). Data were downloaded from ourpassaic.org.
At Surface samples were collected at a depth of 3 feet below the water surface. Below Surface samples were collected at a depth 3 feet above the sediment surface.
Six sampling stations located in the Newark Bay Study Area (NNE, NBN, NNW, NBE, NBS, ARK).
Seven sampling stations located in the Lower Passaic River Study Area (T102, T067, TTR1, T042, TTR2, T014, T000).
One sampling station located in the Kill Van Kull (KVK).
See Figure 2-10 for locations.
n = number of samples
Non-detects plotted at the reporting limit.
For percentiles, non-detects included at the reporting limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the reporting limit.
Pink shaded area represents range of non-detect reporting limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.

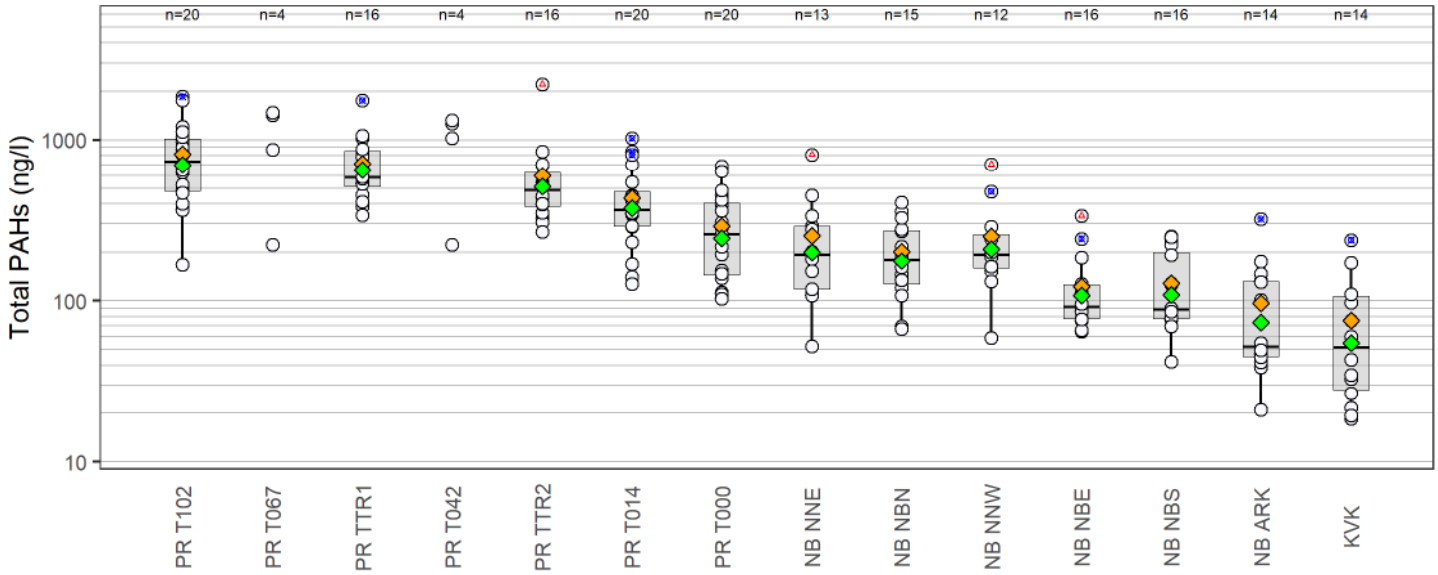
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE WATER RESULTS - TOTAL DDX (4,4')

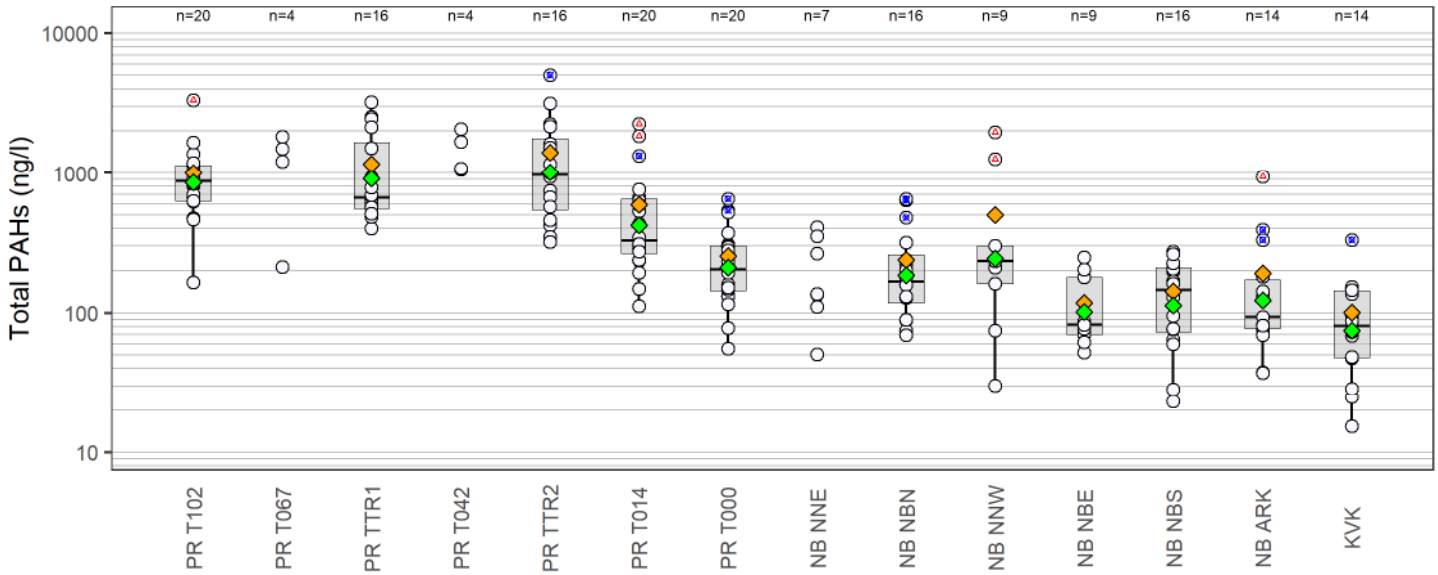
Glenn Springs Holdings, Inc.
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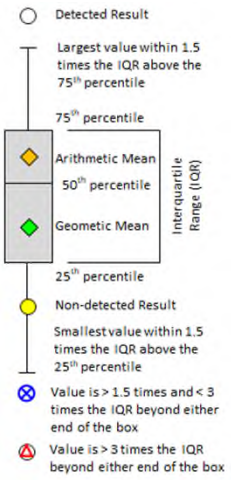
FIGURE
4-32

At Surface



Below Surface





Notes:
Surface water sampling conducted under the Chemical Water Column Monitoring Program (2011-2013). Data were downloaded from ourpassaic.org.
At Surface samples were collected at a depth of 3 feet below the water surface. Below Surface samples were collected at a depth 3 feet above the sediment surface.
Six sampling stations located in the Newark Bay Study Area (NNE, NBN, NNW, NBE, NBS, ARK).
Seven sampling stations located in the Lower Passaic River Study Area (T102, T067, TTR1, T042, TTR2, T014, T000).
One sampling station located in the Kill Van Kull (KVK).
See Figure 2-10 for locations.
n = number of samples
Non-detects plotted at the reporting limit.
For percentiles, non-detects included at the reporting limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the reporting limit.
Pink shaded area represents range of non-detect reporting limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.

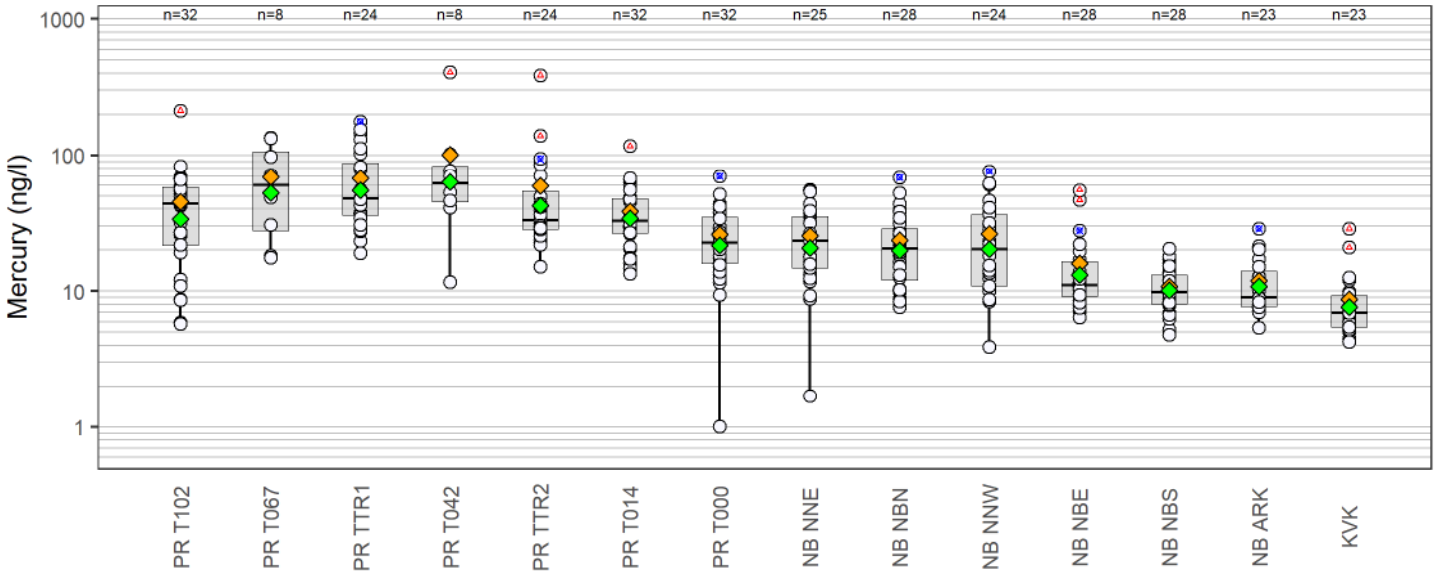
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE WATER RESULTS - TOTAL PAHS

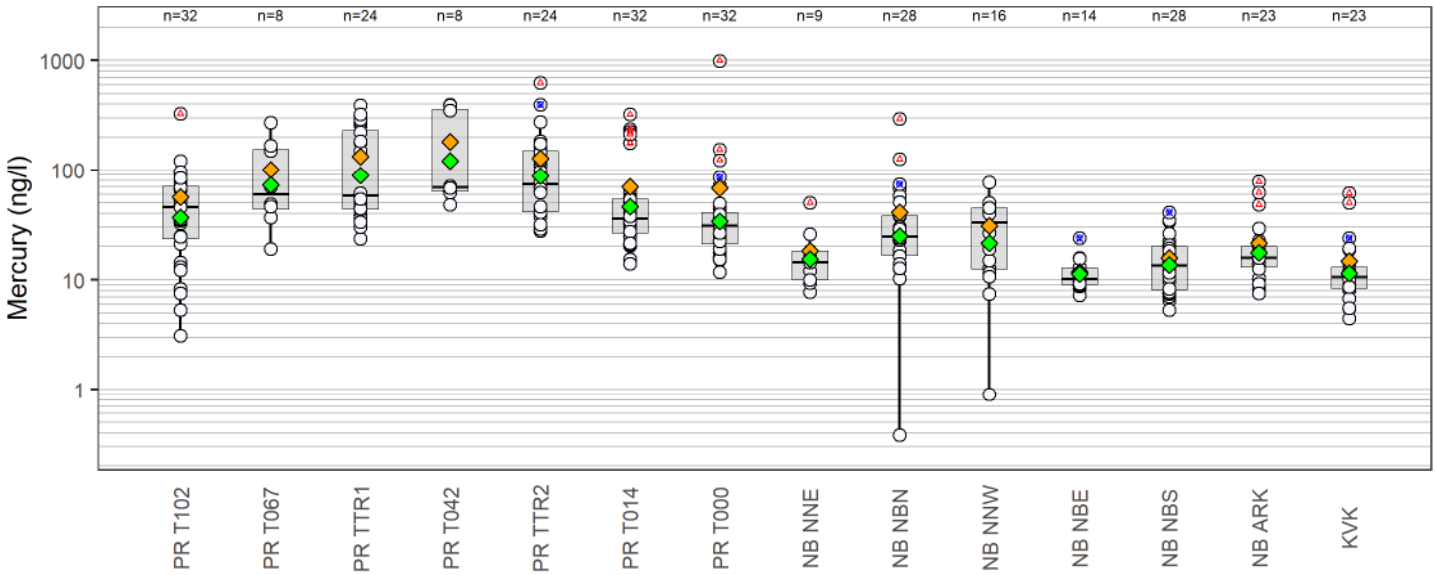
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

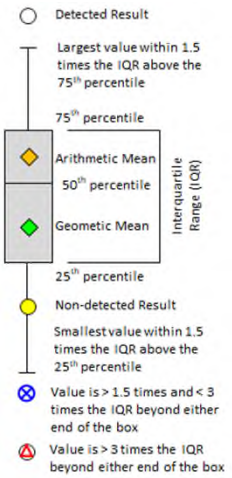
FIGURE
4-33

At Surface



Below Surface





Notes:
Surface water sampling conducted under the Chemical Water Column Monitoring Program (2011-2013). Data were downloaded from ourpassaic.org.
At Surface samples were collected at a depth of 3 feet below the water surface. Below Surface samples were collected at a depth 3 feet above the sediment surface.
Six sampling stations located in the Newark Bay Study Area (NNE, NBN, NNW, NBE, NBS, ARK).
Seven sampling stations located in the Lower Passaic River Study Area (T102, T067, TTR1, T042, TTR2, T014, T000).
One sampling station located in the Kill Van Kull (KVK).
See Figure 2-10 for locations.
n = number of samples
Non-detects plotted at the reporting limit.
For percentiles, non-detects included at the reporting limit.
For arithmetic mean and geometric mean, non-detects included at 1/2 the reporting limit.
Pink shaded area represents range of non-detect reporting limits.
Percentiles/mean not estimated for n<8 and/or frequency of detection<50%.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE WATER RESULTS - MERCURY

Glenn Springs Holdings, Inc.
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FIGURE
4-34

City: SYR Div/Group: IM/DV Created By: ksinsabaugh Last Saved By: ksinsabaugh
Newark Bay (B0009989.0045.00016)
T:\ ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\Figure 4-35 BERA AssessementZones.mxd 1/19/2021 1:20:08 PM

LEGEND:

- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- BOUNDARY OF PHASE III COMPOSITE SAMPLING AREA

BERA ASSESSMENT ZONES

- NORTH
- SOUTHEAST
- SOUTHWEST
- REGULARLY DREDGED DEEP WATER CHANNELS

PASSAIC RIVER
PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
KILL VAN KULL
SHOOTERS ISLAND
ARTHUR KILL
PRALLS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
4. REFERENCE:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

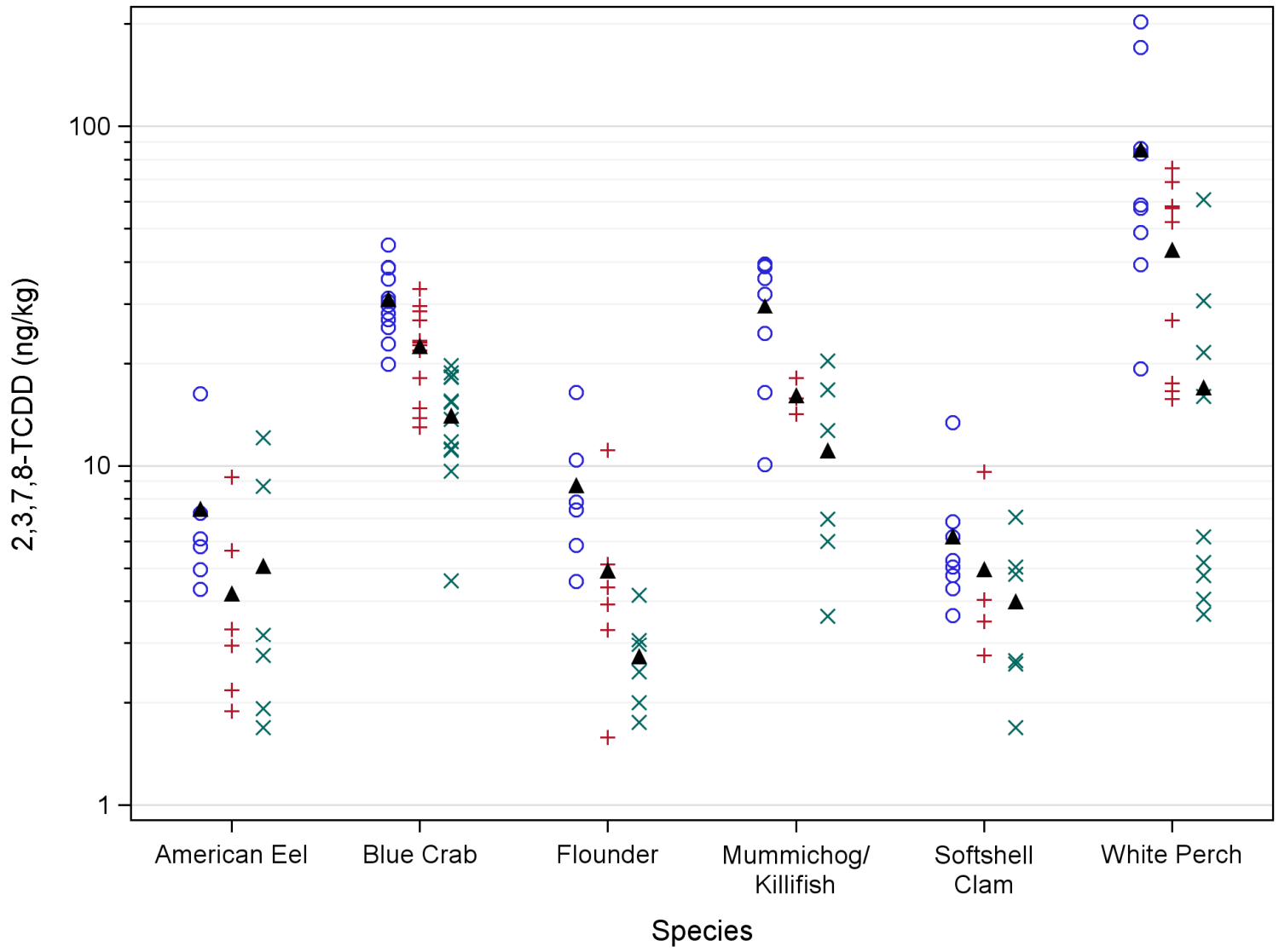
0 3,000 6,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

BERA ASSESSMENT ZONES

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
4-35



Notes:
All values are detected. There were no non-detect results.
Only whole body tissue concentrations are shown.
Flounder includes both summer and winter flounder species. Assessment zones are shown on Figure 4-35.
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
ng/kg = nanogram per kilogram

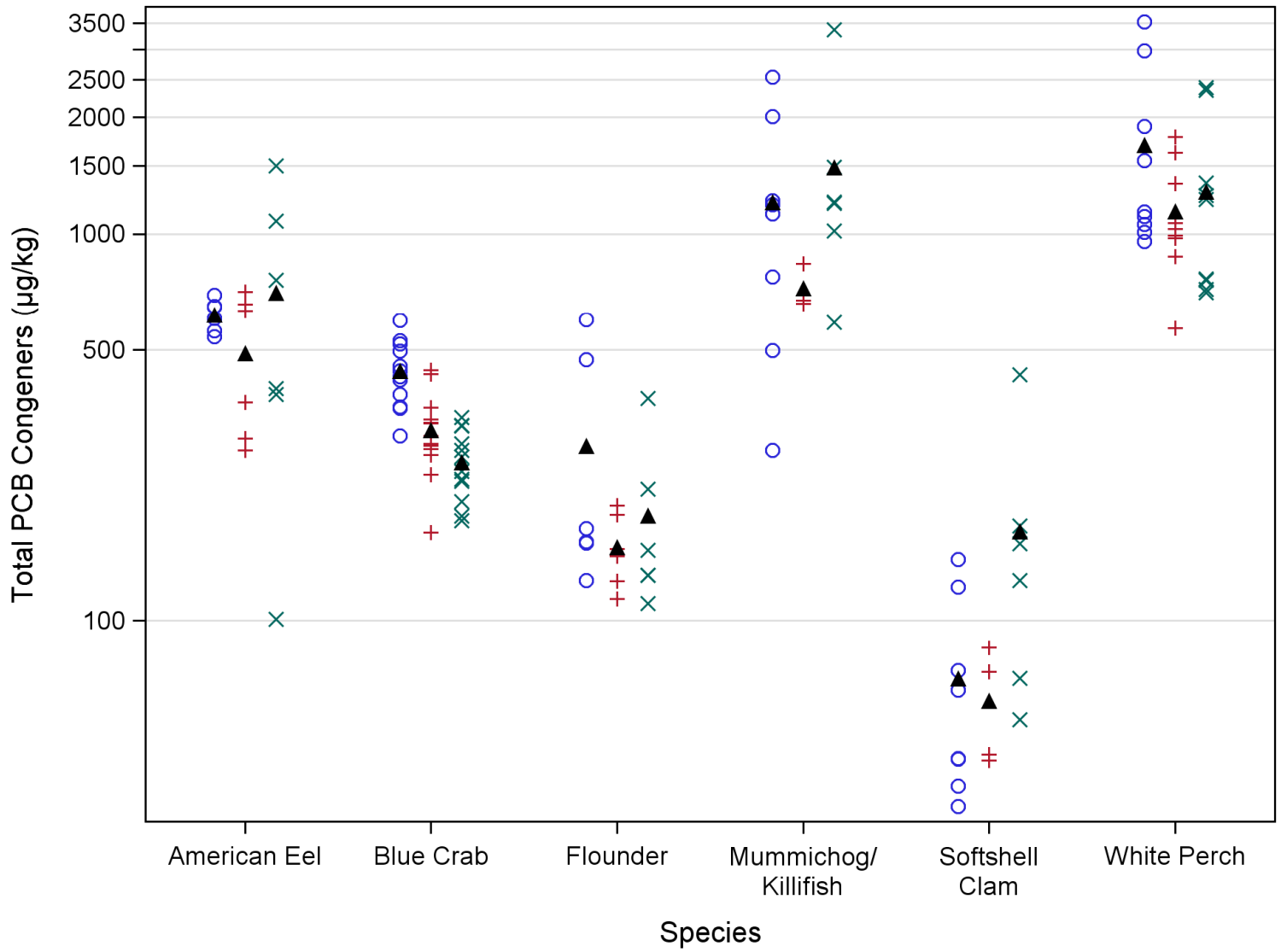
Assessment Zone
- North
- Southeast
- Southwest
- **MEAN**

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CONCENTRATIONS OF 2,3,7,8-TCDD IN WHOLE BODY TISSUE BY SPECIES AND ASSESSMENT ZONE

OXY Glenn Springs Holdings, Inc.
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FIGURE
4-36



Notes:
All values are detected. There were no non-detect results.
Only whole body tissue concentrations are shown.
Flounder includes both summer and winter flounder species. Assessment zones are shown on Figure 4-35.
PCB = polychlorinated biphenyl
µg/kg = microgram per kilogram

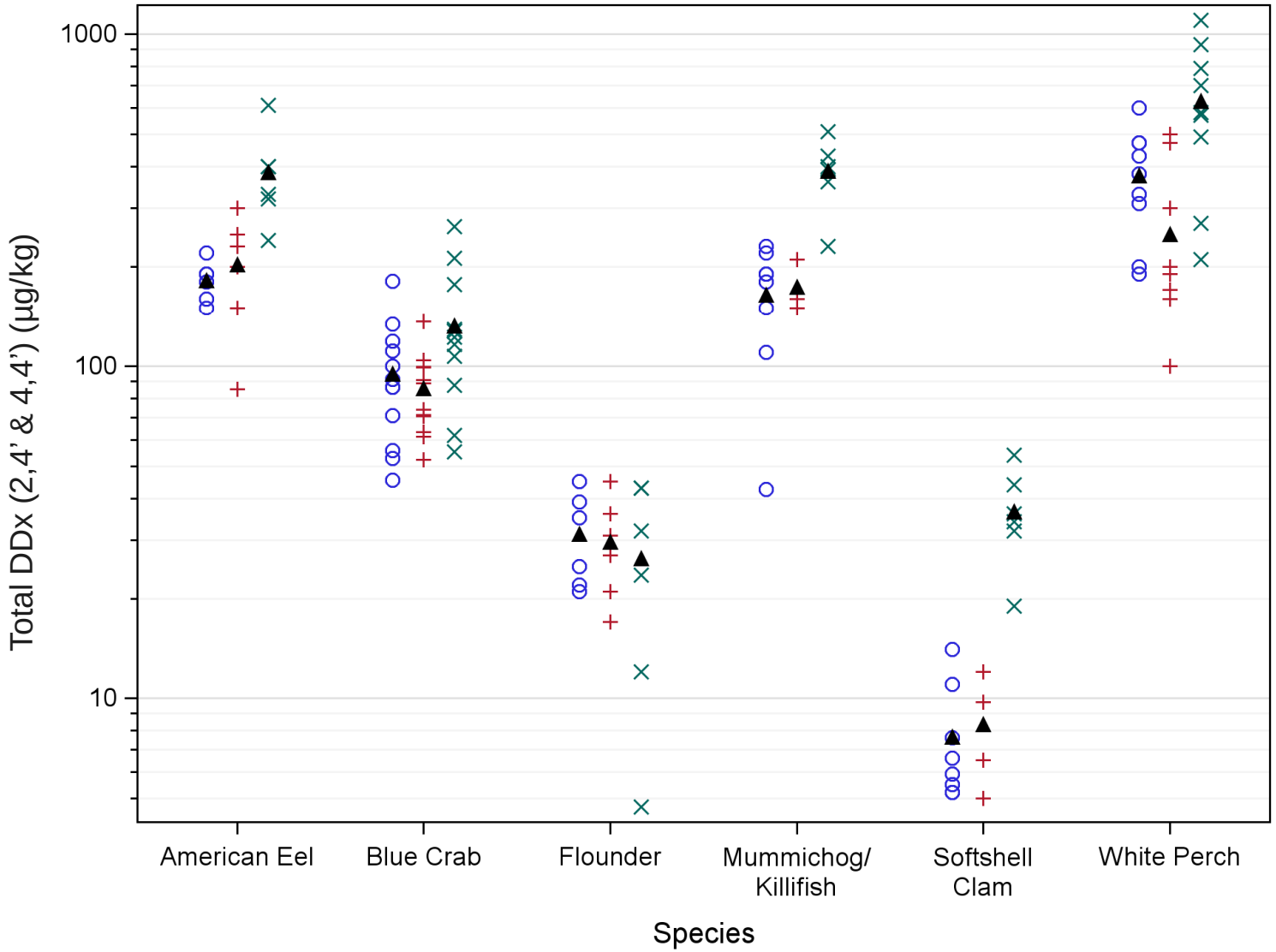
Assessment Zone
- North
- Southeast
- Southwest
- **MEAN**

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CONCENTRATIONS OF TOTAL PCB CONGENERS IN WHOLE BODY TISSUE BY SPECIES AND ASSESSMENT ZONE

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FIGURE
4-37



Notes:
All values are detected. There were no non-detect results.
Only whole body tissue concentrations are shown.
Flounder includes both summer and winter flounder species. Assessment zones are shown on Figure 4-35.
DDx= sum of dichlorodiphenyldichloroethane, dichlorodiphenyldichloroethylene, and dichlorodiphenyltrichloroethane
µg/kg = microgram per kilogram

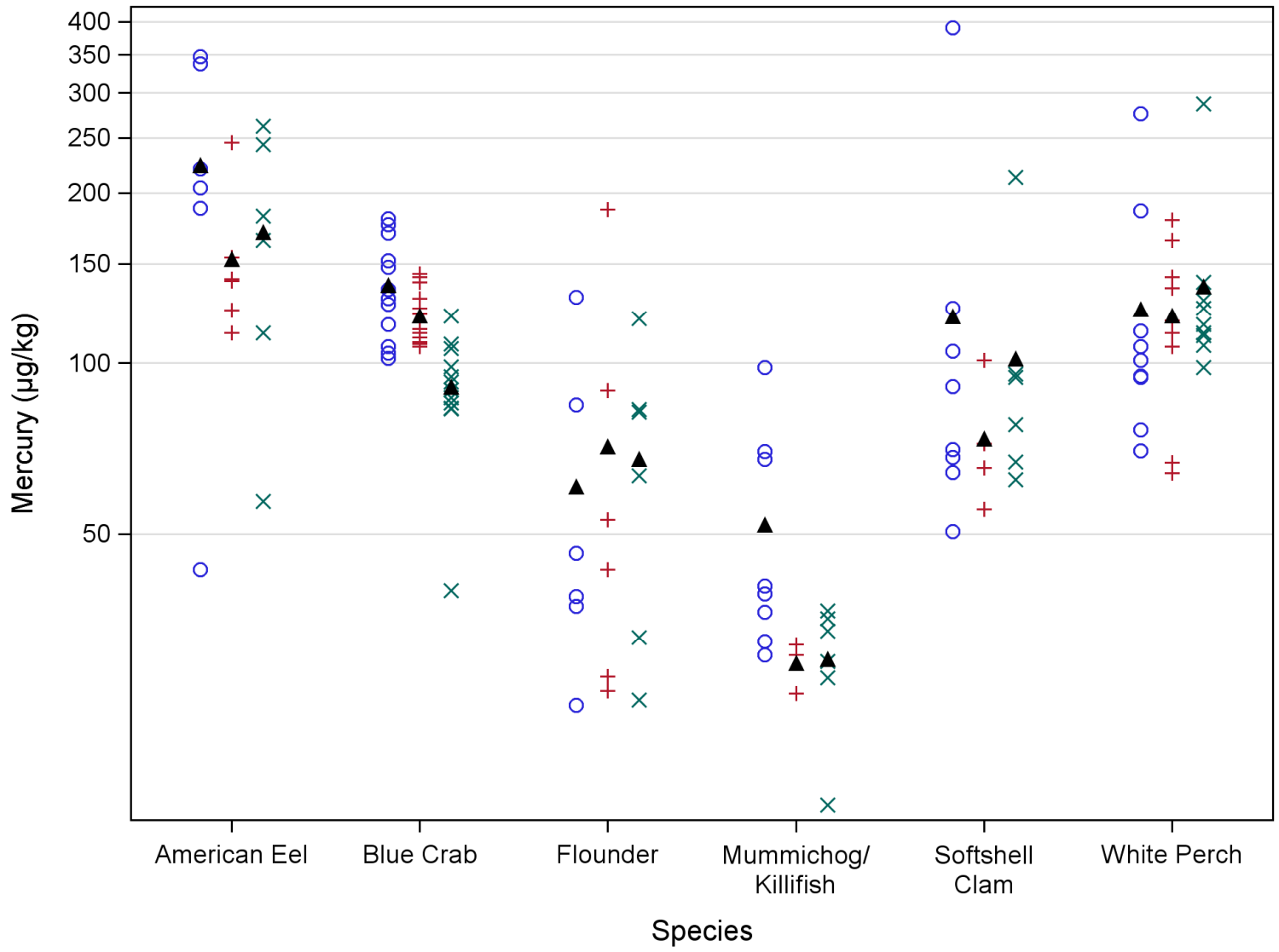
Assessment Zone
- North
- Southeast
- Southwest
- **MEAN**

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CONCENTRATIONS OF TOTAL DDX (2,4' AND 4,4') IN WHOLE BODY TISSUE BY SPECIES AND ASSESSMENT ZONE

OXY Glenn Springs Holdings, Inc.
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FIGURE
4-38



Notes:
All values are detected. There were no non-detect results.
Only whole body tissue concentrations are shown. Flounder includes both summer and winter flounder species.
Assessment zones are shown on Figure 4-35.
µg/kg = microgram per kilogram

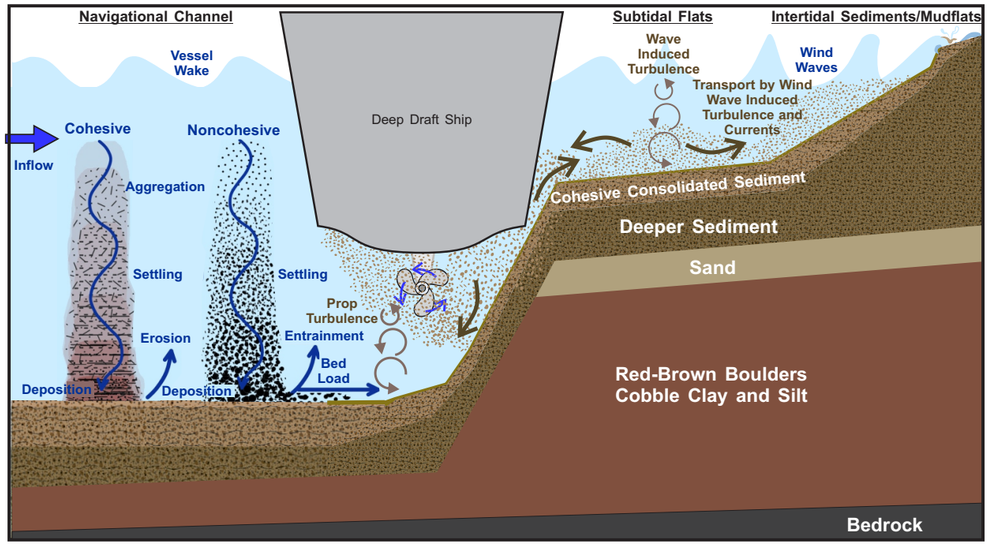
Assessment Zone
- North
- Southeast
- Southwest
- **MEAN**

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

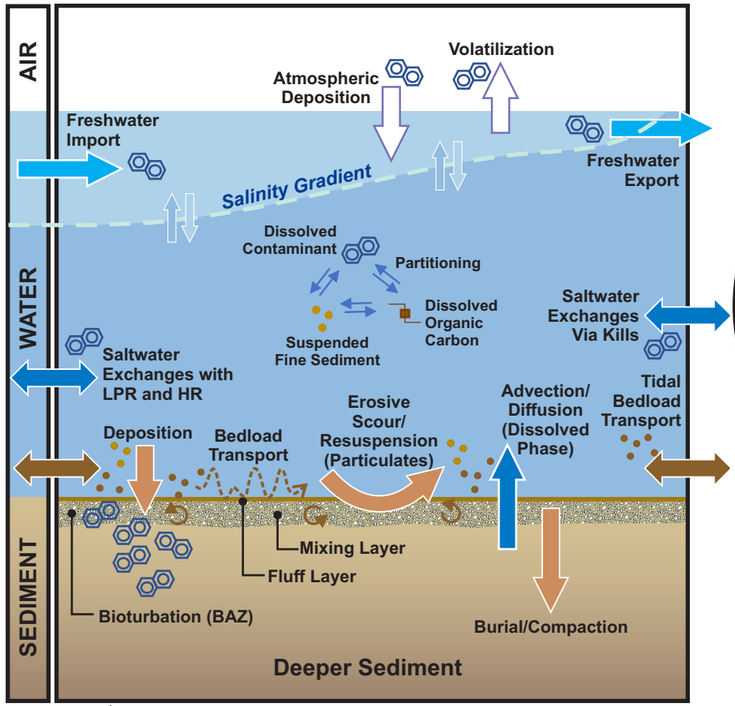
CONCENTRATIONS OF MERCURY IN WHOLE BODY TISSUE BY SPECIES AND ASSESSMENT ZONE

OXY Glenn Springs Holdings, Inc.
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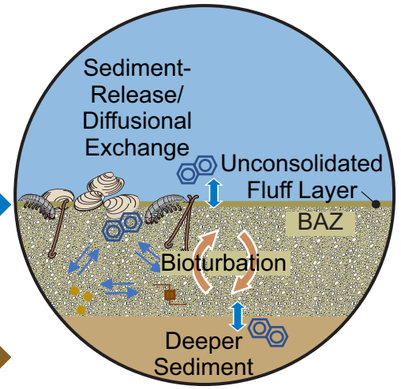
FIGURE
4-39



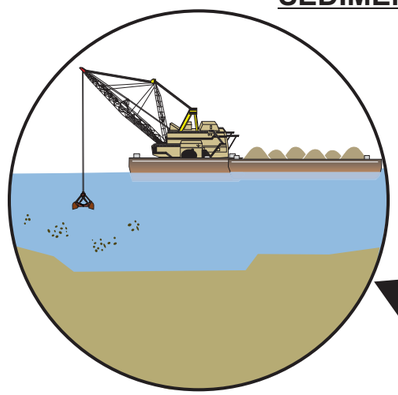
SEDIMENT TRANSPORT PROCESSES - INSET B



PHYSICAL PROCESSES - INSET A

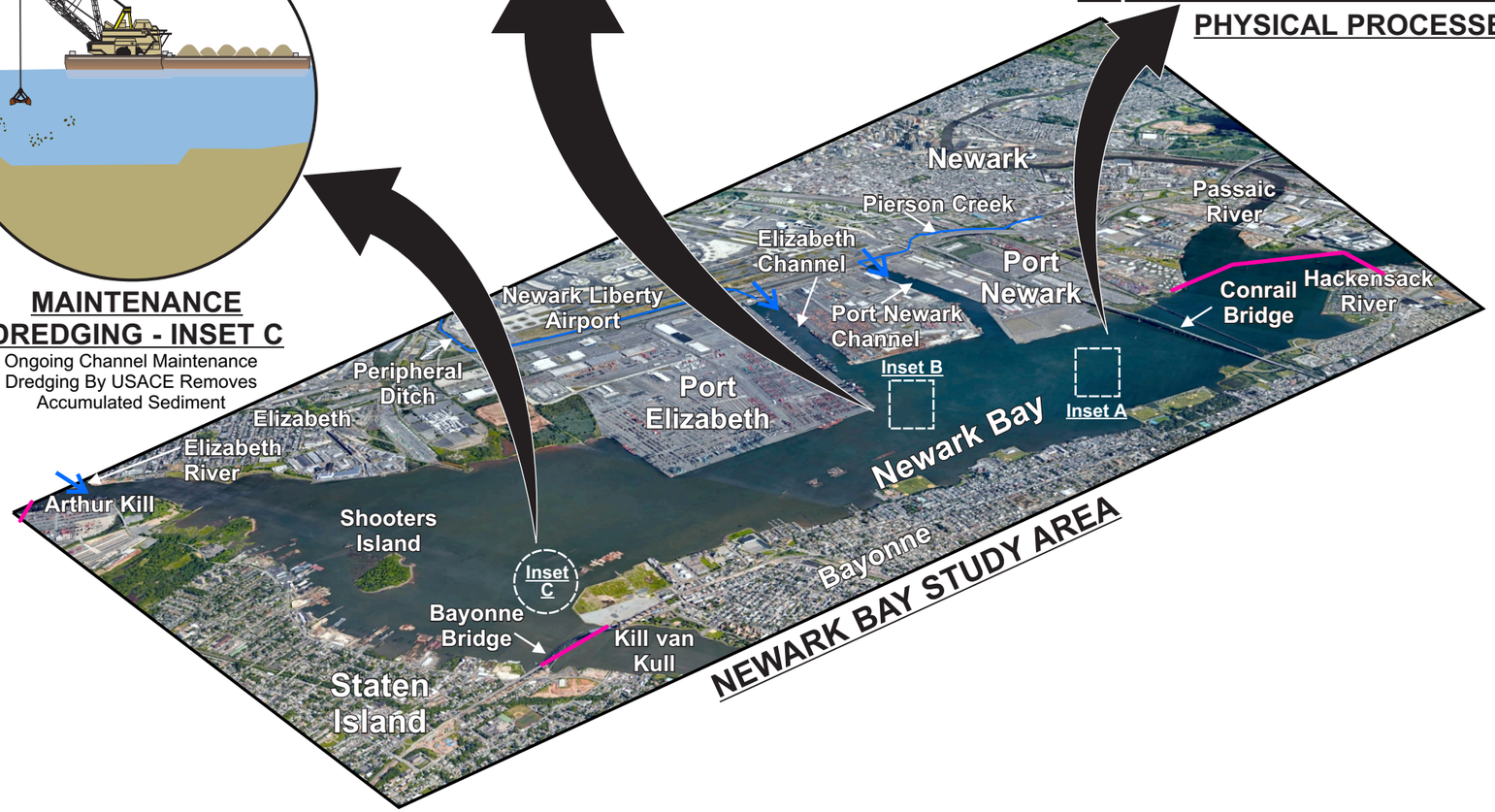


BIOLOGICALLY ACTIVE ZONE (BAZ) - INSET A-A



MAINTENANCE DREDGING - INSET C

Ongoing Channel Maintenance Dredging By USACE Removes Accumulated Sediment



Legend:

NBSA Boundaries

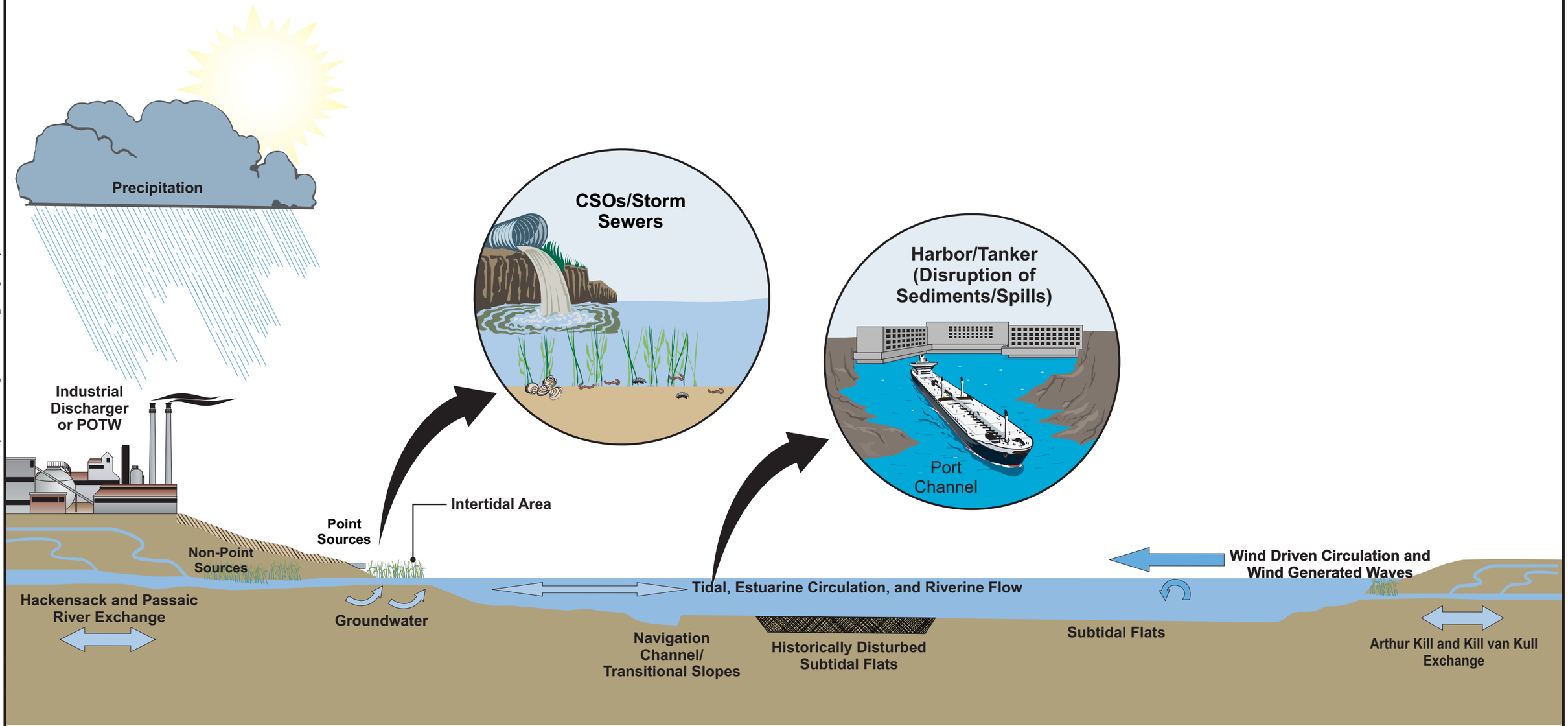
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

NEWARK BAY STUDY AREA
KEY FATE AND TRANSPORT PROCESSES SUMMARY

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FIGURE
5-CFT

12/17/2020 SYRACUSE, NY - K.SARTORI/W.BERNDGEN
ANA - OXY USA INC\NEWARK BAY - RI_RA_FS PROGRAM\2020\30061415\01-DWG\NB_RIR-Fig5-1-DEC2020.CDR



Notes:
1. The relative importance of the sources of COPCs shown on this figure is discussed in detail in Section 5.3.
2. While the contribution of each of the sources shown has not been quantified, the Newark Bay RI/FS Model results discussed in Section 5.4.7 (and shown on associated figures) provide insight on the relative importance of sources and losses to the Bay.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

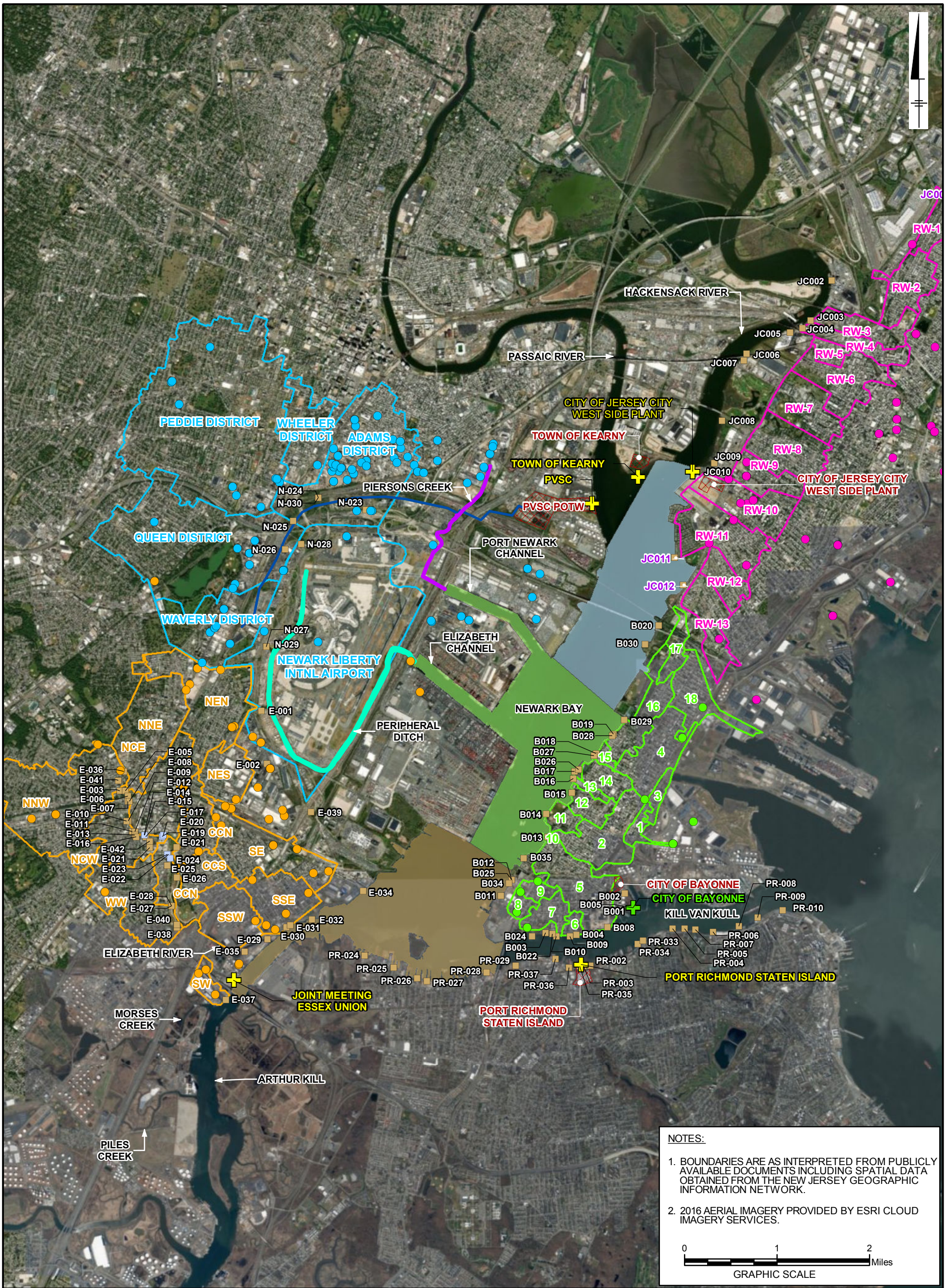
SOURCES OF COPCs

Glenn Springs Holdings, Inc.
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FIGURE
5-SC-1

12/17/2020 SYRACUSE, NY - K.SARTORI/W.BERNDGEN
C:\BIM\OneDrive - ARCADIS\BIM360 - OneDrive Sync Location\AUS-OXY USA-DIAMOND ALKALI SUPERFUND-NEWARK New Jersey\2022\01-In Progress\01-DWG\NB_RIR-Fig5-2-May 2022.cdr

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: kgpeters
Project (B0009989.0045.00002)
Z:\GISProjects_ENV\GSH\GIS\Task\NBSA\CSM\mxd\Figure_5-3_CSO_POTW_SIU_ofCOPCinNB.mxd 3/29/2019 12:13:00 PM



NOTES:

1. BOUNDARIES ARE AS INTERPRETED FROM PUBLICLY AVAILABLE DOCUMENTS INCLUDING SPATIAL DATA OBTAINED FROM THE NEW JERSEY GEOGRAPHIC INFORMATION NETWORK.
2. 2016 AERIAL IMAGERY PROVIDED BY ESRI CLOUD IMAGERY SERVICES.

0 1 2 Miles
GRAPHIC SCALE

LEGEND:

- BAYONNE SIU LOCATION
- ELIZABETH SIU LOCATION
- JERSEY CITY SIU LOCATION
- NEWARK SIU LOCATION
- ACTIVE CSO
- INACTIVE CSO
- PUMP STATION OUTFALL
- POTW OUTFALL
- PERIPHERAL DITCH
- PIERSON'S CREEK
- PVSC SOUTHSIDE INTERCEPTOR
- BAYONNE CSO DISTRICT
- JERSEY CITY CSO DISTRICT
- ELIZABETH CSO DISTRICT
- NEWARK CSO DISTRICT
- POTW AND/OR PUMP STATION LOCATION

NBSA GEOGRAPHIC AREAS:

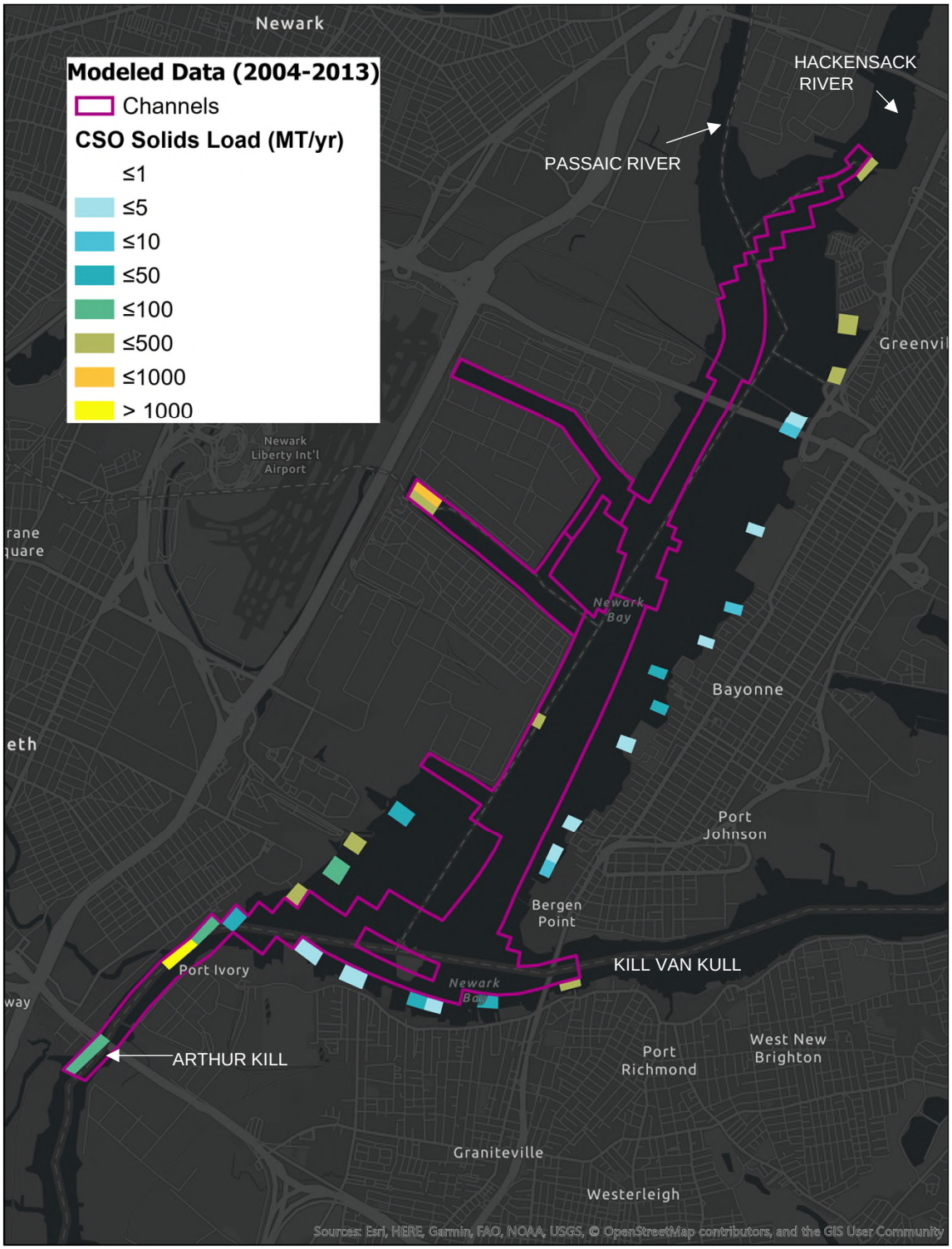
- NEWARK BAY NORTH
- NEWARK BAY CENTRAL
- NEWARK BAY SOUTH

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CSO, POTW, AND SIU SOURCES OF COPCs IN NEWARK BAY

Glenn Springs Holdings, Inc.
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FIGURE
5-SC-2



Notes:
CSO = combined sewer overflow

Results represent values computed by the NBSA RI/FS model and provided by HDR.

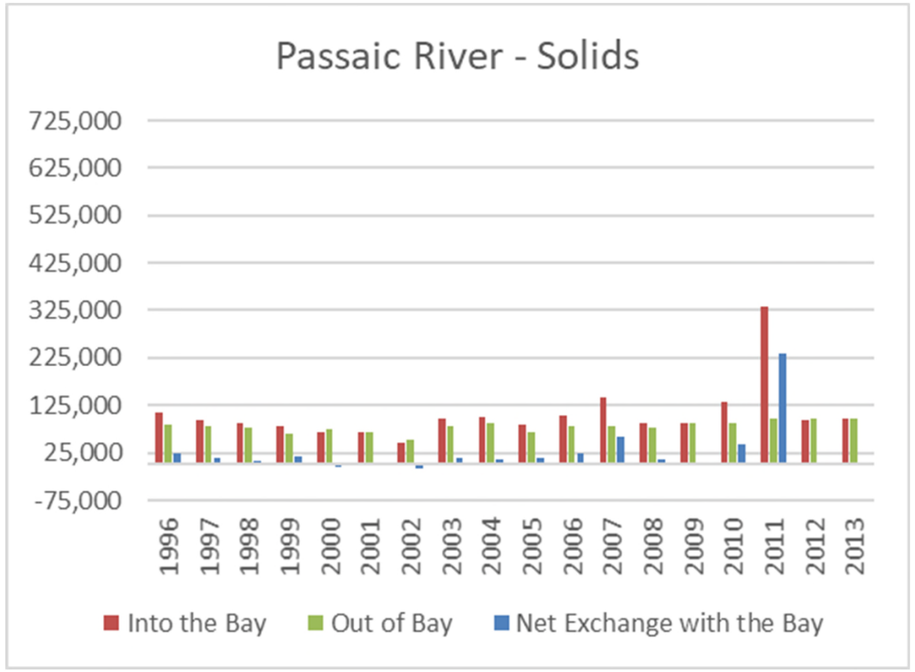
Cell level model results report annual average CSO solids load and were extracted through post-processing of the model output files. Model outputs and post-processing routines were provided by HDR in December 2018 and updated in December 2020.

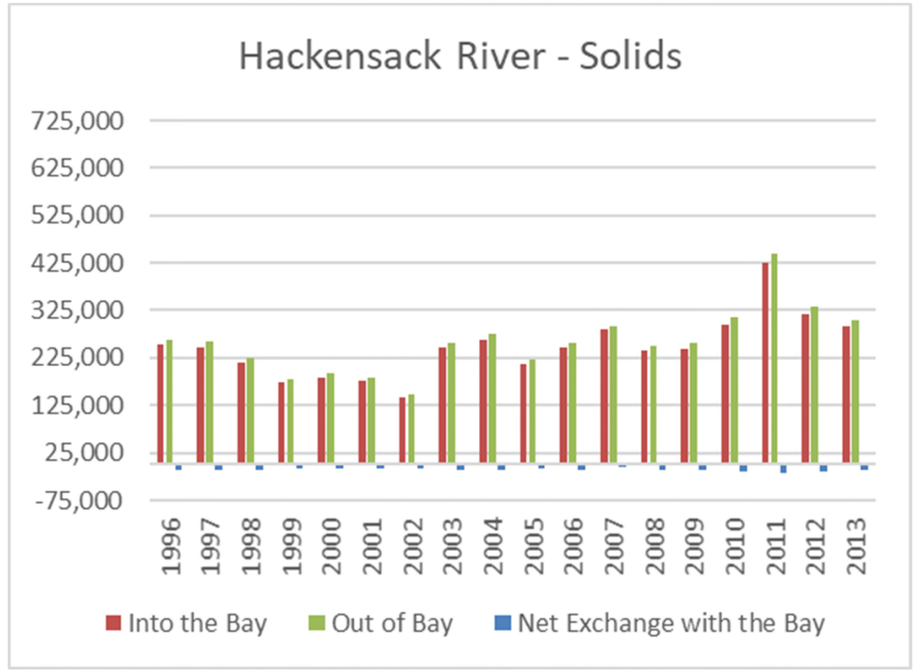
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

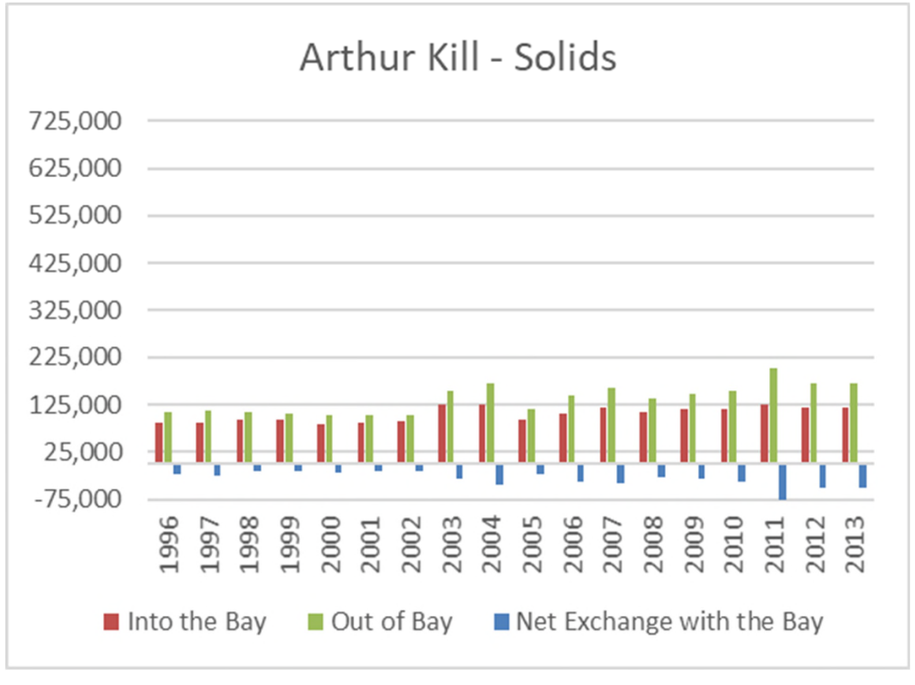
MODELED 2004-2013 COMBINED SEWER OVERFLOW SOLIDS LOAD

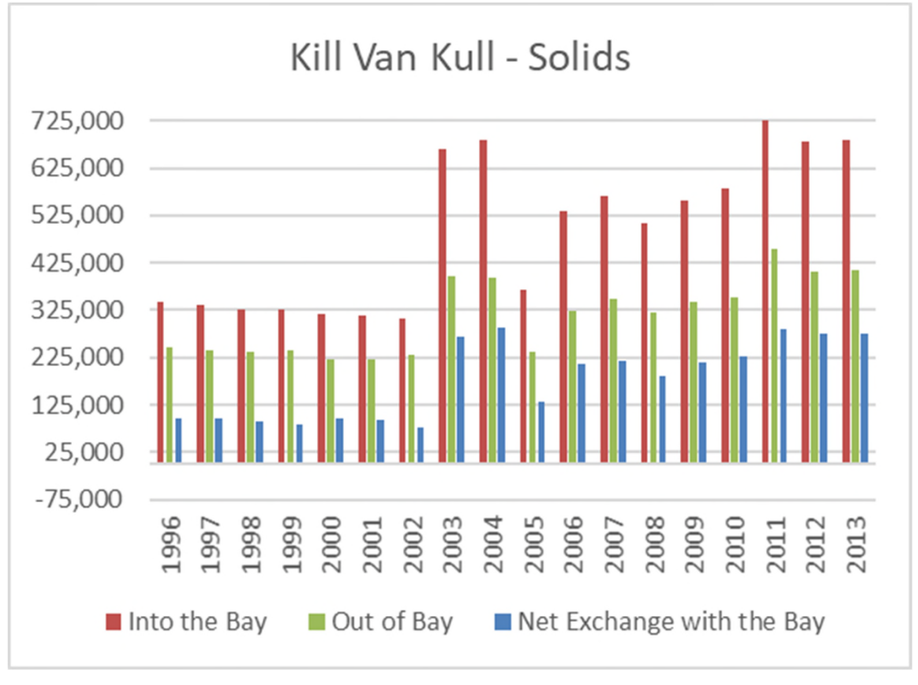
Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-1









Notes:
Total flux for 1996-2013.

Negative values indicate losses from Newark Bay.

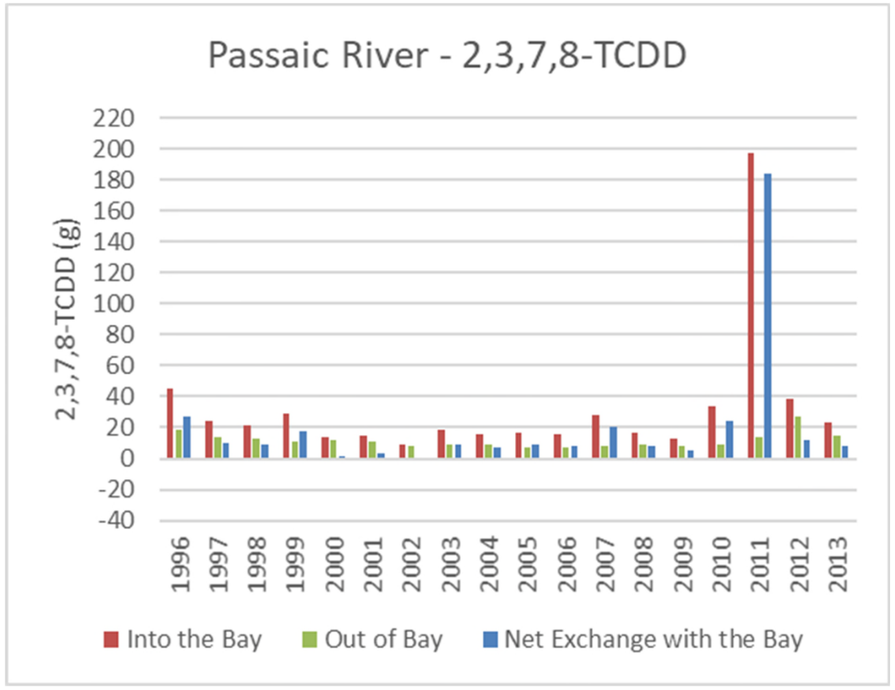
Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR.

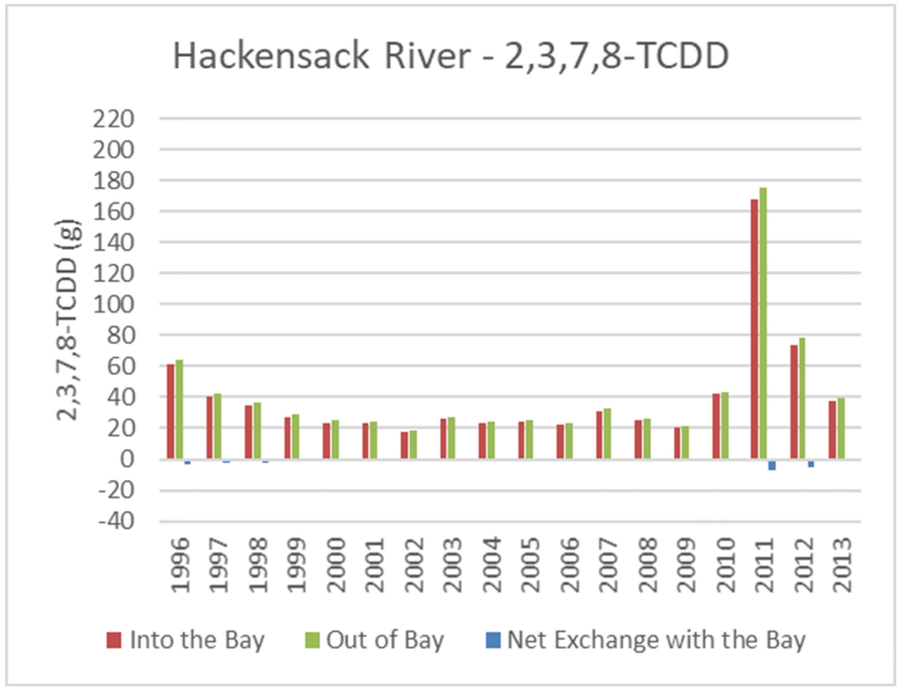
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

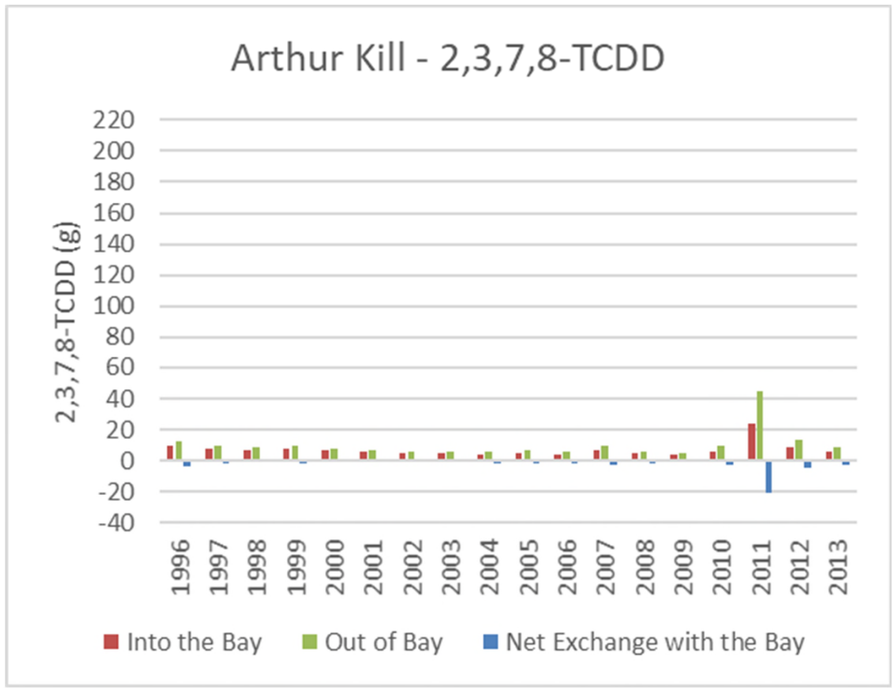
MODELED 1996-2013 ANNUAL SOLIDS FLUX BETWEEN NBSA AND CONNECTED WATERWAYS

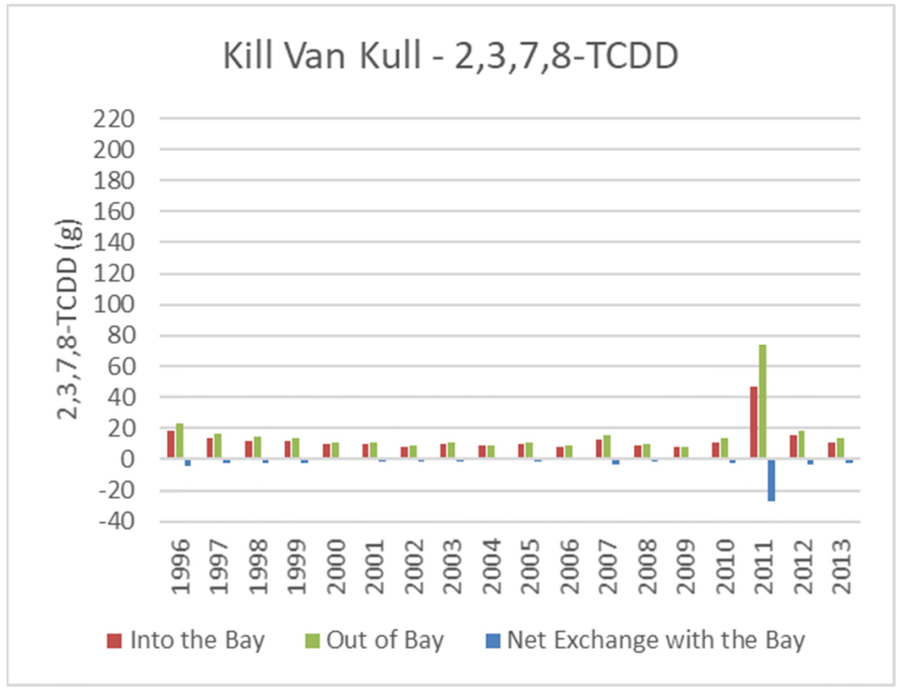
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-MOD-2A









Notes:
Total flux for 1996-2013.

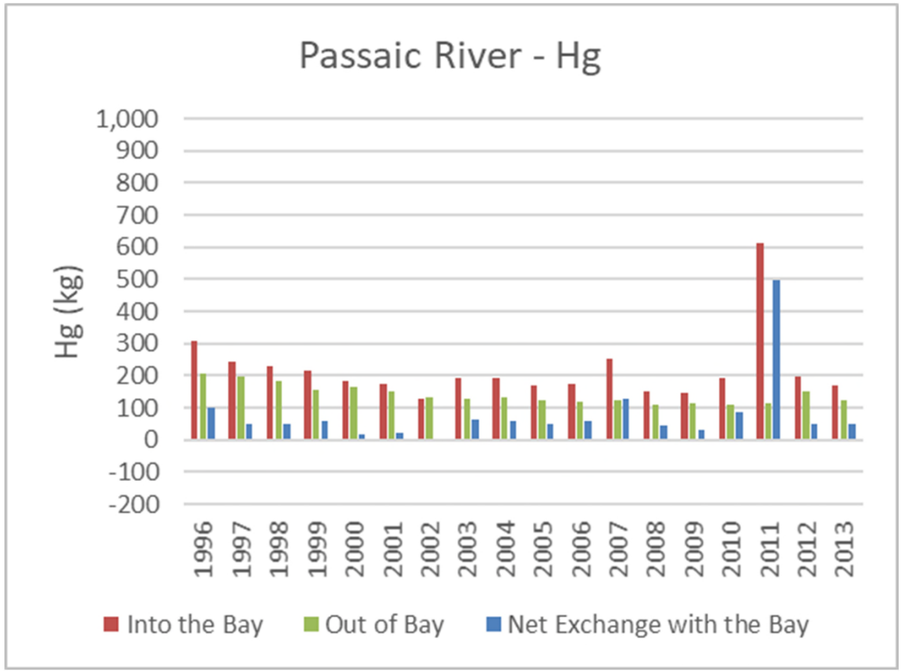
Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR.

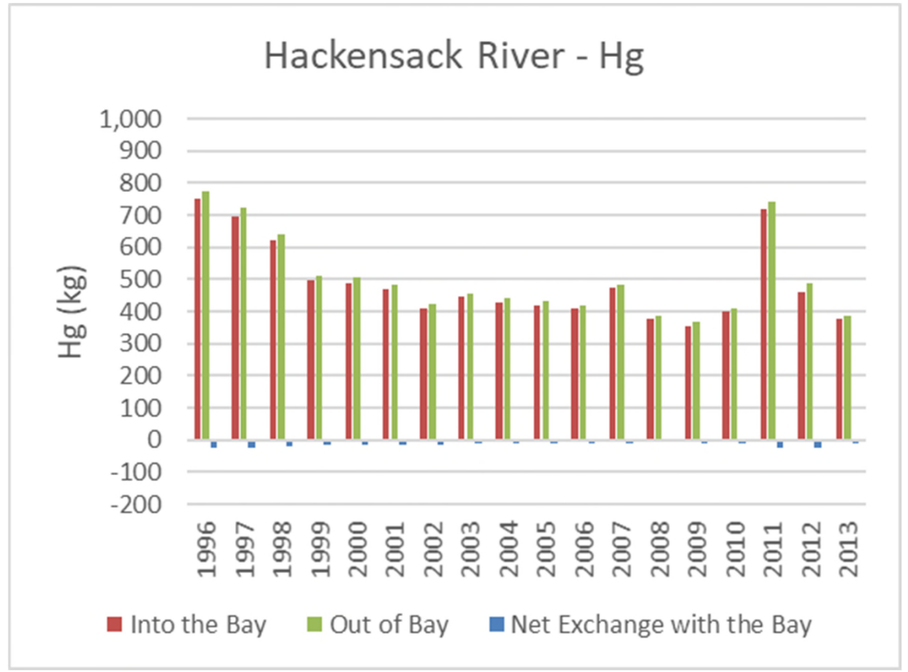
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

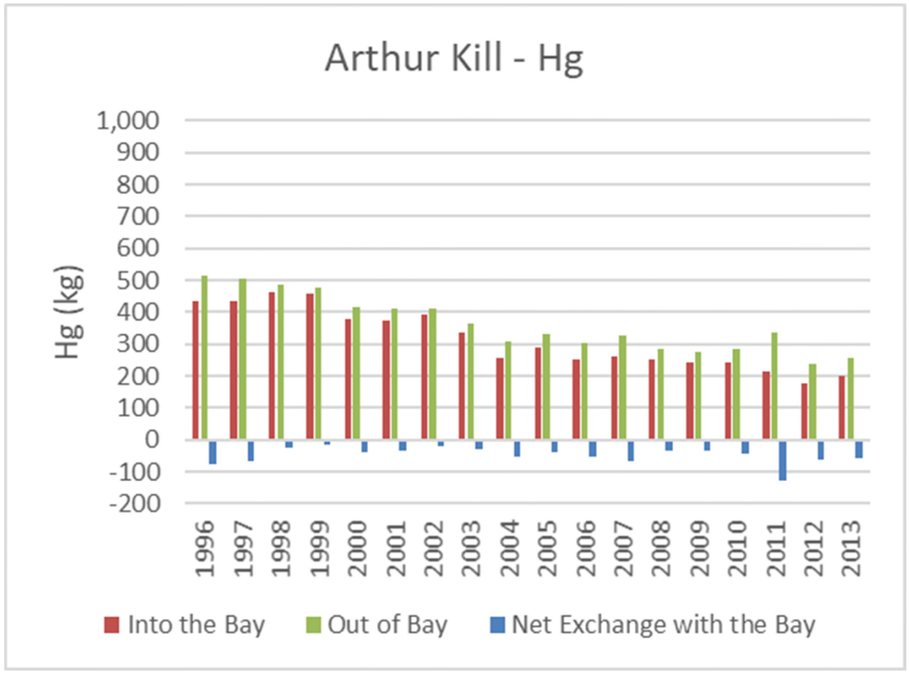
MODELED 1996-2013 ANNUAL 2,3,7,8-TCDD MASS FLUX BETWEEN NBSA AND CONNECTED WATERWAYS

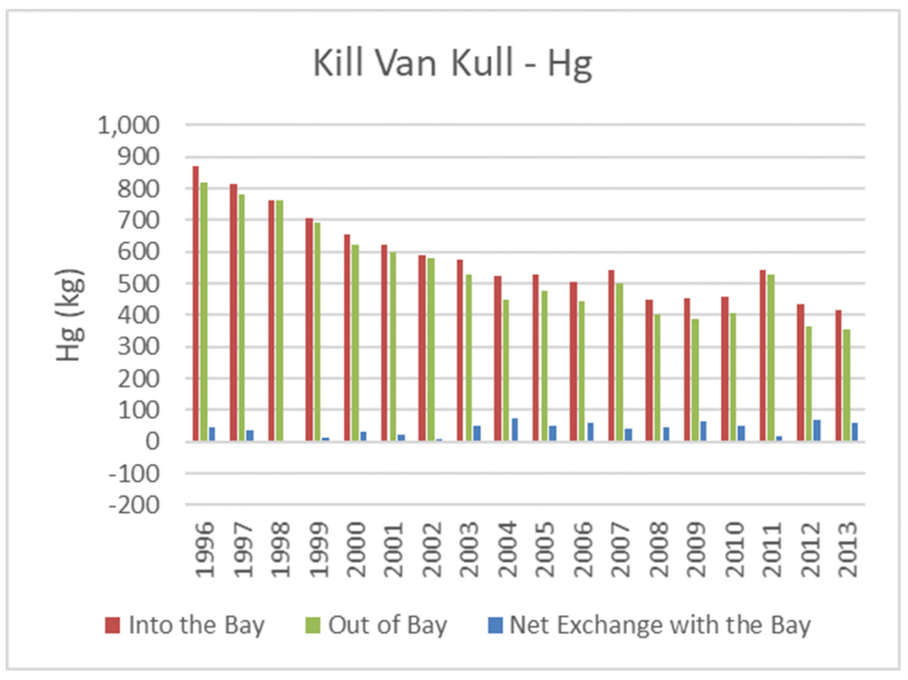
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-MOD-2B









Notes:
Total flux for 1996-2013.

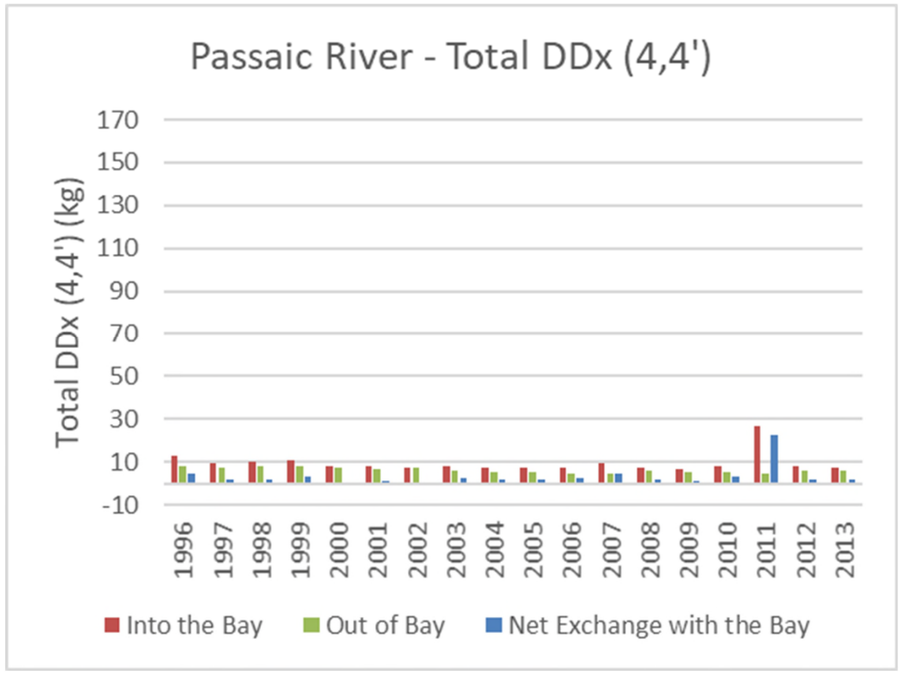
Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR.

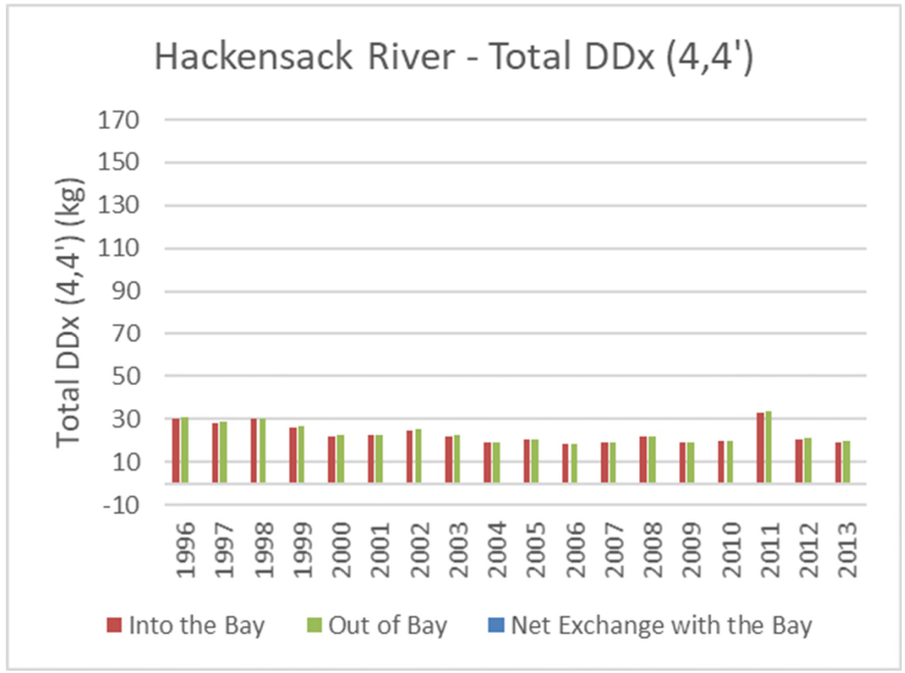
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

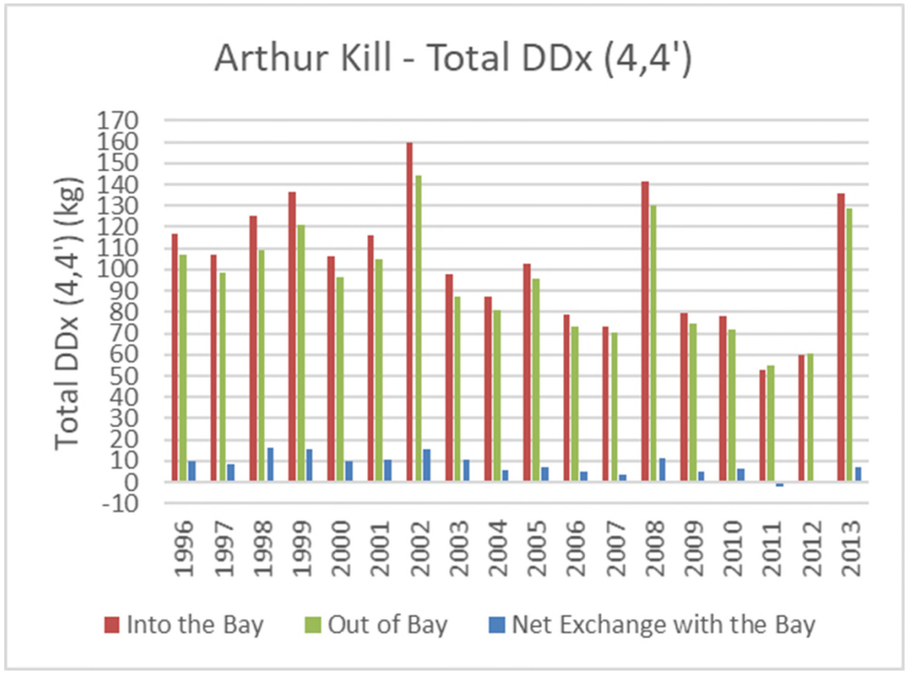
MODELED 1996-2013 ANNUAL MERCURY MASS FLUX BETWEEN NBSA AND CONNECTED WATERWAYS

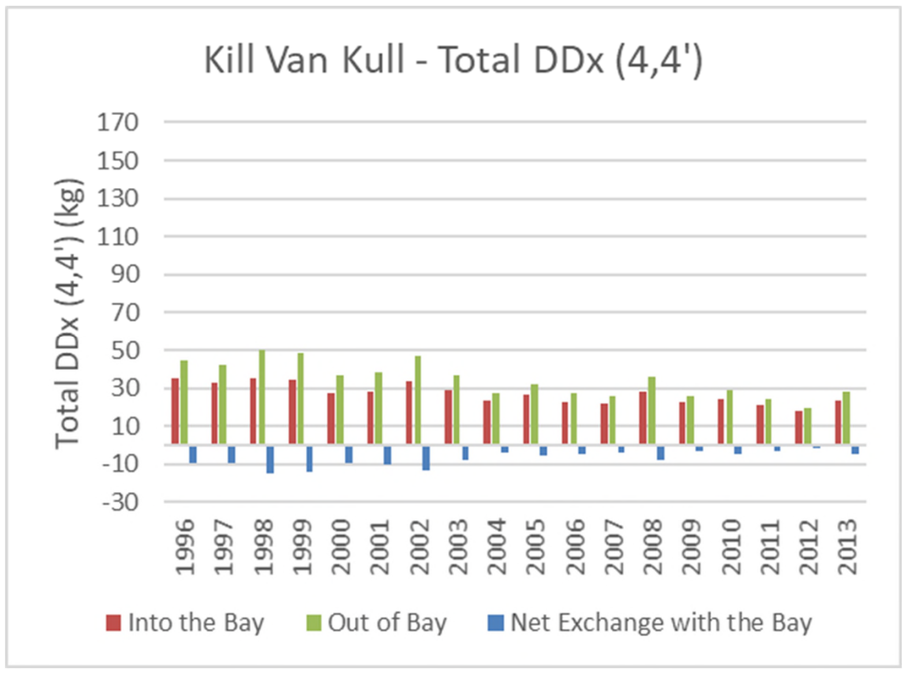
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-MOD-2C









Notes:
Total flux for 1996-2013.

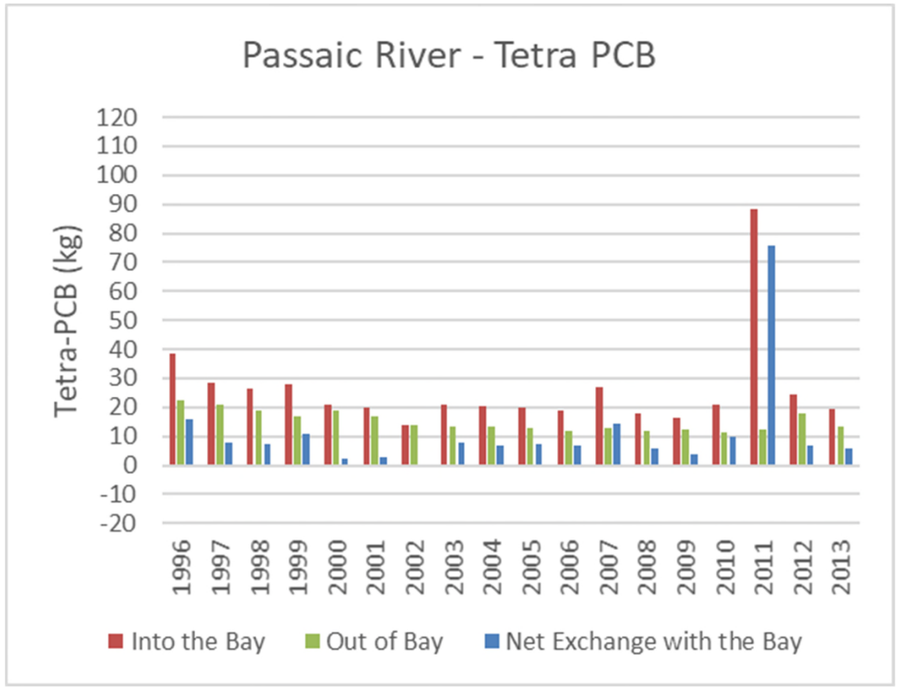
Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR.

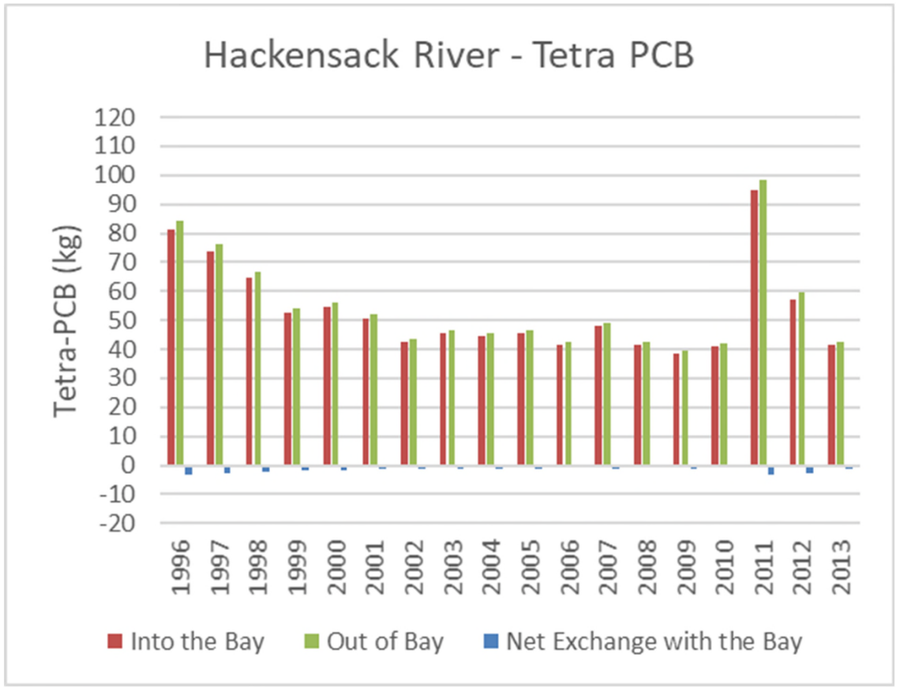
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

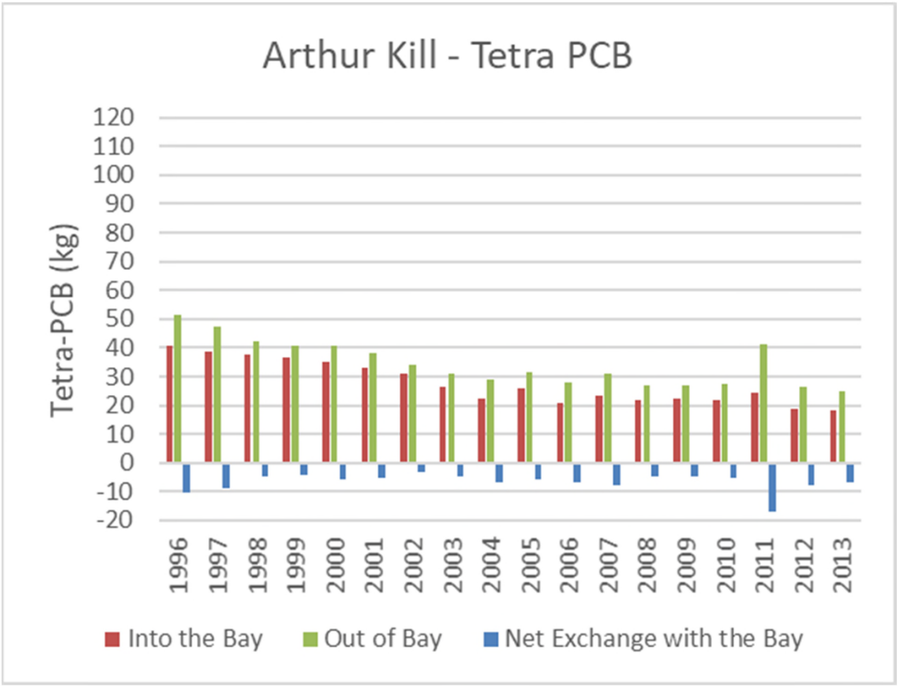
MODELED 1996-2013 ANNUAL TOTAL DDX (4,4') MASS FLUX BETWEEN NBSA AND CONNECTED WATERWAYS

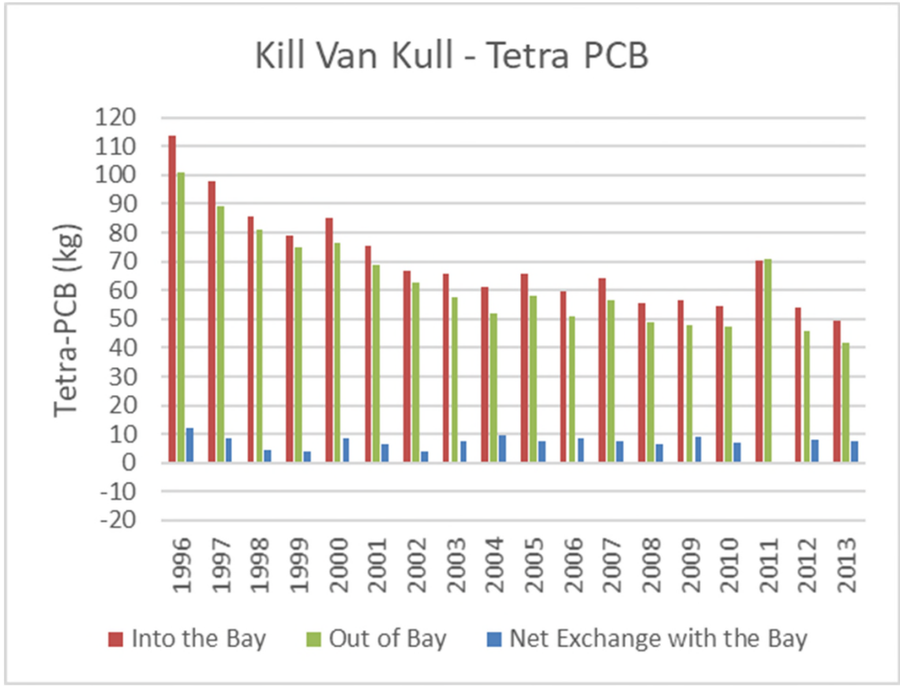
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-MOD-2D









Notes:
Total flux for 1996-2013.

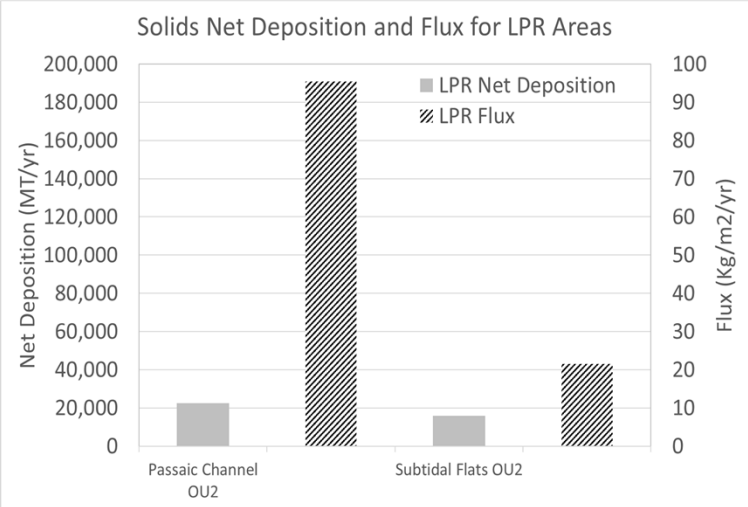
Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR.

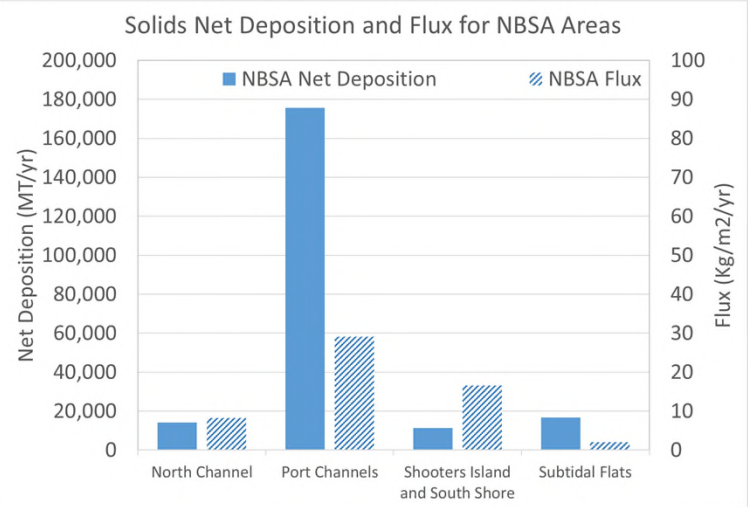
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

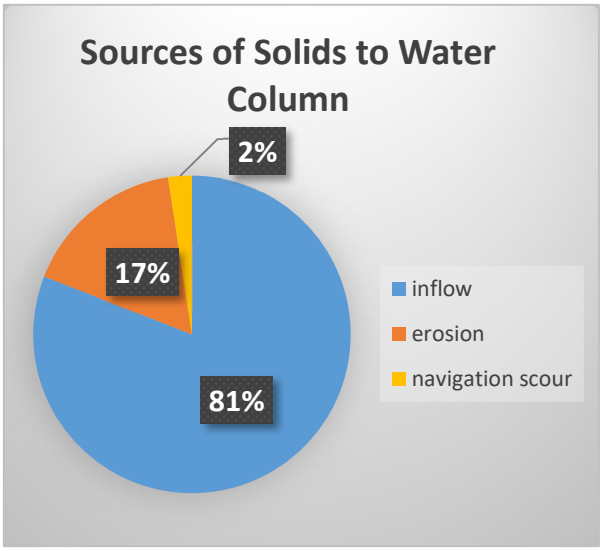
MODELED 1996-2013 ANNUALTETRA-PCB MASS FLUX IN THE WATER COLUMN

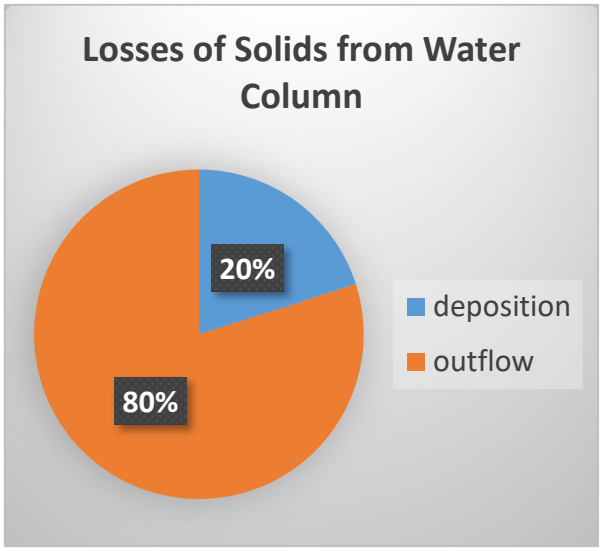
OXY Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-2E









Notes:
LPR = Lower Passaic River
MT/yr = metric ton per year

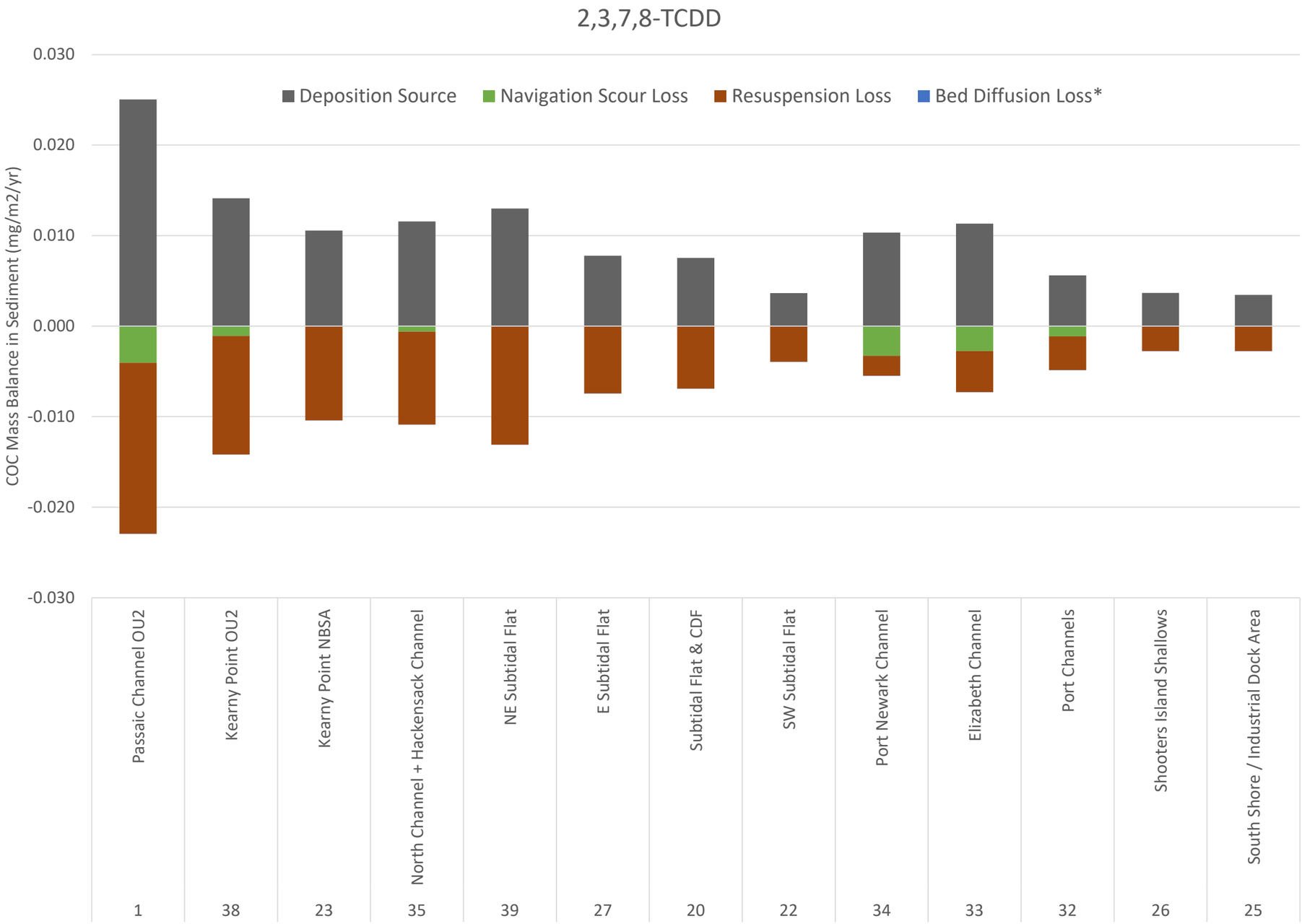
Area	km^2
Passaic Channel OU2	0.24
North Channel	1.72
Port Channels	6.04
Shooters Island and South Shore	0.68
Subtidal Flats	8.35
Subtidal Flats OU2	0.74

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED SOLIDS DEPOSITION AND WATER COLUMN SOURCES AND LOSSES
1996-2013

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
5-MOD-3



Notes:
Average annual results for 1996-2013.

Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR.

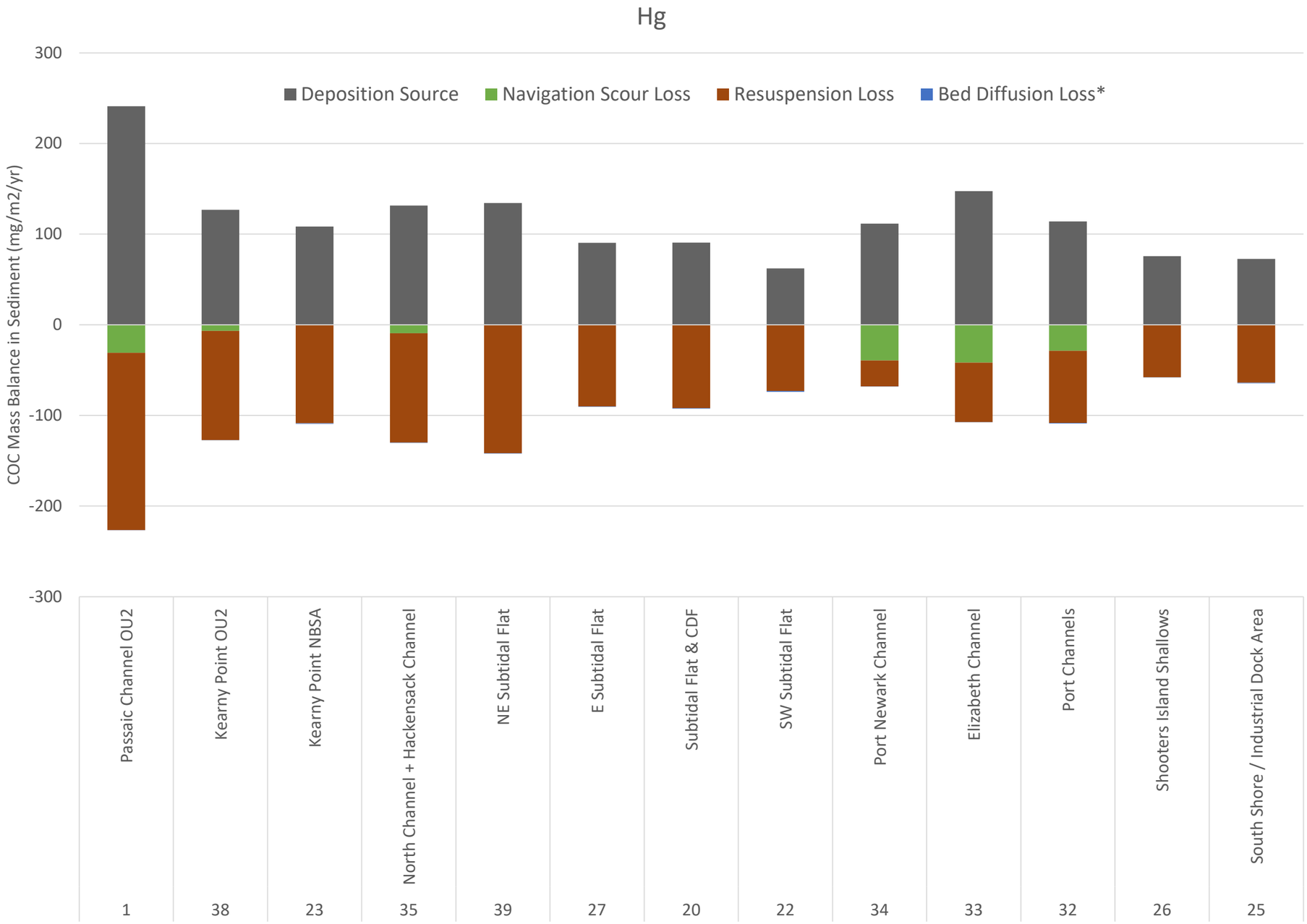
* Bed diffusion losses plotted but not visible due to scale.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 1996-2013 ANNUAL AVERAGE MASS BALANCE FOR 2,3,7,8-TCDD

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-4A



Notes:
Average annual results for 1996-2013.

Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR.

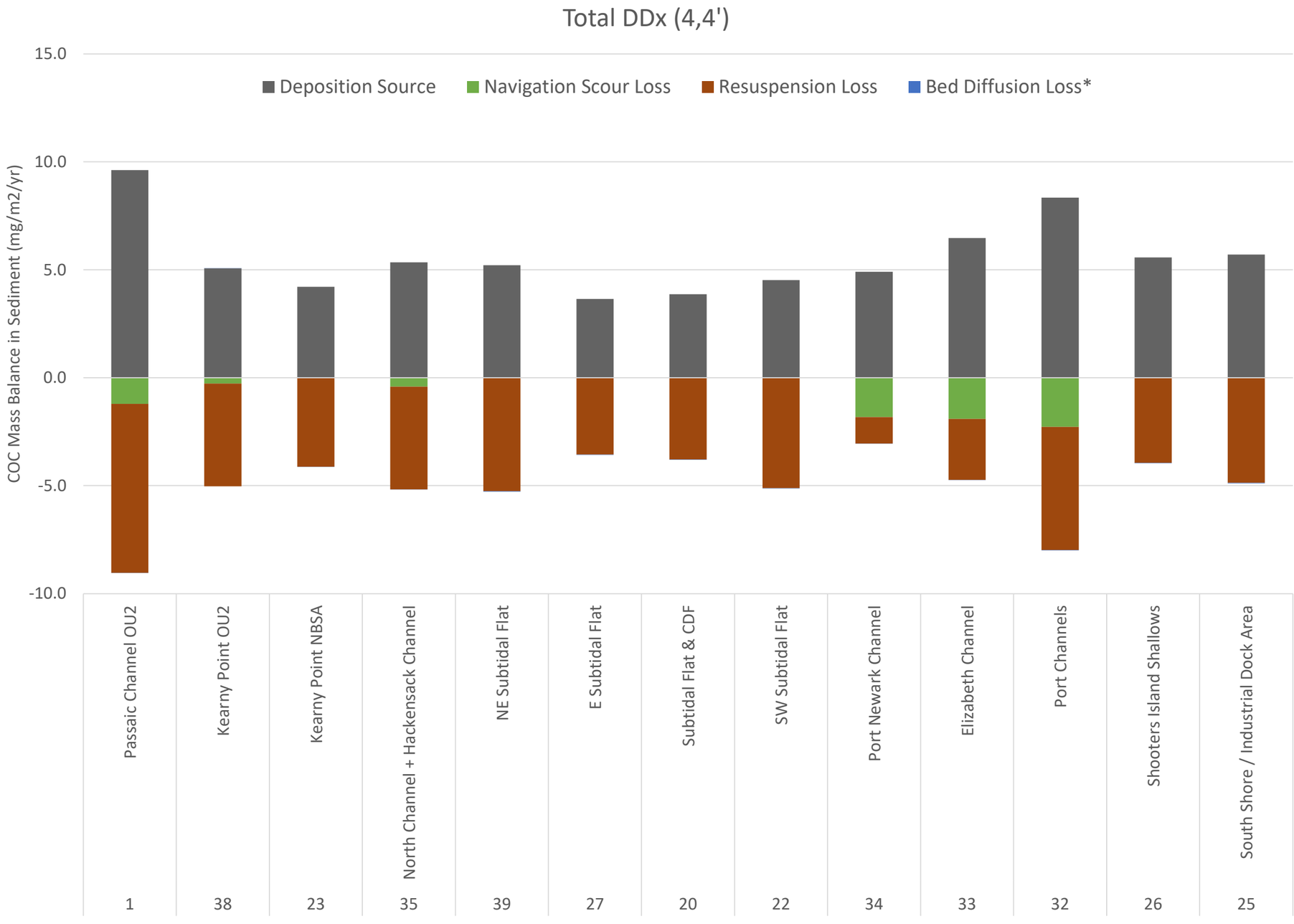
* Bed diffusion losses plotted but not visible due to scale.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 1996-2013 ANNUAL AVERAGE MASS BALANCE FOR MERCURY

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-MOD-4B



Notes:
Average annual results for 1996-2013.

Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR.

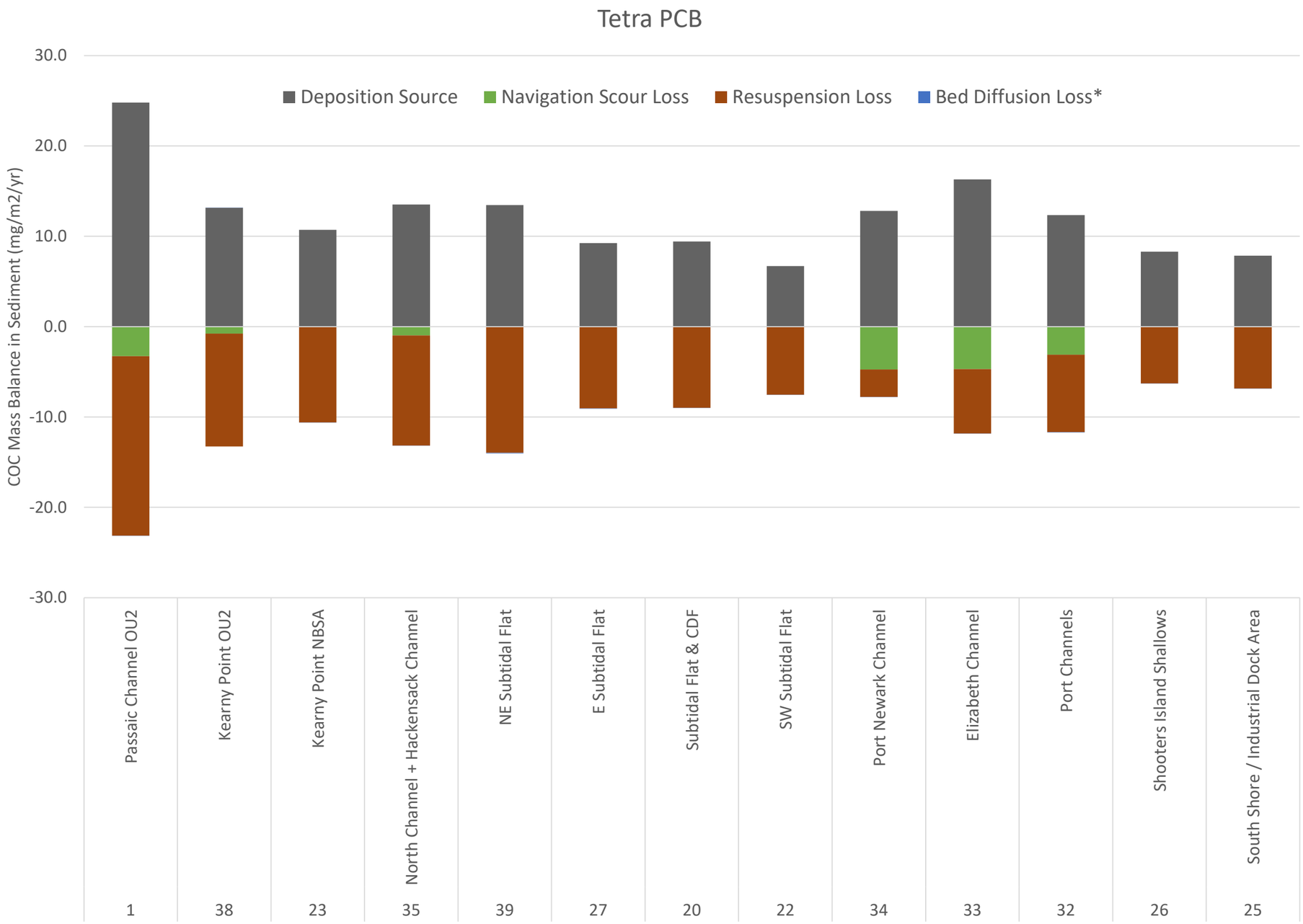
* Bed diffusion losses plotted but not visible due to scale.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 1996-2013 ANNUAL AVERAGE MASS BALANCE FOR TOTAL DDX (4,4')

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-4C



Notes:
Average annual results for 1996-2013.

Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR.

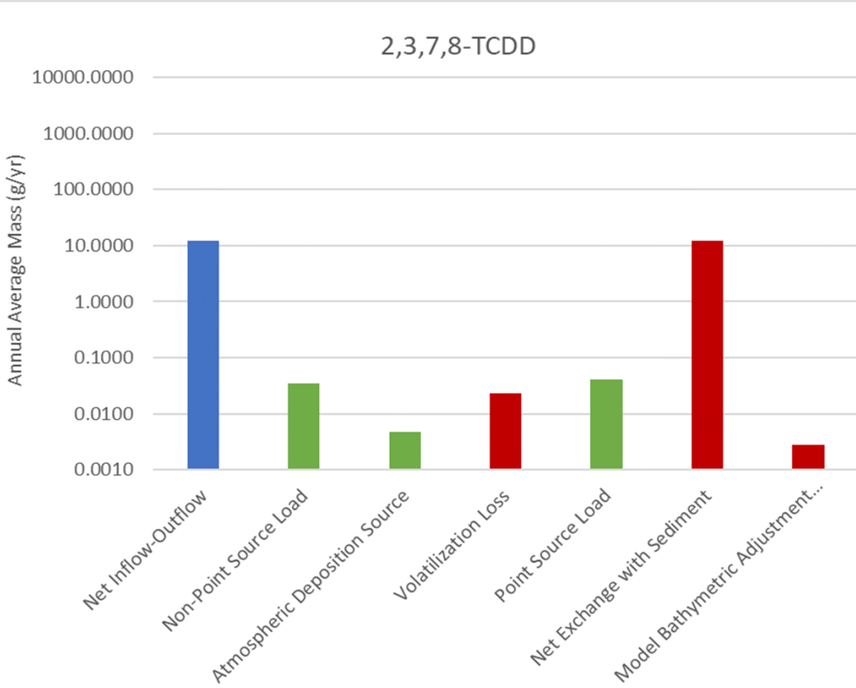
* Bed diffusion losses plotted but not visible due to scale.

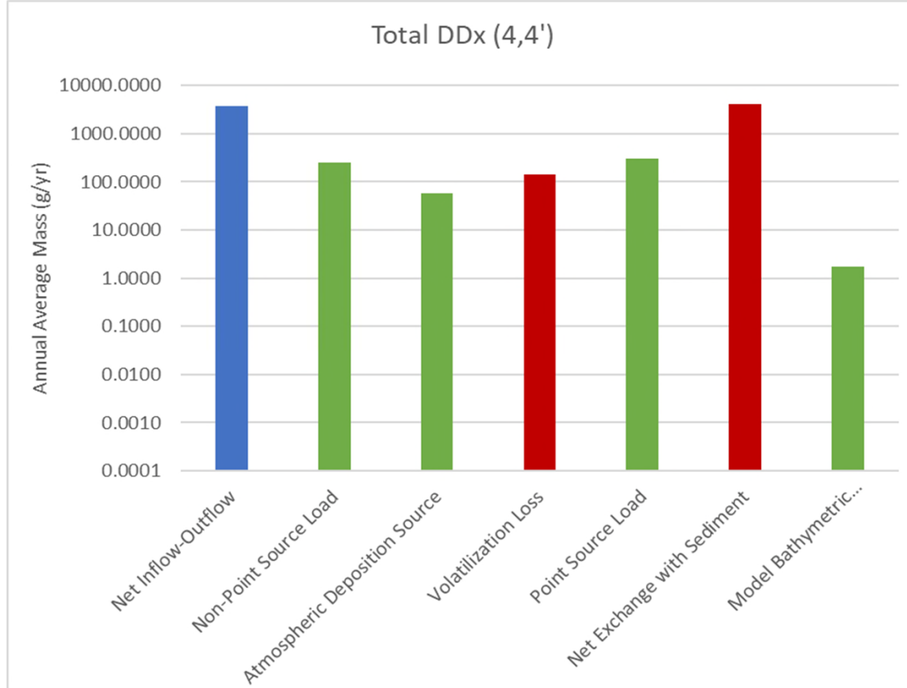
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

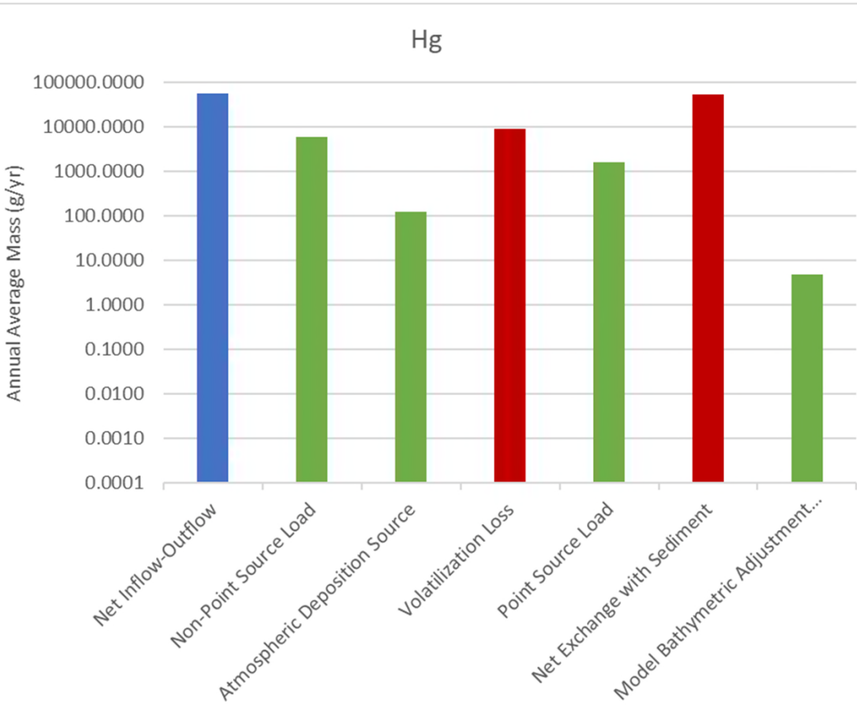
MODELED 1996-2013 ANNUAL AVERAGE MASS BALANCE FOR TETRA-PCB

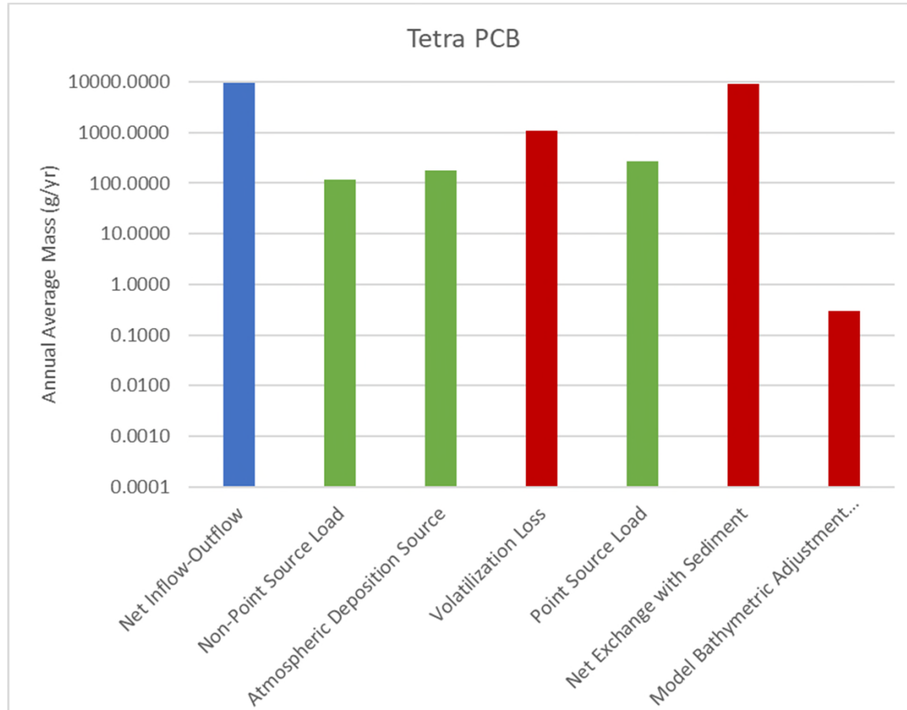
Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-4D









Legend:

- Sources
- Losses
- Total Net Flux

Notes:

Average annual results for 1996-2013.

Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR on 9/13/2021.

Numerical error corrections and initial and final mass differences are small magnitude additional values that are not illustrated on these charts for simplicity.

Model Bathymetric Adjustment refers to changes in mass introduced by changing water depths in response to sediment erosion or deposition (mass is added when the water depth is increased, and concentrations are not adjusted).

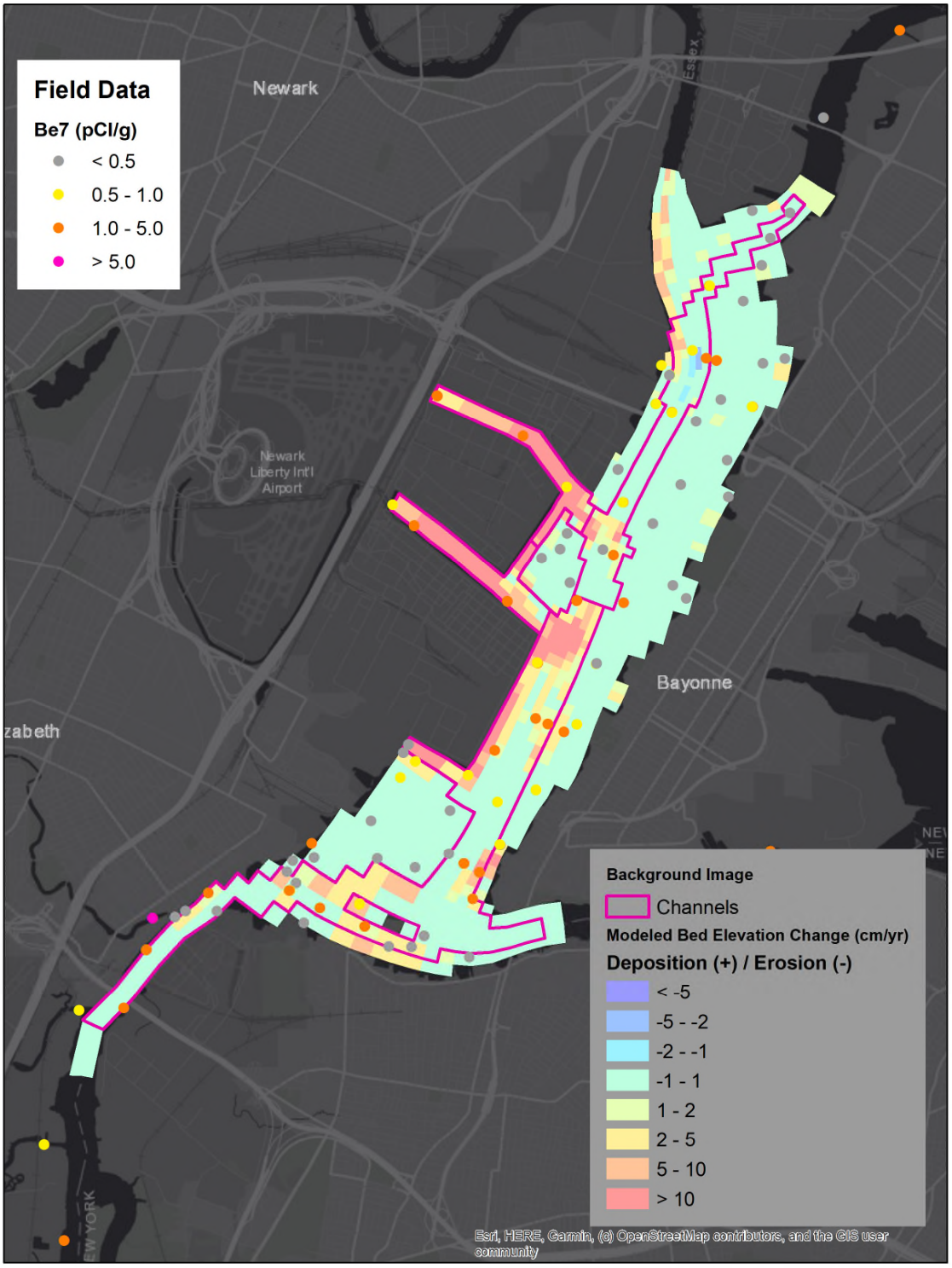
Net Exchange with Sediment represents: Deposition – (Resuspension+ Diffusion + Navigation Scour)

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

1996-2013 ANNUAL AVERAGE NBSA WATER COLUMN MASS BALANCE

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-5



Notes:
Background image is modeled annual bed elevation change for 2004-2013 computed by the NBSA RI/FS model.

Values less than 0.5 pCi/g are considered non-detects.

The Be-7 activities shown were reported in the data evaluation and analysis report (Tierra 2014).

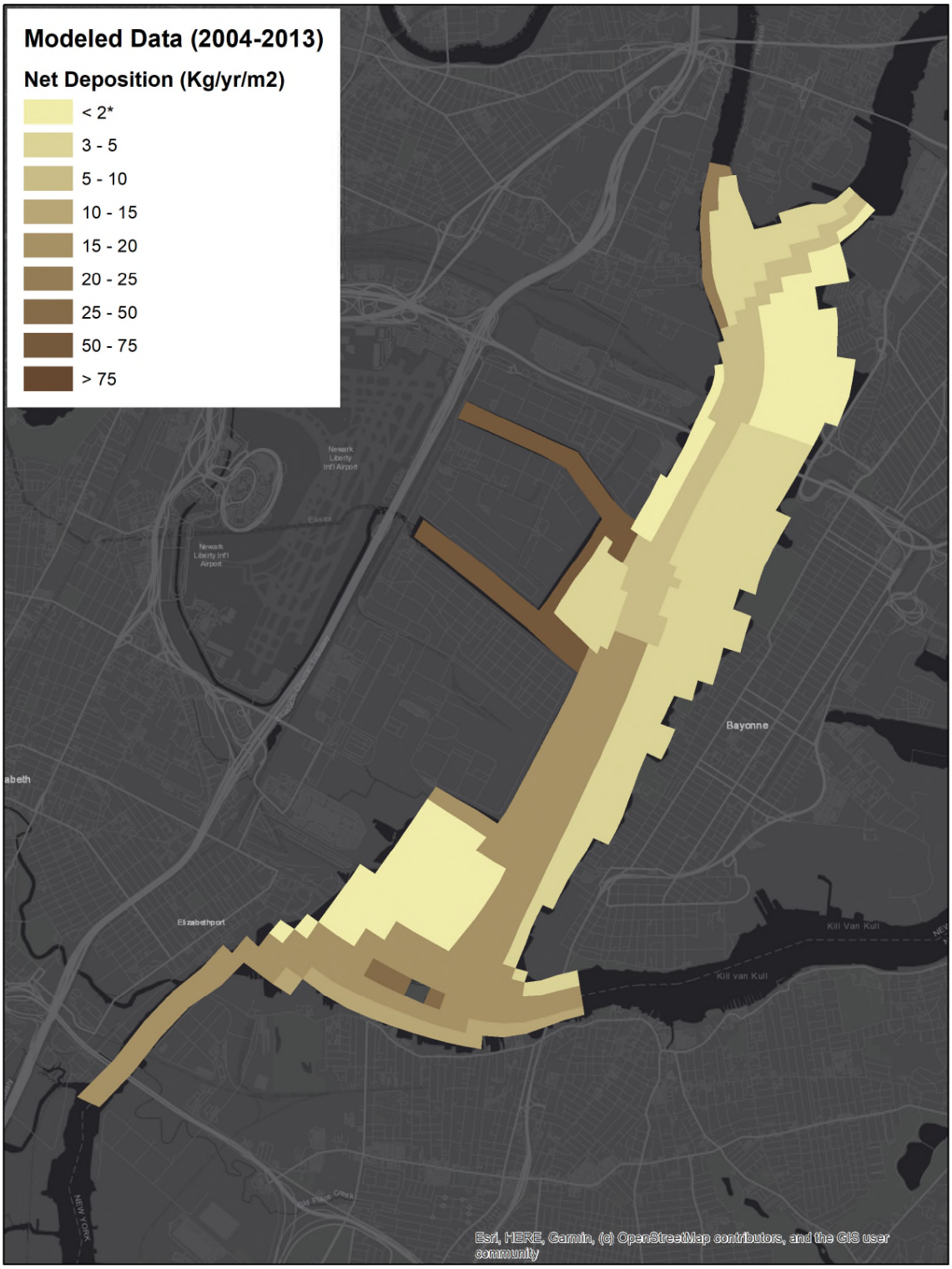
References:
Tierra. 2014. Phase I and Phase II Data Evaluation and Analysis Report. Newark Bay Study Area Remedial Investigation. Revision 2. September.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 2004-2013 BED ELEVATION CHANGES AND BE7 DATA

Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-6



Notes:
Results show modeled net average deposition for 2004-2013 computed by the NBSA RI/FS model.

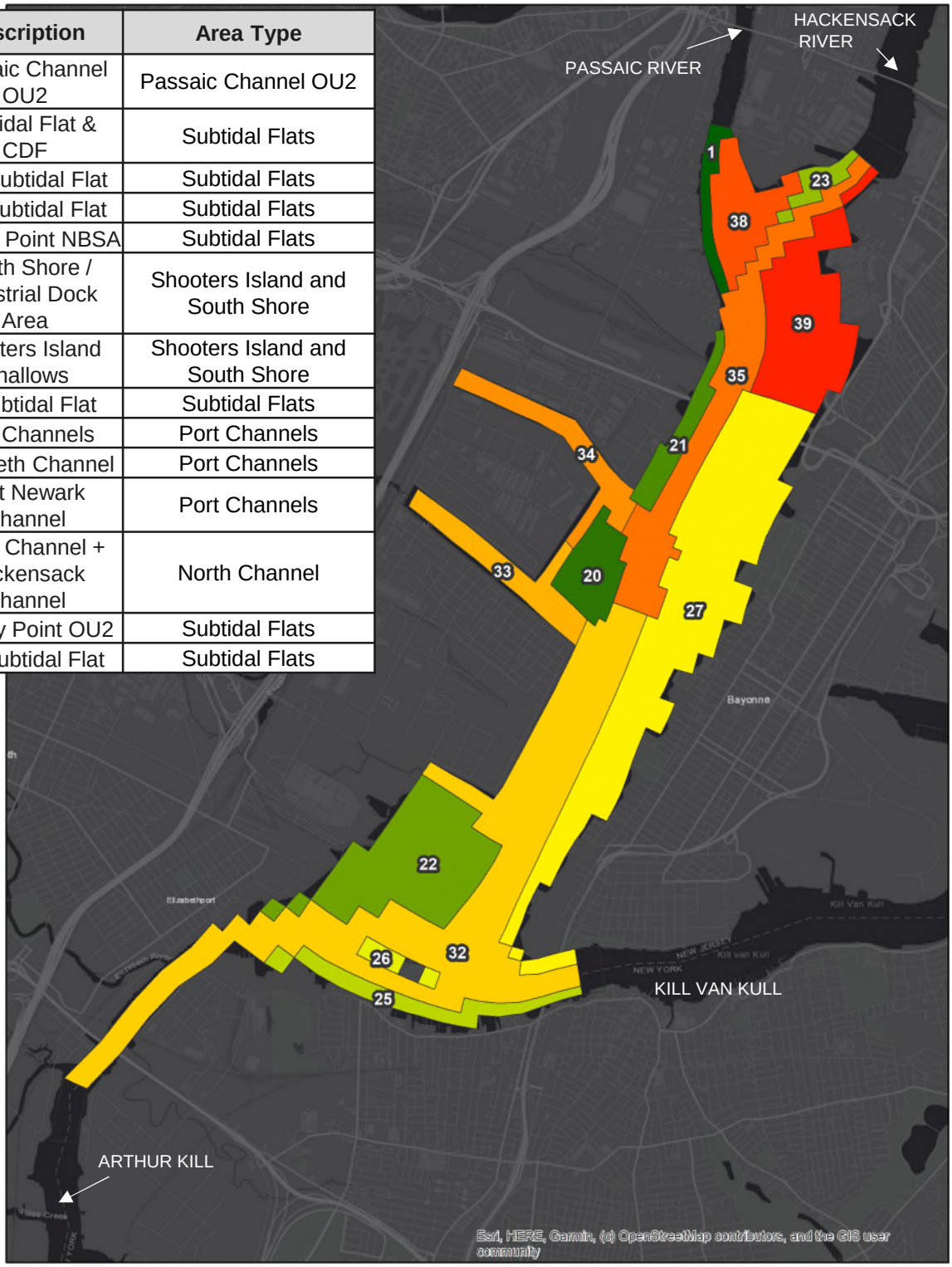
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED AVERAGE DEPOSITION RATES
2004-2013

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
5-MOD-7

Region	Description	Area Type
1	Passaic Channel OU2	Passaic Channel OU2
20	Subtidal Flat & CDF	Subtidal Flats
21	NW Subtidal Flat	Subtidal Flats
22	SW Subtidal Flat	Subtidal Flats
23	Kearny Point NBSA	Subtidal Flats
25	South Shore / Industrial Dock Area	Shooters Island and South Shore
26	Shooters Island Shallows	Shooters Island and South Shore
27	E Subtidal Flat	Subtidal Flats
32	Port Channels	Port Channels
33	Elizabeth Channel	Port Channels
34	Port Newark Channel	Port Channels
35	North Channel + Hackensack Channel	North Channel
38	Kearny Point OU2	Subtidal Flats
39	NE Subtidal Flat	Subtidal Flats



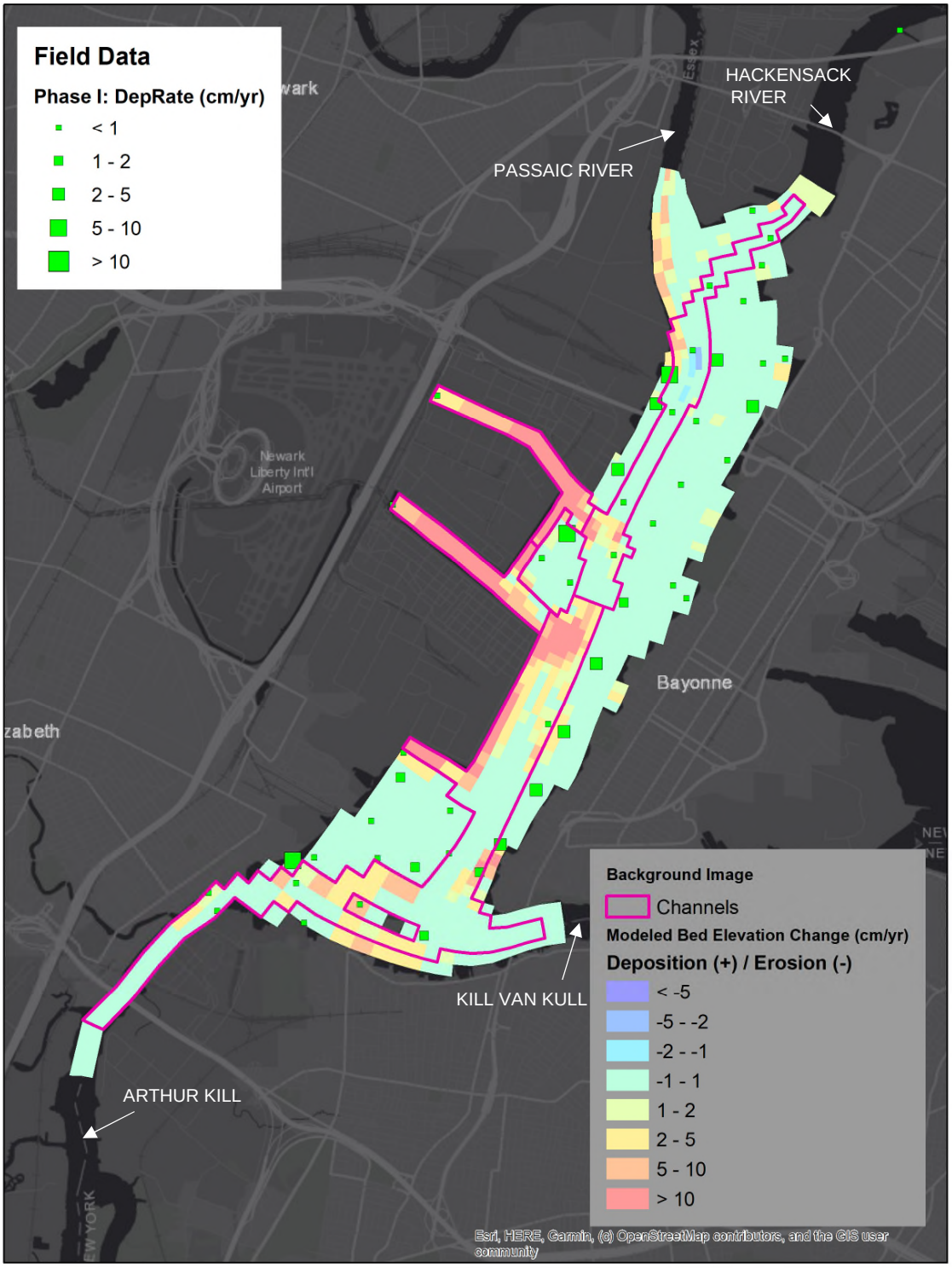
Note:
Colors are included for visual identification of the regions.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODEL MASS BALANCE REGIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
5-MOD-8



Notes:
Model results shown are the annual bed elevation change for 2004-2013 computed by the NBSA RI/FS model.
Deposition rates shown were reported in the final Newark Bay Study Area Remedial Investigation Phase I and Phase II Sediment Deposition Report (Tierra 2011).
Field Data indicates deposition rates from the 1950's through 2005 (Phase I) and 2007 (Phase II).

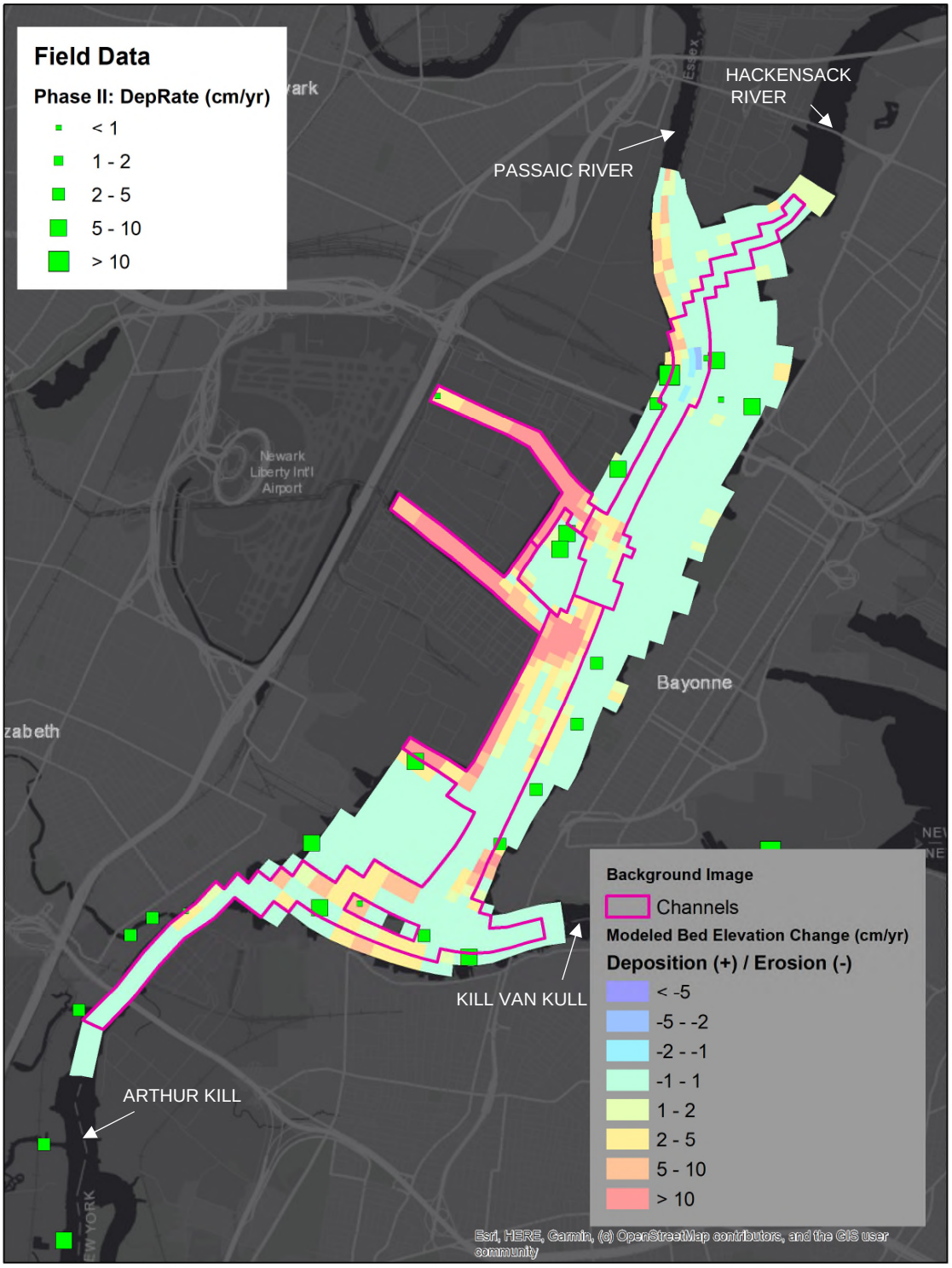
References:
Tierra. 2011. Final Newark Bay Study Area Remedial Investigation Phase I and Phase II Sediment Deposition Report. Revision 1. October.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 2004-2013 BED ELEVATION CHANGES AND FIELD DATA PHASE I DEPOSITION RATE

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
5-MOD-9



Notes:
Background image is modeled annual bed elevation change for 2004-2013 computed by the NBSA RI/FS model.
Deposition rates shown were reported in the final Newark Bay Study Area Remedial Investigation Phase I and Phase II Sediment Deposition Report (Tierra 2011).

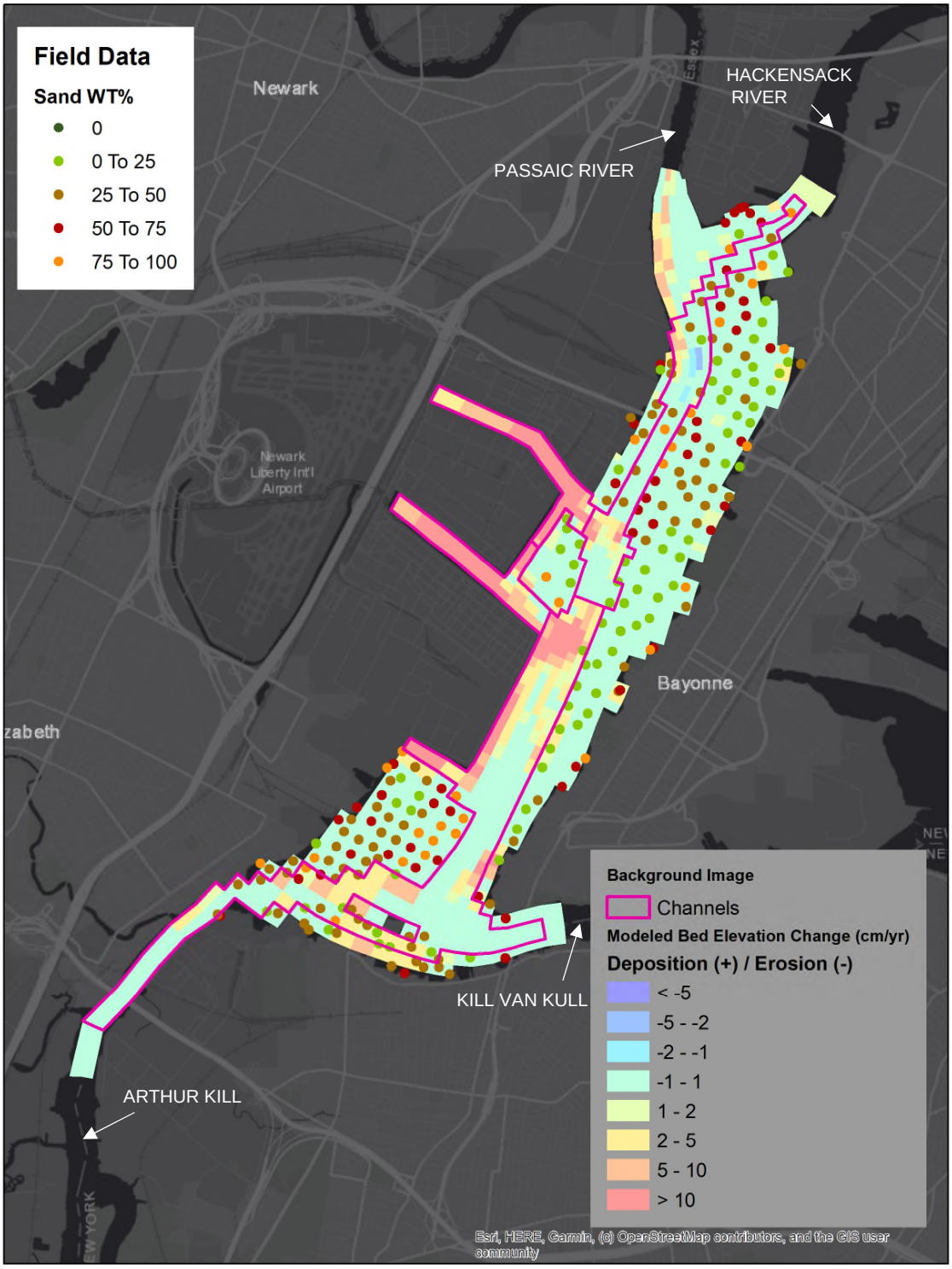
References:
Tierra. 2011. Final Newark Bay Study Area Remedial Investigation Phase I and Phase II Sediment Deposition Report. Revision 1. October.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 2004-2013 BED ELEVATION CHANGES AND FIELD DATA PHASE II DEPOSITION RATE

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
5-MOD-10



Notes:
Background image is modeled annual bed elevation change for 2004-2013 computed by the NBSA RI/FS model.
Grain size was analyzed during Phase III activities in 2014 as part of the Crab and Clam Sampling Program (GSH 2017a), In 2015 as part of the Sediment Quality Triad and Porewater Sampling Program (GSH 2017b), and in 2016 as part of the Surface Sediment Sampling Program (GSH 2019).

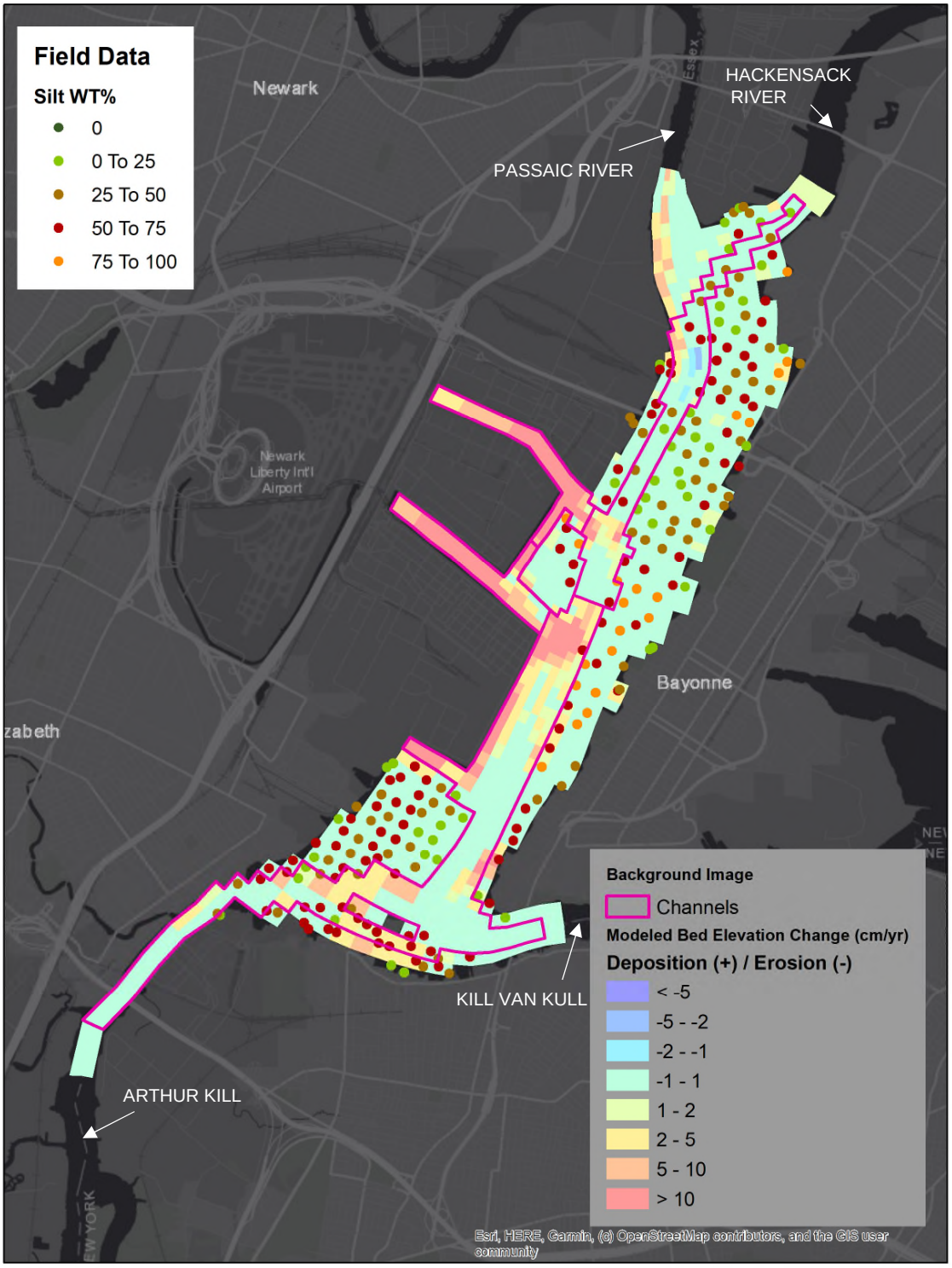
References:
GSH. 2017a. Newark Bay Study Area Crab and Clam Data Report. Baseline Human Health and Ecological Risk Assessment. Revision 1. March.
GSH. 2017b. Newark Bay Study Area Sediment Quality Triad and Porewater Data Report. Baseline Human Health and Ecological Risk Assessment. Revision 2. September.
GSH. 2019. Newark Bay Study Area Conceptual Site Model. Revision 3. January.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 2004-2013 BED ELEVATION CHANGE AND FIELD DATA SAND PERCENTAGE BY WEIGHT

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
5-MOD-11



Notes:
Background image is modeled annual bed elevation change for 2004-2013 computed by the NBSA RI/FS model.
Grain size was analyzed during Phase III activities in 2014 as part of the Crab and Clam Sampling Program (GSH 2017a), In 2015 as part of the Sediment Quality Triad and Porewater Sampling Program (GSH 2017b), and in 2016 as part of the Surface Sediment Sampling Program (GSH 2019).

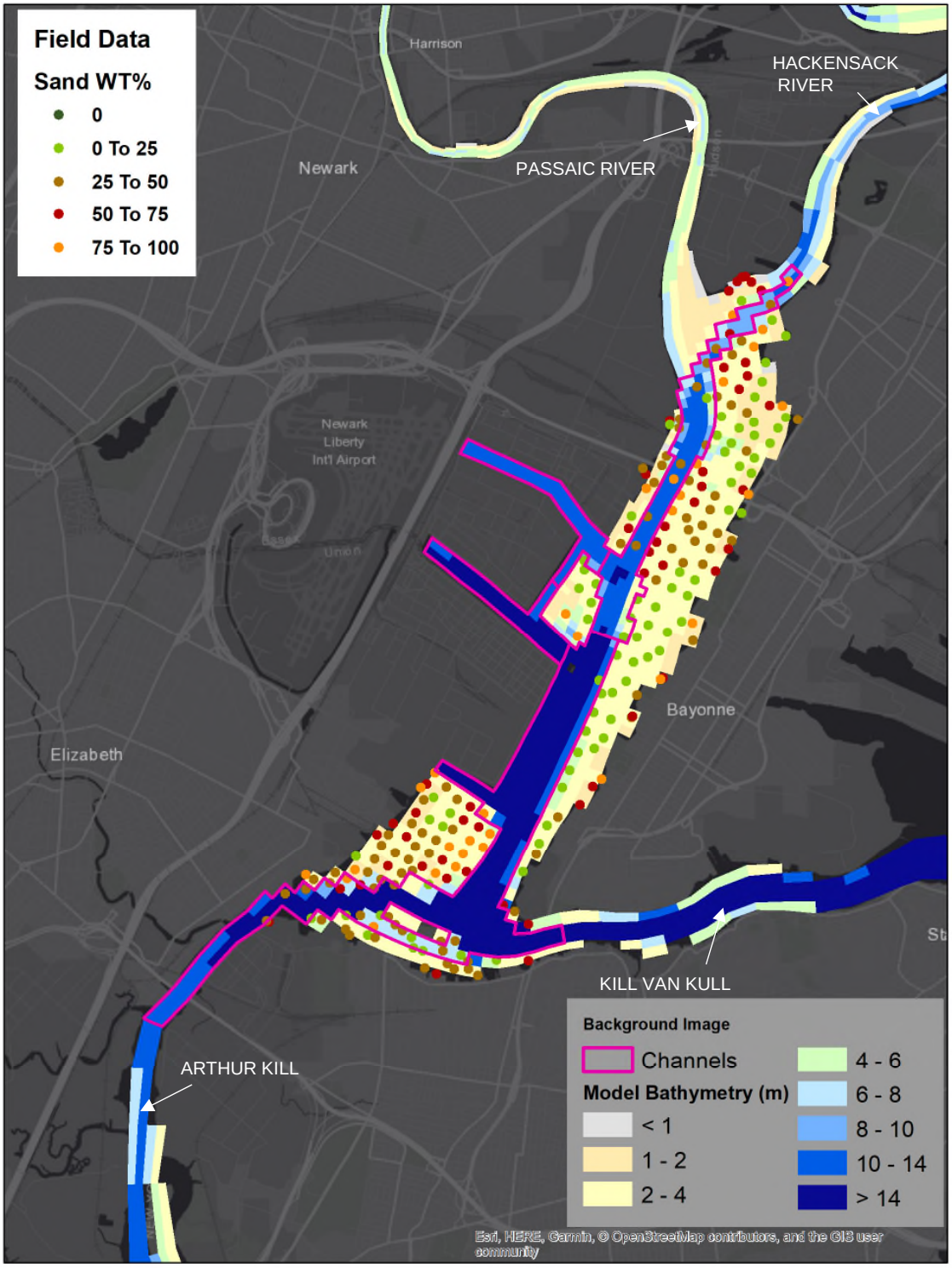
References:
GSH. 2017a. Newark Bay Study Area Crab and Clam Data Report. Baseline Human Health and Ecological Risk Assessment. Revision 1. March.
GSH. 2017b. Newark Bay Study Area Sediment Quality Triad and Porewater Data Report. Baseline Human Health and Ecological Risk Assessment. Revision 2. September.
GSH. 2019. Newark Bay Study Area Conceptual Site Model. Revision 3. January.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 2004-2013 BED ELEVATION CHANGE FIELD DATA SILT PERCENTAGE BY WEIGHT

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
5-MOD-12



Notes:
Background image is 2012 NBSA multibeam bathymetry referenced to Mean Sea Level.
Grain size was analyzed during Phase III activities in 2014 as part of the Crab and Clam Sampling Program (GSH 2017a), In 2015 as part of the Sediment Quality Triad and Porewater Sampling Program (GSH 2017b), and in 2016 as part of the Surface Sediment Sampling Program (GSH 2019).

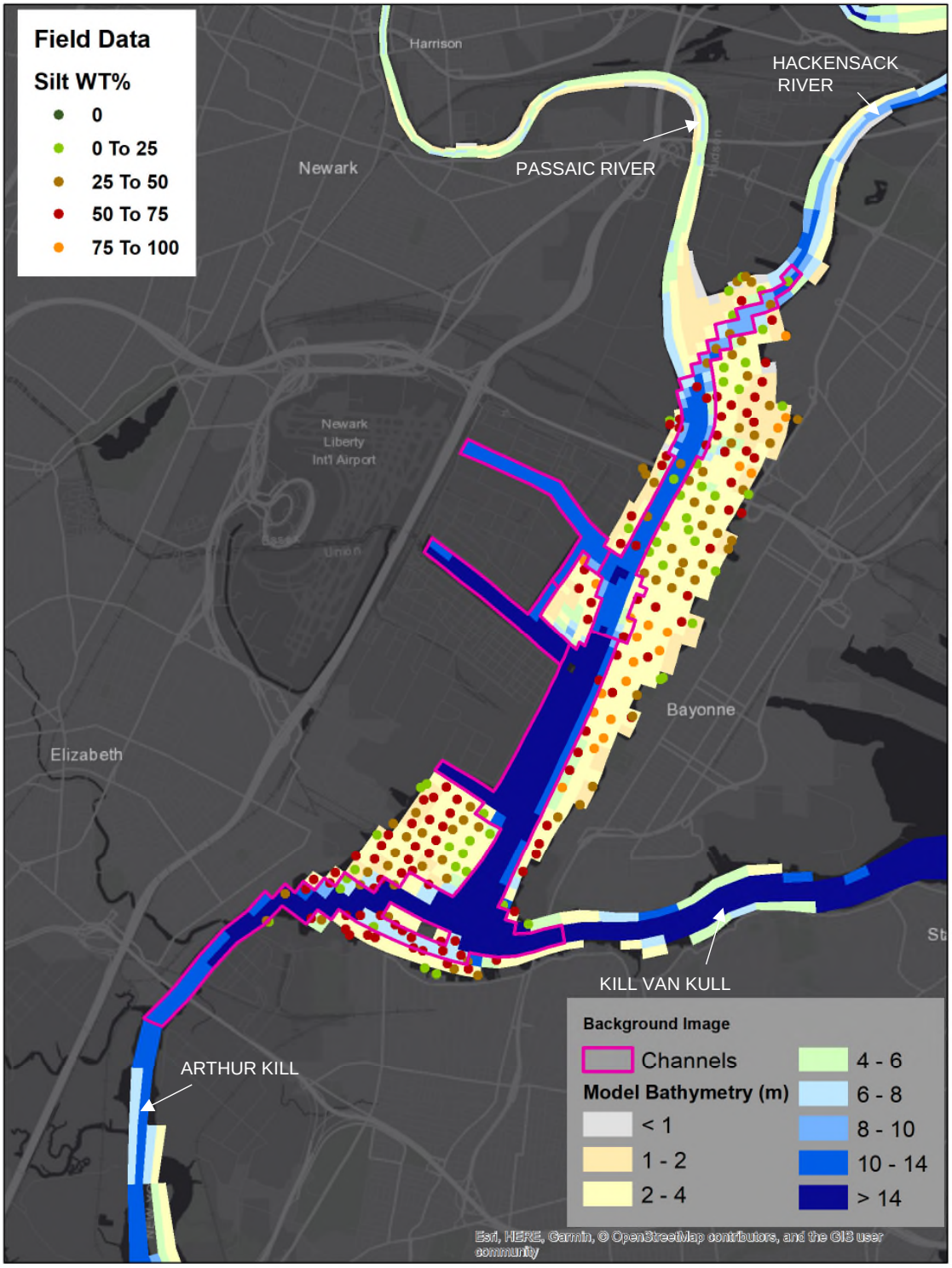
References:
GSH. 2017a. Newark Bay Study Area Crab and Clam Data Report. Baseline Human Health and Ecological Risk Assessment. Revision 1. March.
GSH. 2017b. Newark Bay Study Area Sediment Quality Triad and Porewater Data Report. Baseline Human Health and Ecological Risk Assessment. Revision 2. September.
GSH. 2019. Newark Bay Study Area Conceptual Site Model. Revision 3. January.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

BATHYMETRY AND FIELD DATA SAND PERCENTAGE BY WEIGHT

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
5-MOD-13



Notes:
Background image is 2012 NBSA multibeam bathymetry referenced to Mean Sea Level.
Grain size was analyzed during Phase III activities in 2014 as part of the Crab and Clam Sampling Program (GSH 2017a), In 2015 as part of the Sediment Quality Triad and Porewater Sampling Program (GSH 2017b), and in 2016 as part of the Surface Sediment Sampling Program (GSH 2019).

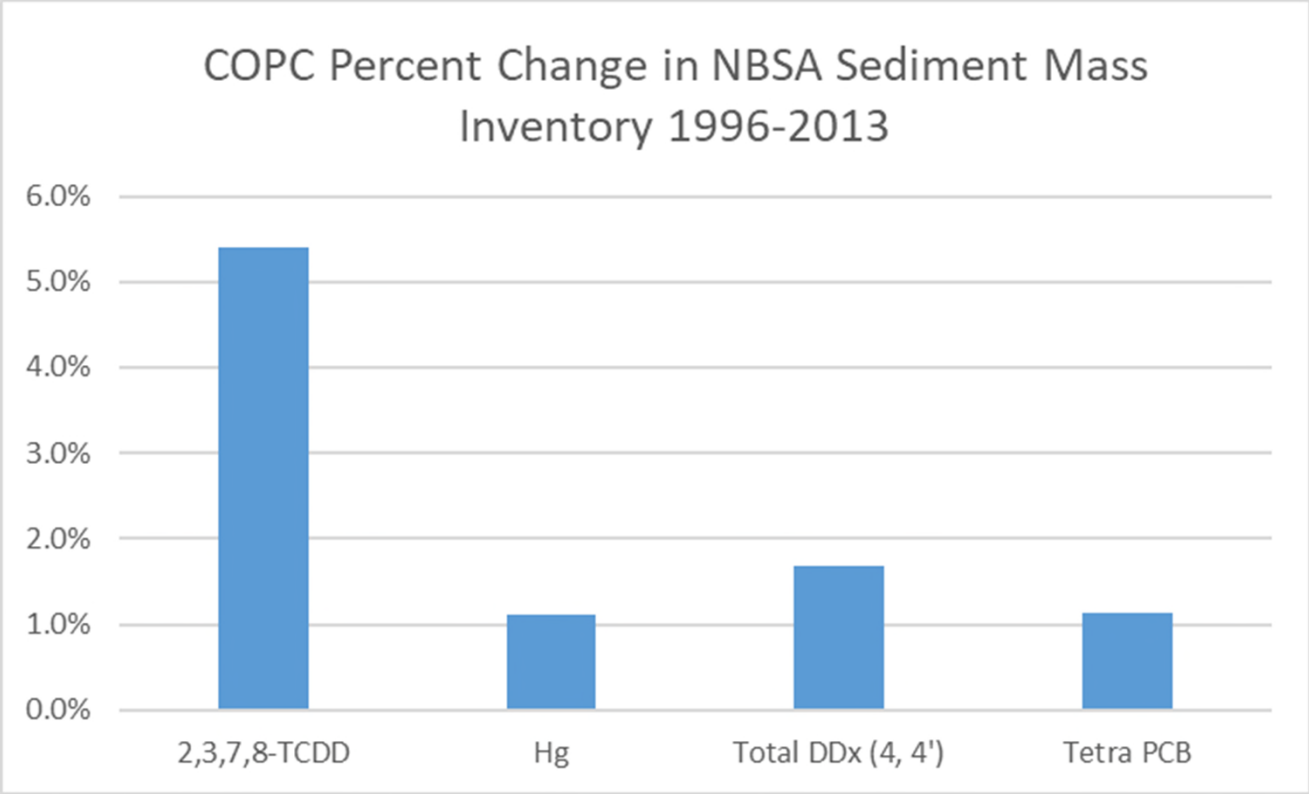
References:
GSH. 2017a. Newark Bay Study Area Crab and Clam Data Report. Baseline Human Health and Ecological Risk Assessment. Revision 1. March.
GSH. 2017b. Newark Bay Study Area Sediment Quality Triad and Porewater Data Report. Baseline Human Health and Ecological Risk Assessment. Revision 2. September.
GSH. 2019. Newark Bay Study Area Conceptual Site Model. Revision 3. January.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

BATHYMETRY AND FIELD DATA SILT PERCENTAGE BY WEIGHT

Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-14



Notes:
COPC = constituent of potential concern

The positive percent change indicates the model computed a net accumulation of COPC mass in the sediment bed over the period 1996-2013. The values do not reflect bathymetric adjustments based on maintenance dredging.

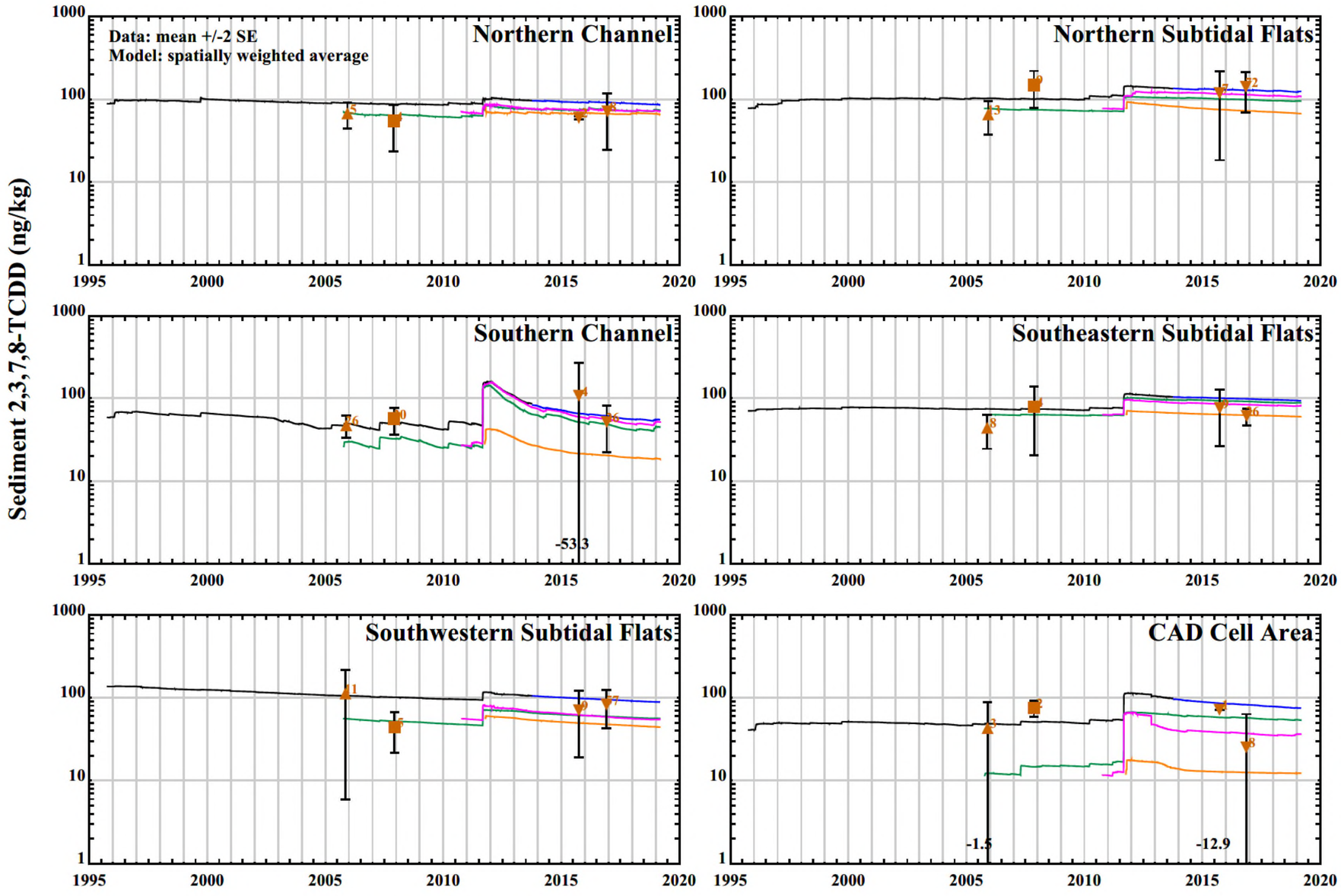
Information shown was developed from NBSA RI/FS Model results provided by USEPA for the model calibration period (1996-2013).

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED PERCENT CHANGE IN SEDIMENT MASS INVENTORY FOR SELECT COPCS, 1996-2013

Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-15



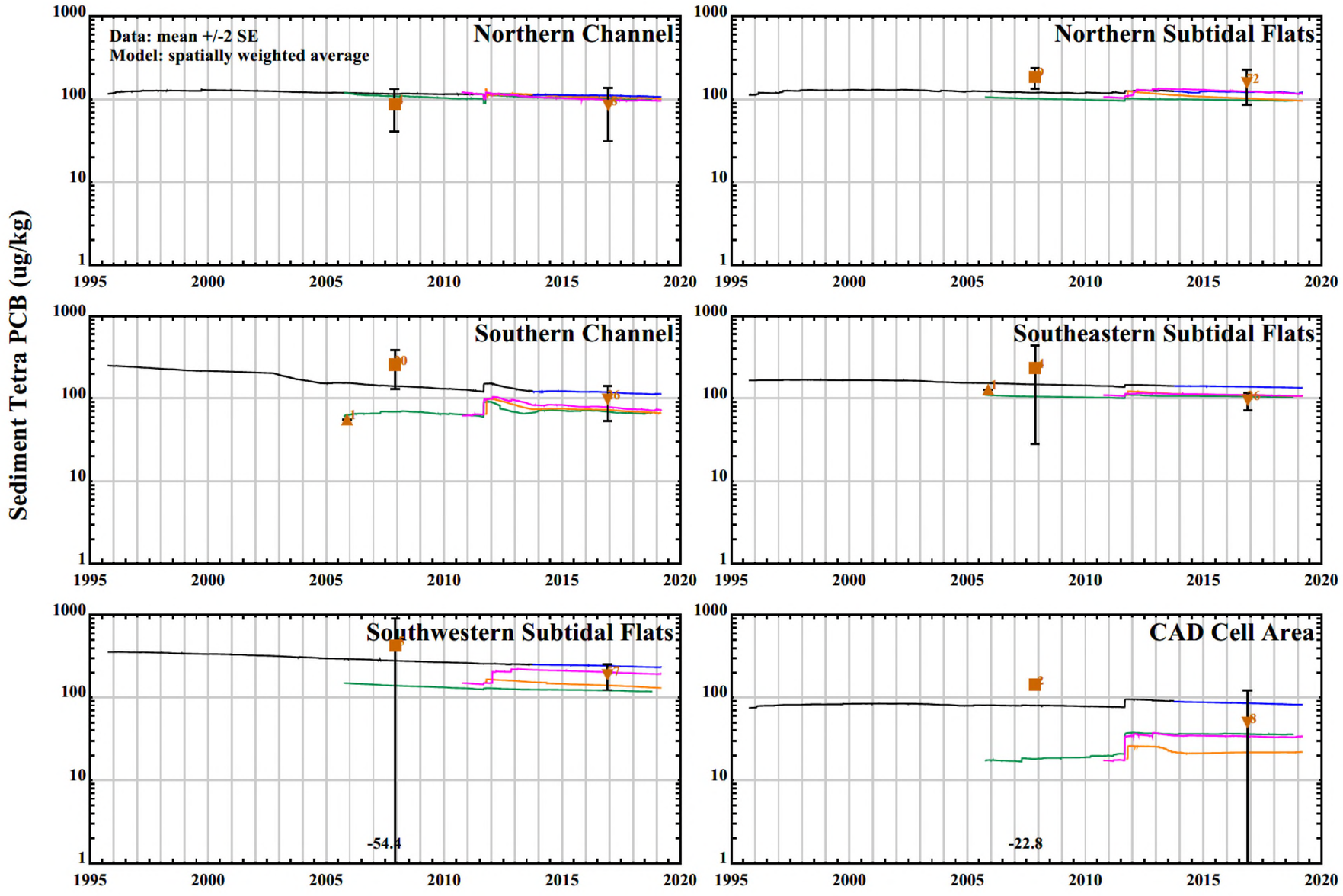
Note:
Model output summaries are from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group provided by HDR on 11/26/2019.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 1995-2019 SURFACE SEDIMENT CONCENTRATIONS FOR 2,3,7,8-TCDD

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-16



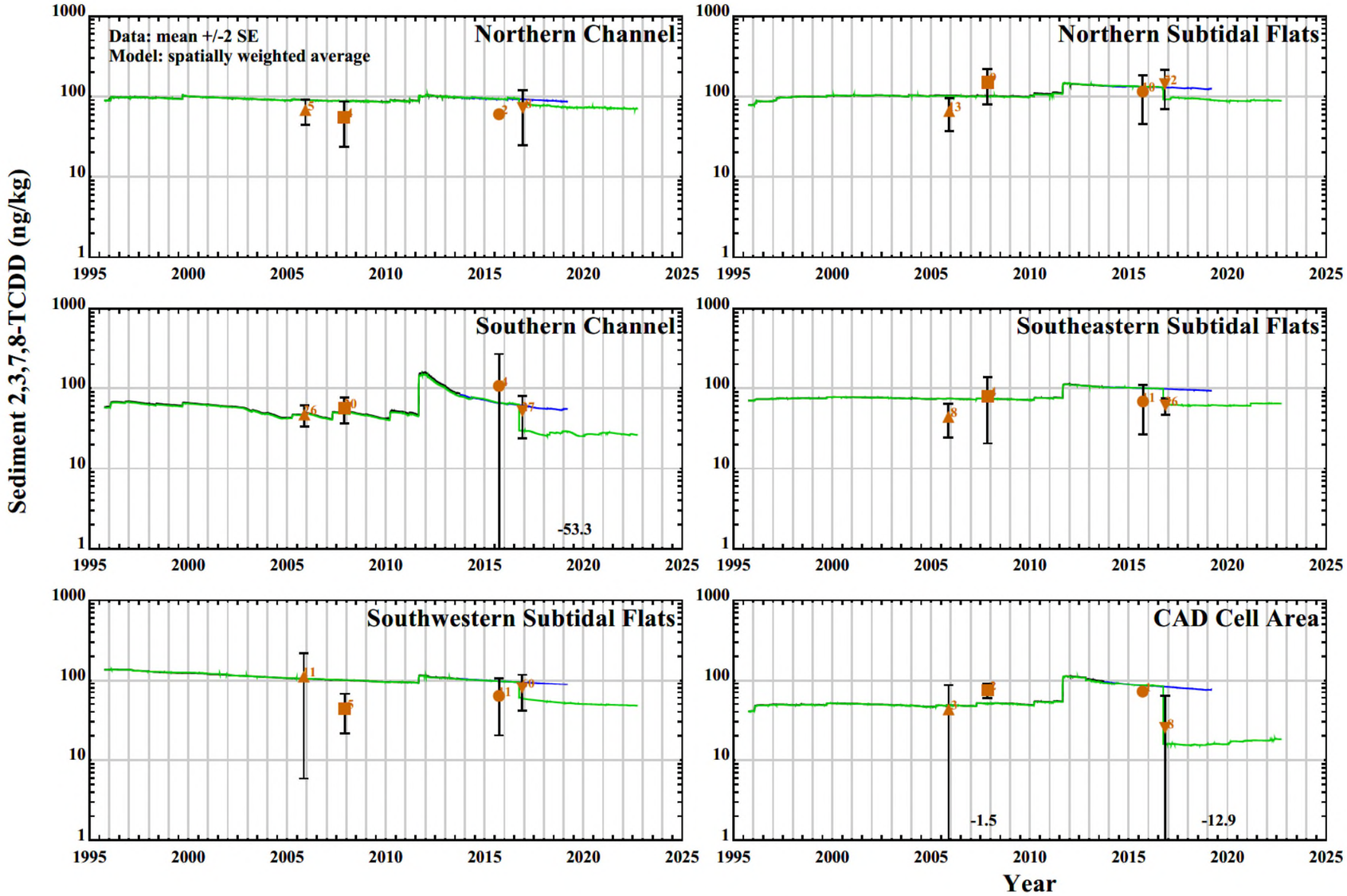
Note:
Model output summaries are from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group provided by HDR on 11/26/2019.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 1995-2019 SURFACE SEDIMENT CONCENTRATIONS FOR TETRA-PCB

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-17



▲ Phase I ● SQT
■ Phase II ▼ Phase III
0.5DL

CPG Long Term Calibration
Oct. 1995 - Sept. 2013

Extension of CPG simulation
Oct. 2013 - Apr. 2019

NBSA Baseline
Oct. 1995 - Sept. 2016 w/ Navigation Scour Fix, NOAA ICs
Arcadis proposed opt power interpolation
& Adjusted Nav Scour fix in AK

Oct. 2016 - Sept. 2022 w/ Phase III ICs
Maintained D50 Avg from Calib Run

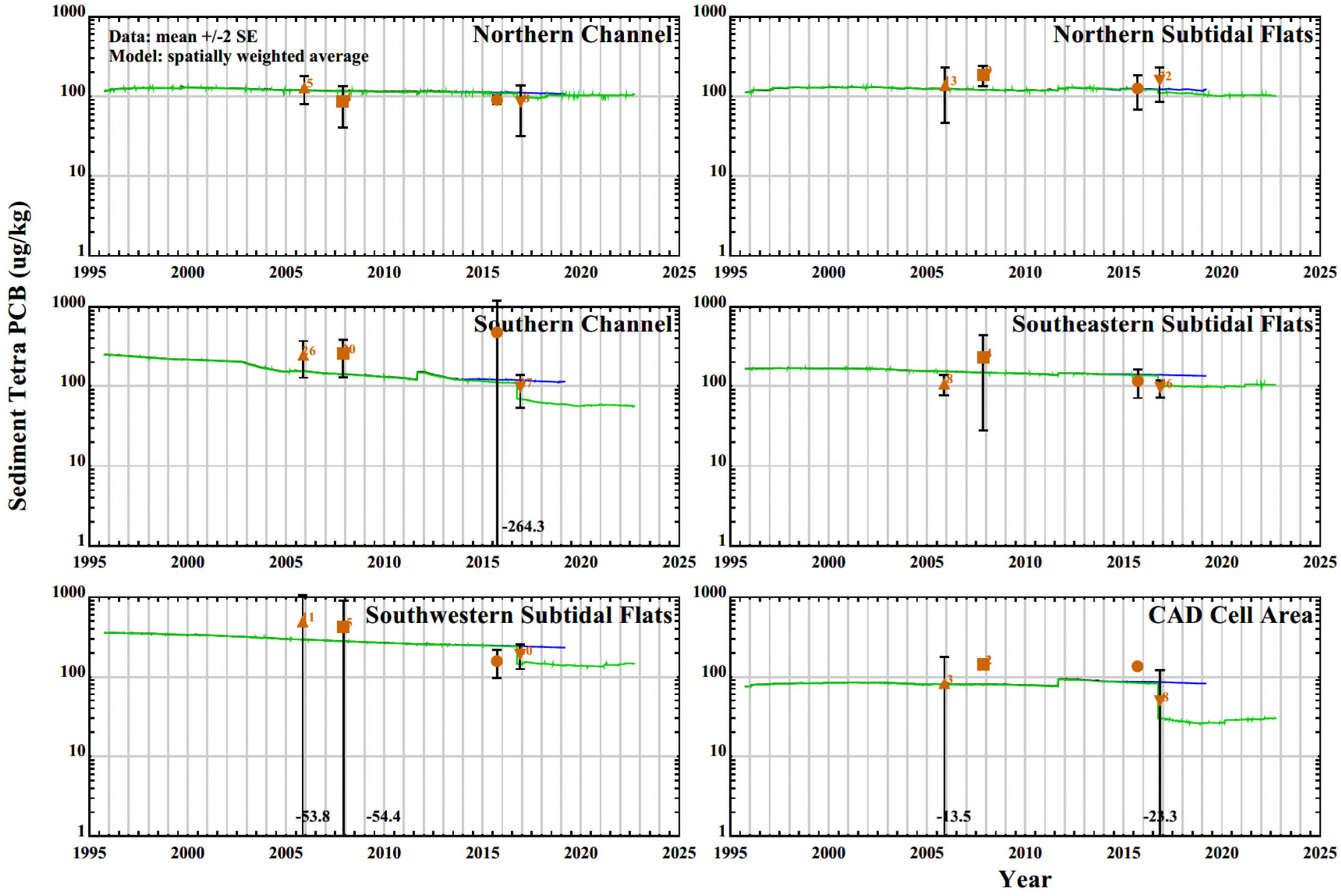
Note:
Model output summaries are from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group and modified by HDR. Results depicted were provided by HDR on 9/13/2021.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 1995-2019 SURFACE SEDIMENT CONCENTRATIONS FOR 2,3,7,8-TCDD (UPDATED MODEL)

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-MOD-18



▲ Phase I ● SQT
■ Phase II ▼ Phase III
0.5DL

CPG Long Term Calibration
Oct. 1995 - Sept. 2013

Extension of CPG simulation
Oct. 2013 - Apr. 2019

NBSA Baseline
Oct. 1995 - Sept. 2016 w/ Navigation Scour Fix, NOAA ICs
Arcadis proposed opt power interpolation
& Adjusted Nav Scour fix in AK

Oct. 2016 - Sept. 2022 w/ Phase III ICs
Maintained D50 Avg from Calib Run

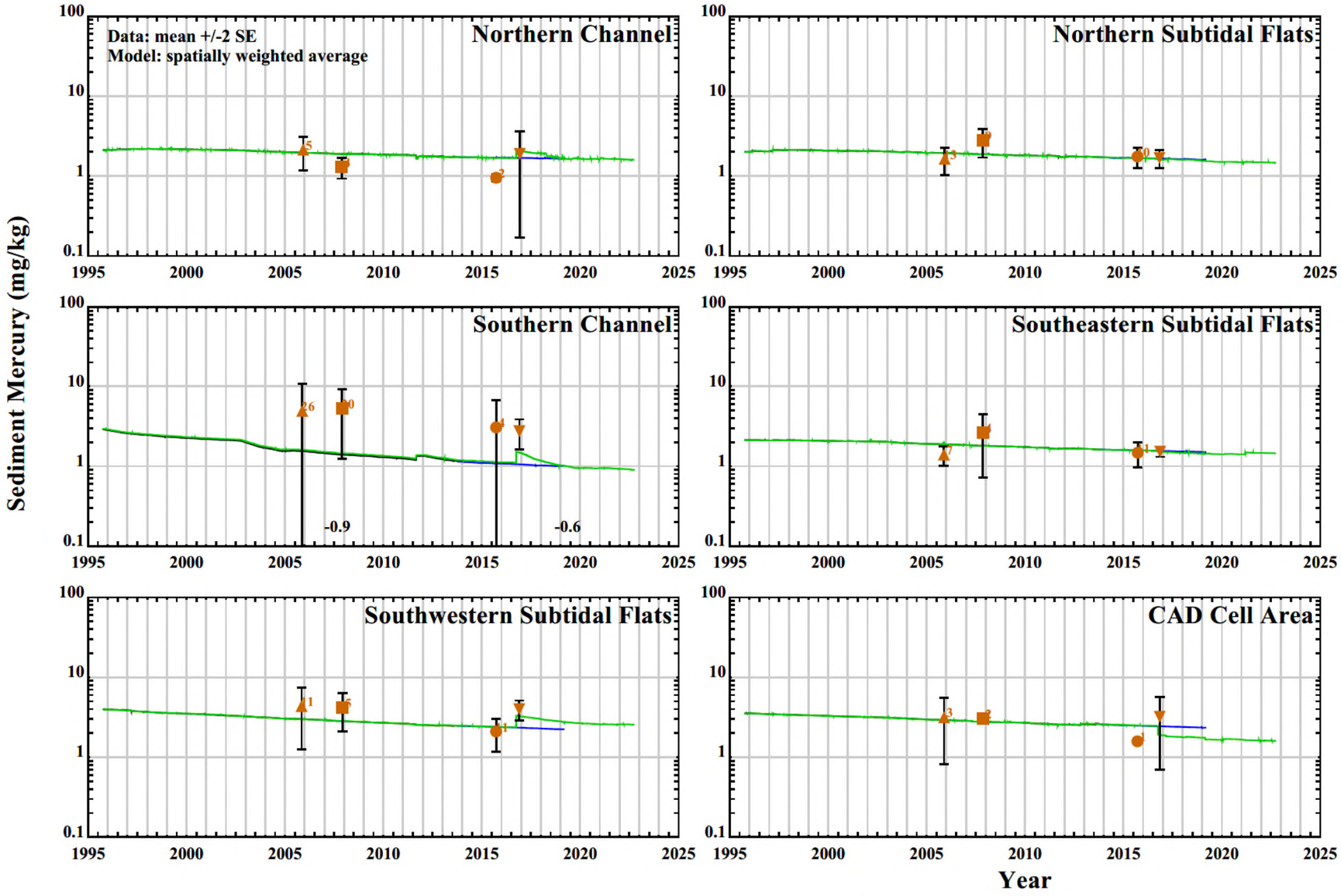
Note:
Model output summaries are from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group and modified by HDR. Results depicted were provided by HDR on 9/13/2021.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 1995-2019 SURFACE SEDIMENT CONCENTRATIONS FOR TETRA-PCB (UPDATED MODEL)

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-19



▲ Phase I ● SQT
■ Phase II ▼ Phase III
0.5DL

CPG Long Term Calibration
Oct. 1995 - Sept. 2013

Extension of CPG simulation
Oct. 2013 - Apr. 2019

NBSA Baseline
Oct. 1995 - Sept. 2016 w/ Navigation Scour Fix, NOAA ICs
Arcadis proposed opt power interpolation
& Adjusted Nav Scour fix in AK

Oct. 2016 - Sept. 2022 w/ Phase III ICs
Maintained D50 Avg from Calib Run

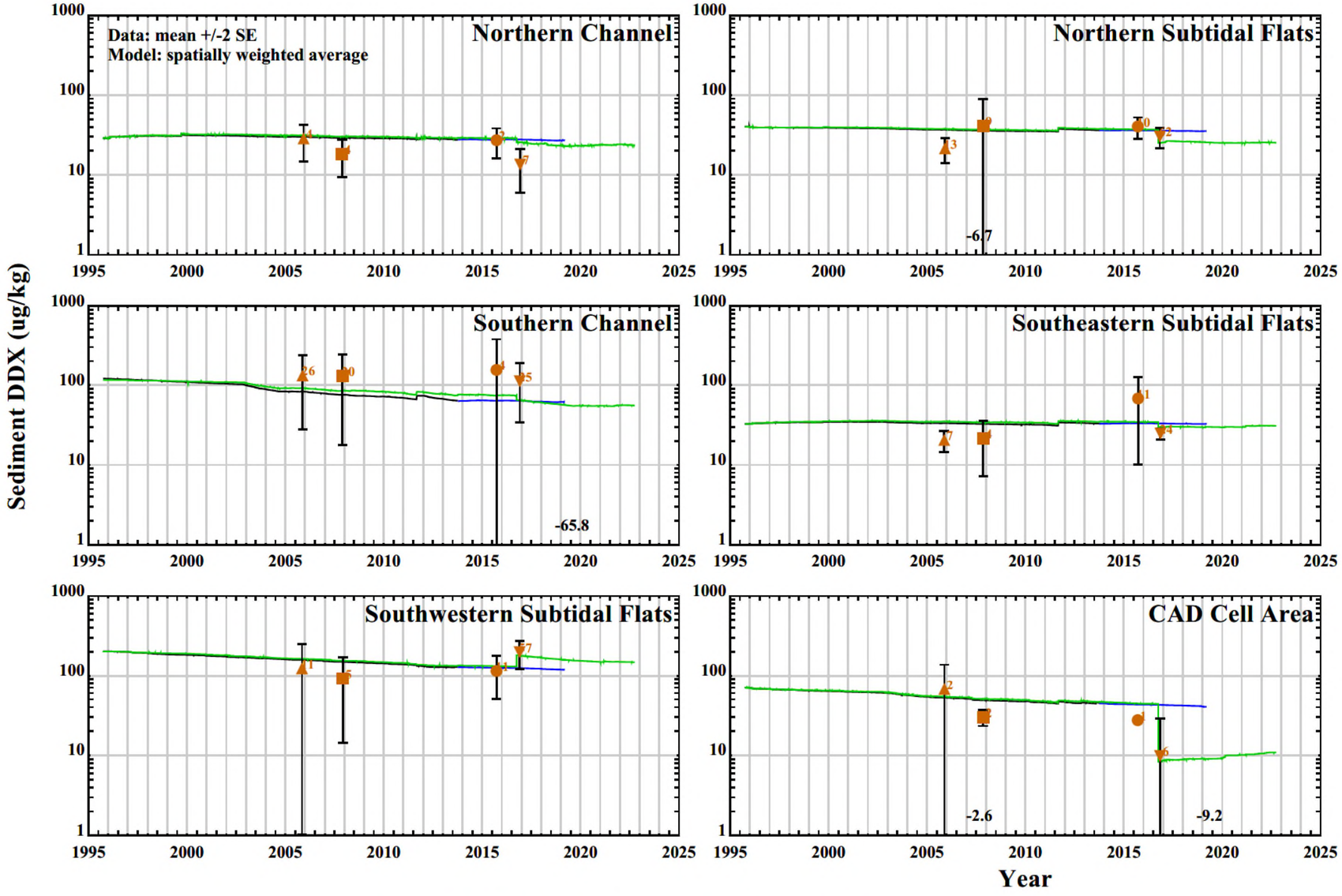
Note:
Model output summaries are from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group and modified by HDR. Results depicted were provided by HDR on 9/13/2021.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 1995-2019 SURFACE SEDIMENT CONCENTRATIONS FOR MERCURY (UPDATED MODEL)

Glenn Springs Holdings, Inc.
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FIGURE
5-MOD-20



▲ Phase I ● SQT
■ Phase II ▼ Phase III
0.5DL

CPG Long Term Calibration
Oct. 1995 - Sept. 2013

Extension of CPG simulation
Oct. 2013 - Apr. 2019

NBSA Baseline
Oct. 1995 - Sept. 2016 w/ Navigation Scour Fix, NOAA ICs
Arcadis proposed opt power interpolation
& Adjusted Nav Scour fix in AK

Oct. 2016 - Sept. 2022 w/ Phase III ICs
Maintained D50 Avg from Calib Run

Note:
Model output summaries are from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group and modified by HDR. Results depicted were provided by HDR on 9/13/2021.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODELED 1995-2019 SURFACE SEDIMENT CONCENTRATIONS FOR TOTAL DDX (4,4') (UPDATED MODEL)

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-MOD-21

City: Citrix Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: MEstifanos
Project (B0009989.0045.00002)
T:\ ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Fig5_PotentialHighDepositionAreasUSACE.mxd 4/6/2021 7:06:17 PM

LEGEND:

- PHASE I CORE LOCATION
- PHASE II CORE LOCATION
- CO-LOCATED CORE LOCATION
- SHORELINE
- UNDERGROUND TRIBUTARY
- NAVIGATION CHANNEL
- PHASE I/PHASE II STUDY AREA BOUNDARY
- USACE ACCUMULATION AREA
- 1 ACCUMULATION AREA ID

ESTIMATED DEPOSITION OVER TIME (1934 TO 2006; FEET):

- 0 -2
- 2 - 5
- 5 - 10
- 10 - 17
- 17 - 33

0 0.6 1.2 Miles

GRAPHIC SCALE

NOTES:

1. DEPOSITION RATES WERE ESTIMATED BY USACE (2006) BASED ON CHANGES IN ELEVATION ON HISTORICAL BATHYMETRIC MAPS. BATHYMETRY AND HISTORICAL DATA WERE USED TO IDENTIFY 18 AREAS OF SEDIMENT ACCUMULATION ASSOCIATED WITH KNOWN ANTHROPOGENIC INFLUENCES. THE TABLE BELOW DESCRIBES THESE INFLUENCES AND PROVIDES THE AREAL EXTENT OF EACH ACCUMULATION AREA IN SQUARE YARDS.
2. THE LOCATION OF A HISTORIC DIKE IS SHOWN ON BATHYMETRIC MAPS COMPILED BY TIERRA (2011). IT WAS CONSTRUCTED IN 1923 TO PREVENT SEDIMENTATION WITHIN THE CHANNEL NORTH OF SHOOTERS ISLAND. AFTER DETERIORATION, IT WAS RECONSTRUCTED IN 1964. IT FURTHER DETERIORATED BY 1984 AND WAS DEMOLISHED IN 2010.
3. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020).
4. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.

PASSAIC RIVER
HACKENSACK RIVER
CONRAIL BRIDGE REMNANTS
CONRAIL BRIDGE REMNANTS
PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
KILL VAN KULL
MORSES CREEK
LOCATION OF HISTORICAL DIKE
BAYONNE BRIDGE
GOETHALS BRIDGE
ARTHUR KILL
PILES CREEK
PRALL'S ISLAND

Accumulation Area	Accumulation Area Description	Area (square yards)
1	Mouth of Lower Passaic River	282,654.6
2	Kearney Point cut and fill in the flats	13,897.6
3	Droyers Point cut and fill in the flats	124,607.5
4	Lehigh Valley Bridge west	156,260.8
5	Lehigh Valley Bridge east	241,344.4
6	Newark cut and fill in the flats south of I-76 [*sic*] extension bridge	50,792.4
7	Cut and fill in the flats west of Confined Disposal Facility (CDF)	263,053.5
8	Bayonne cut and fill in the flats across from Port Elizabeth Channel	28,110.3
9	Bayonne cut and fill in the flats across from Port Elizabeth pierhead	202,690.2
10	Abandoned Allied Signal Channel immediately south of South Elizabeth Channel	81,767.6
11	Old Bay Draw railroad bridge alignment on the Elizabeth flats	131,476.4
12	Abandoned berths at Texaco Pier just north of Bergen Point	57,301.4
13	Abandoned Elizabethport Channel	104,290.6
14	Elizabethport Reach cut and fill in the flats	39,366.8
15	Port Ivory cut and fill in the flats	39,377.4
16	South of Shooters Island Channel	2,319,589.5
17	Shooters Island	116,579.8
18	Richmond Terrace cut and fill in flats south of Bergen Point West Reach	58,076.0

REFERENCES:

TIERRA. 2011. FINAL NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION PHASE I AND PHASE II SEDIMENT DEPOSITION REPORT. REVISION 1. OCTOBER.

USACE. 2006. GEOMORPHOLOGICAL/GEOPHYSICAL CHARACTERIZATION OF THE NATURE AND DYNAMICS OF SEDIMENTATION AND SEDIMENT TRANSPORT IN NEWARK BAY FOCUSING THE EFFECTS RELATED TO CONTINUED AND FUTURE FEDERAL NAVIGATION CHANNEL DEEPENING AND MAINTENANCE. CONTRACT #W912DS-06-D-0001. DELIVERY ORDER #0004. U.S. ARMY CORPS OF ENGINEERS, NEW YORK DISTRICT. DECEMBER 31.

USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE – BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

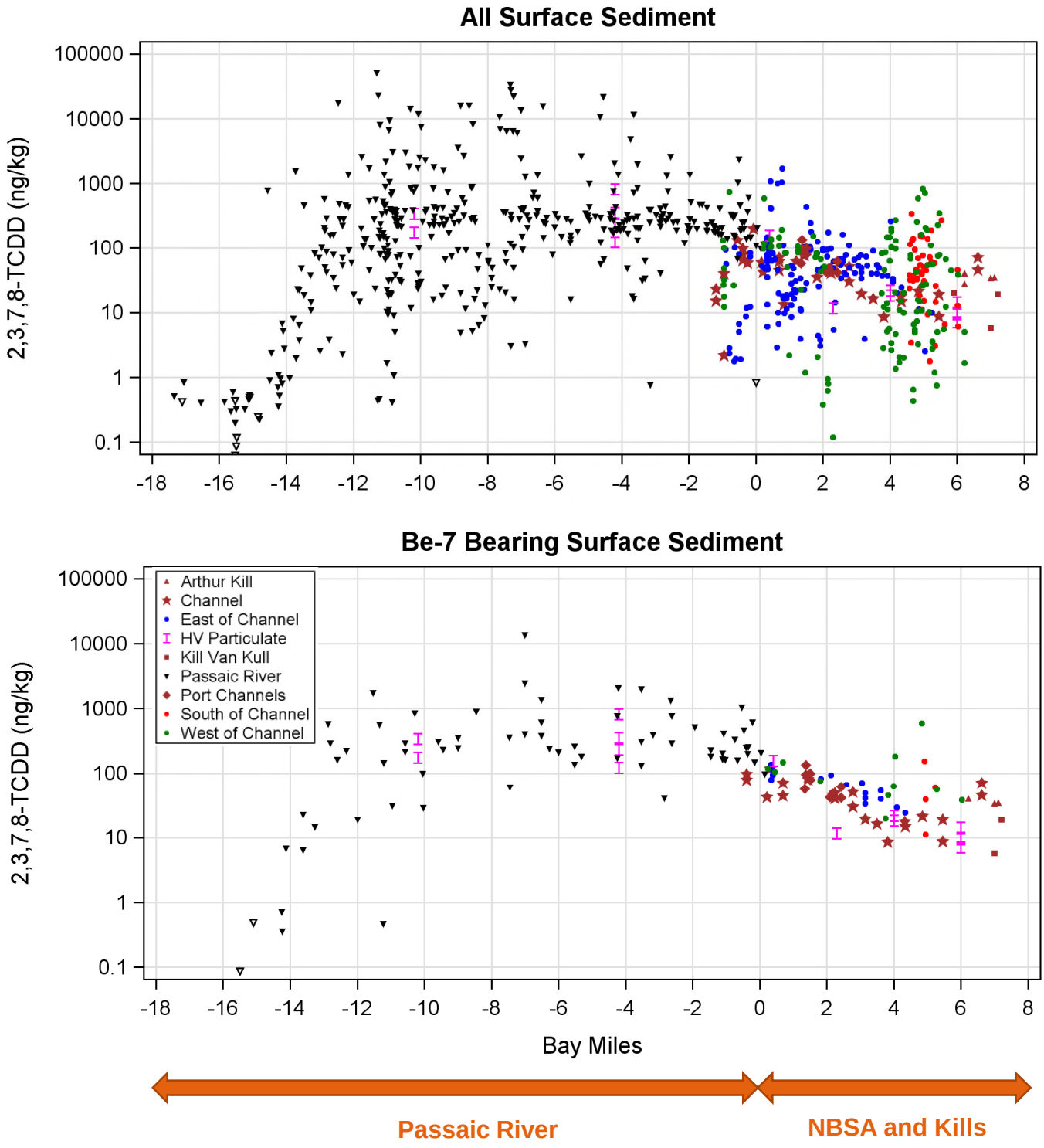
DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION REMEDIAL INVESTIGATION REPORT

POTENTIAL SEDIMENT ACCUMULATION AREAS AND PHASE I/II CORE LOCATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
5-ACCUM



Notes:

The bottom graph shows only Be-7 bearing samples (i.e., Be-7 concentration greater than 0.5 picocuries per gram).

"Channel" refers to main stem of the navigation channel. Subtidal flats and transitional slope samples are identified with respect to their orientation to the channel (i.e., east, west, or south). Arthur Kill and Kill Van Kull samples are located outside the NBSA boundary. Passaic River samples were collected for the OU4 RI (2008-2013).

HV Particulate are concentrations in water column solids from the High Volume Water Column Monitoring (see Table 4-22). Open symbols indicate observation is a non-detect plotted at the value of the quantitation limit.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin

Be-7 = beryllium-7

ng/kg = nanogram per kilogram

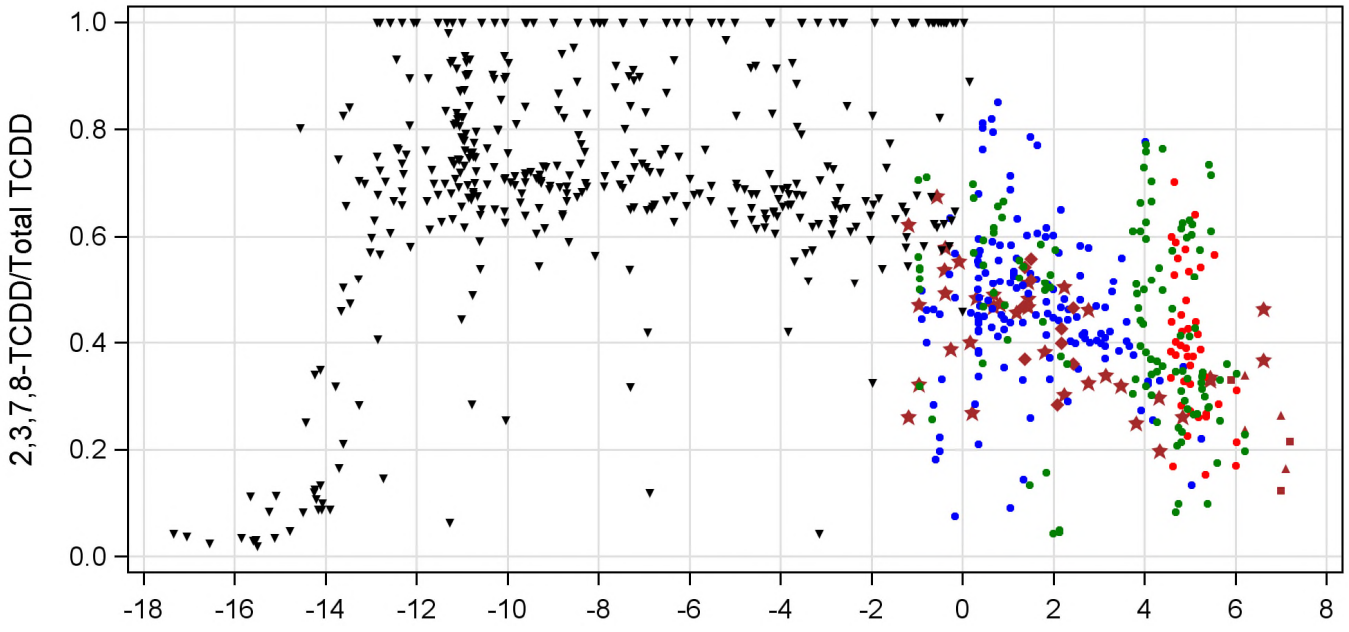
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT CONCENTRATIONS BY BAY MILE: 2,3,7,8-TCDD

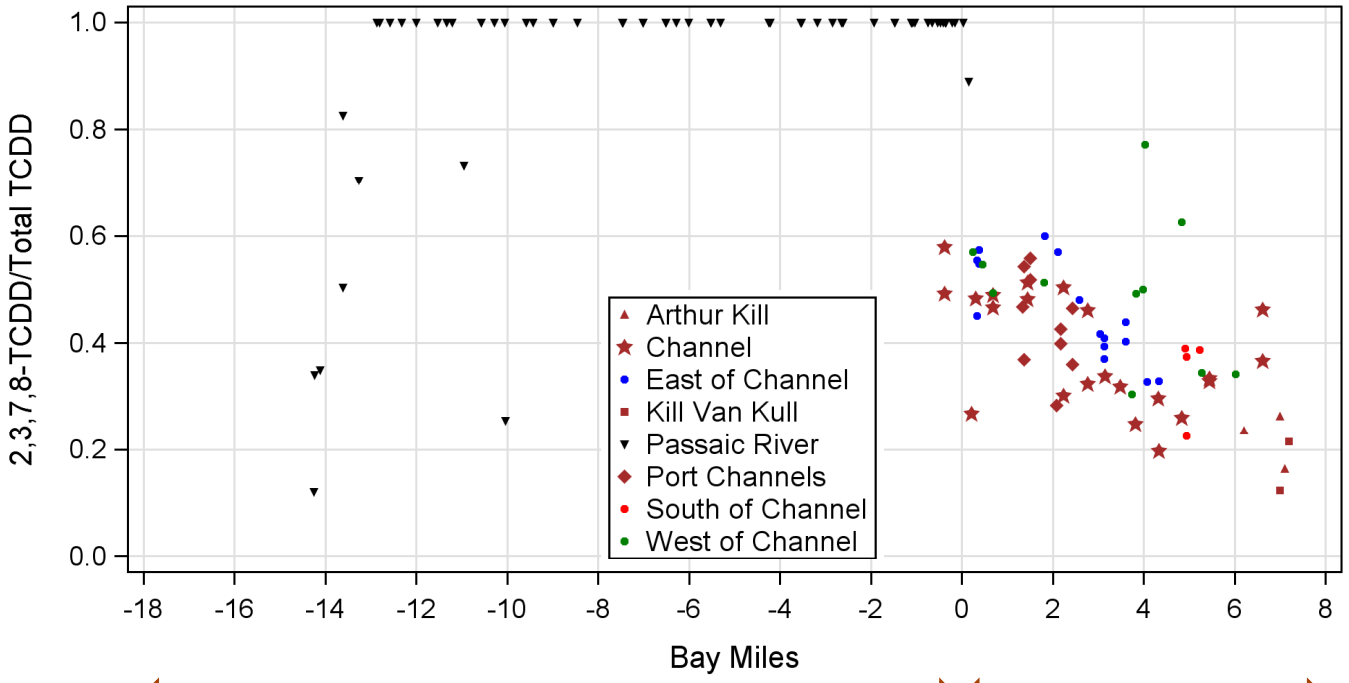
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

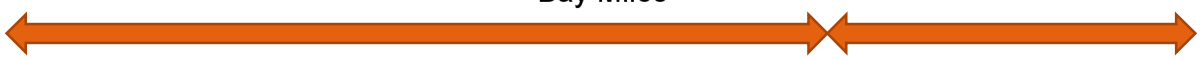
FIGURE
5-B7-1a

All Surface Sediment



Be-7 Bearing Surface Sediment





Passaic River **NBSA and Kills**

Notes:

The bottom graph shows only Be-7 bearing samples (i.e., Be-7 concentration greater than 0.5 picocuries per gram).

"Channel" refers to main stem of the navigation channel. Subtidal flats and transitional slope samples are identified with respect to their orientation to the channel (i.e., east, west, or south). Arthur Kill and Kill Van Kull samples are located outside the NBSA boundary.

Passaic River samples were collected for the OU4 RI (2008-2013). Non-detect samples excluded. Passaic River ratios that exceeded one due to adjustment of the 2,3,7,8-TCDD data in the 2008 LRC program were capped at one.

TCDD = tetrachlorodibenzo-p-dioxin

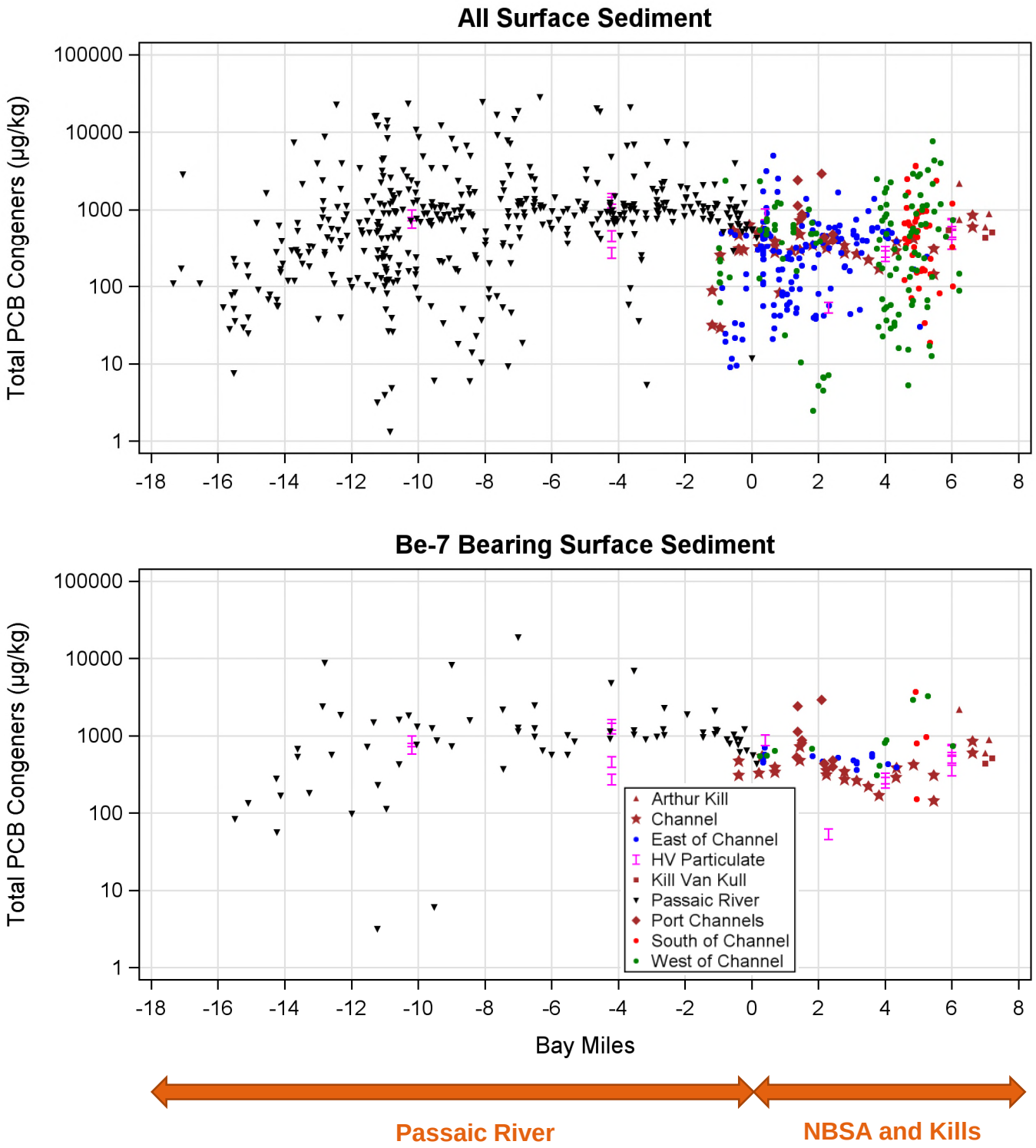
Be-7 = beryllium-7

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT CONCENTRATIONS BY BAY MILE: 2,3,7,8-TCDD/TOTAL TCDD

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FIGURE
5-B7-1b



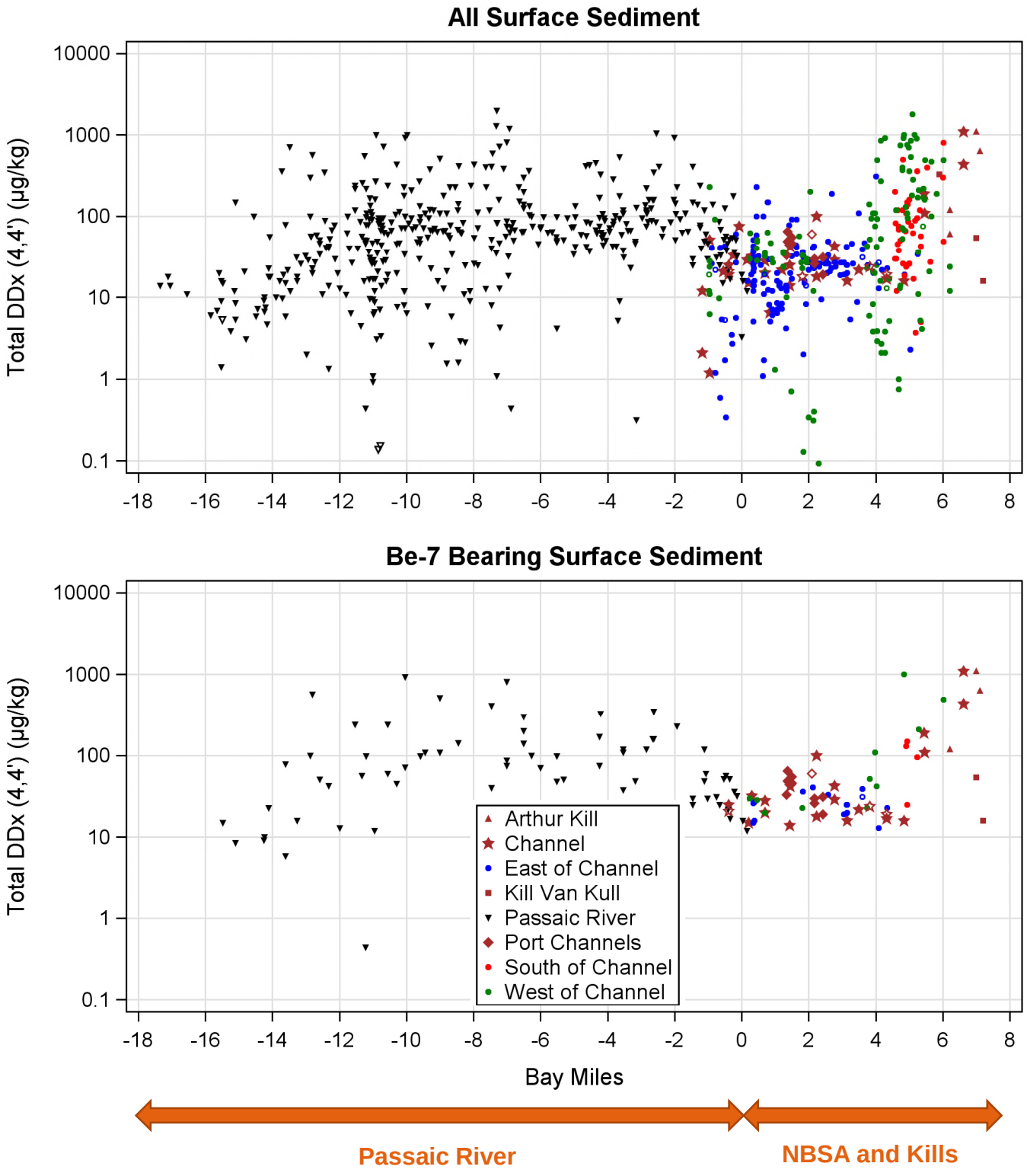
Notes:
The bottom graph shows only Be-7 bearing samples (i.e., Be-7 concentration greater than 0.5 picocuries per gram).
"Channel" refers to main stem of the navigation channel. Subtidal flats and transitional slope samples are identified with respect to their orientation to the channel (i.e., east, west, or south). Arthur Kill and Kill Van Kull samples are located outside the NBSA boundary.
Passaic River samples were collected for the OU4 RI (2008-2013).
HV Particulate are concentrations in water column solids from the High Volume Water Column Monitoring (see Table 4-22).
Be-7 = beryllium-7
PCB = polychlorinated biphenyl
µg/kg = microgram per kilogram

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT CONCENTRATIONS BY BAY MILE: TOTAL PCB CONGENERS

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-B7-2



Notes:

The bottom graph shows only Be-7 bearing samples (i.e., Be-7 concentration greater than 0.5 picocuries per gram).

"Channel" refers to main stem of the navigation channel. Subtidal flats and transitional slope samples are identified with respect to their orientation to the channel (i.e., east, west, or south). Arthur Kill and Kill Van Kull samples are located outside the NBSA boundary.

Passaic River samples were collected for the OU4 RI (2008-2013).

Open symbols indicate observation is a non-detect plotted at the value of the quantitation limit.

Be-7 = beryllium-7

DDx = sum of dichlorodiphenyldichloroethane, dichlorodiphenyldichloroethylene, and dichlorodiphenyltrichloroethane

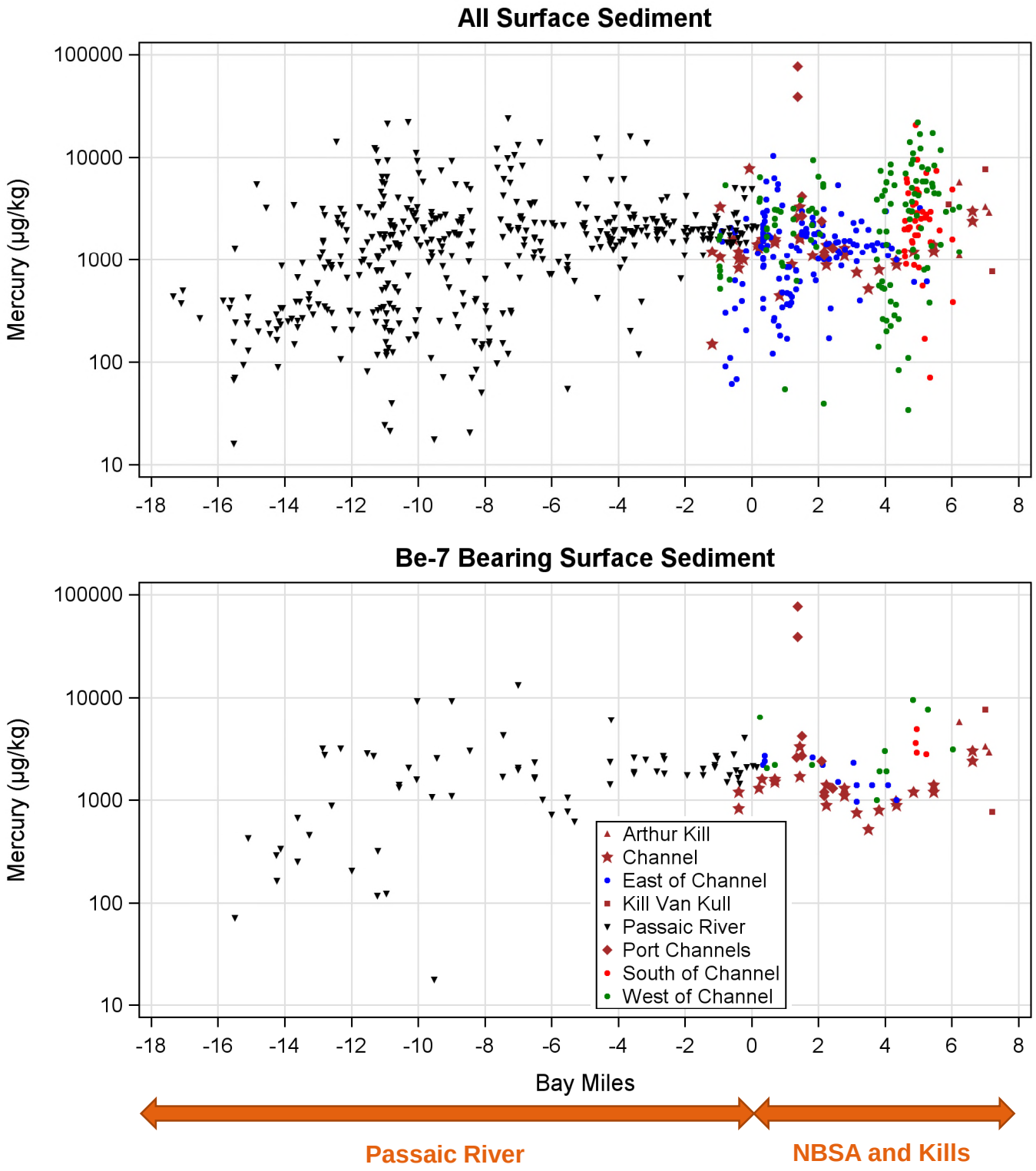
µg/kg = microgram per kilogram

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT CONCENTRATIONS BY BAY MILE: TOTAL DDX (4,4')

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-B7-3



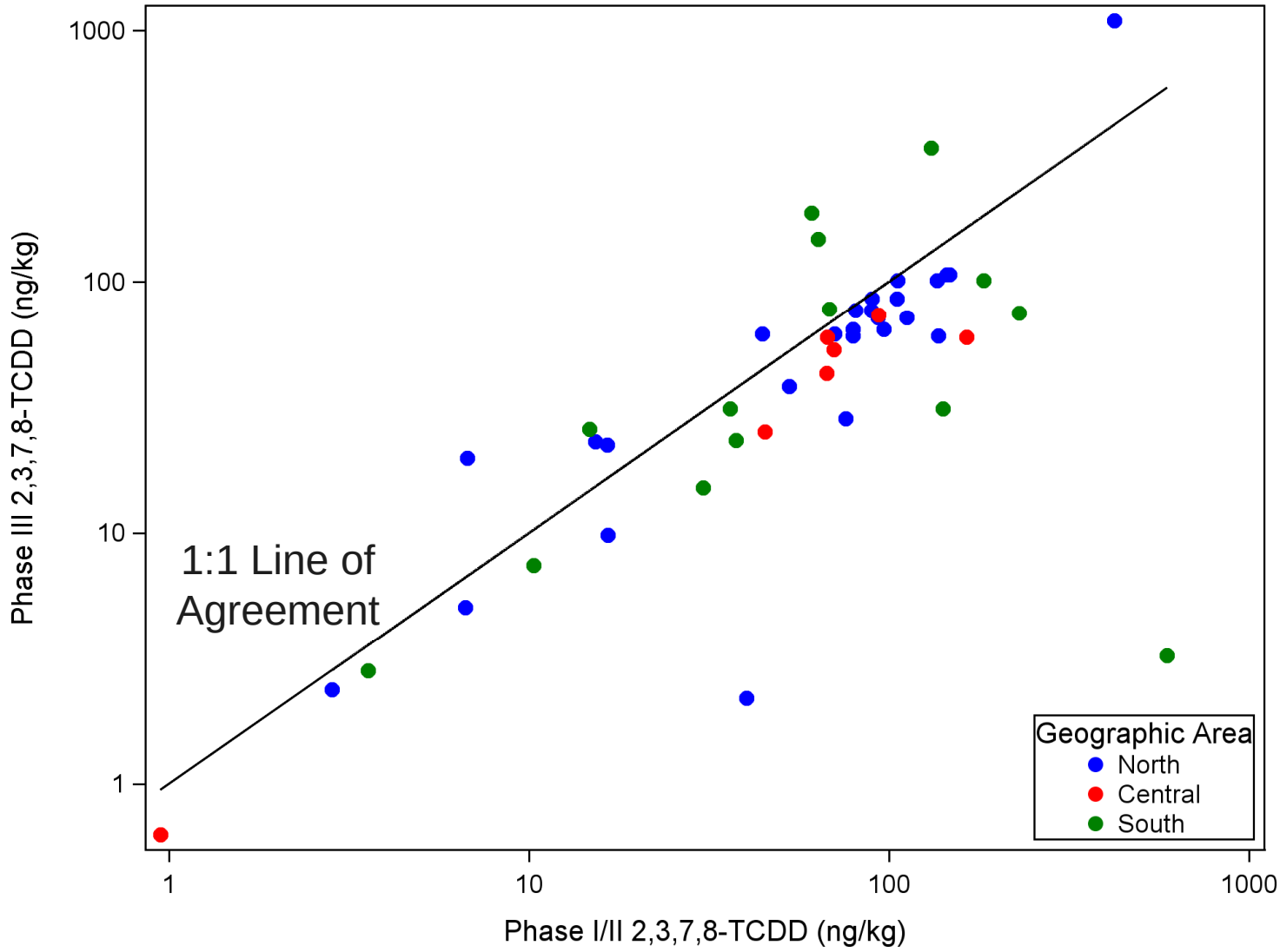
Notes:
The bottom graph shows only Be-7 bearing samples (i.e., Be-7 concentration greater than 0.5 picocuries per gram).
"Channel" refers to main stem of the navigation channel. Subtidal flats and transitional slope samples are identified with respect to their orientation to the channel (i.e., east, west, or south). Arthur Kill and Kill Van Kull samples are located outside the NBSA boundary.
Passaic River samples were collected for the OU4 RI (2008-2013).
Be-7 = beryllium-7
µg/kg = microgram per kilogram

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE SEDIMENT CONCENTRATIONS BY BAY MILE: MERCURY

Glenn Springs Holdings, Inc.
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FIGURE
5-B7-4



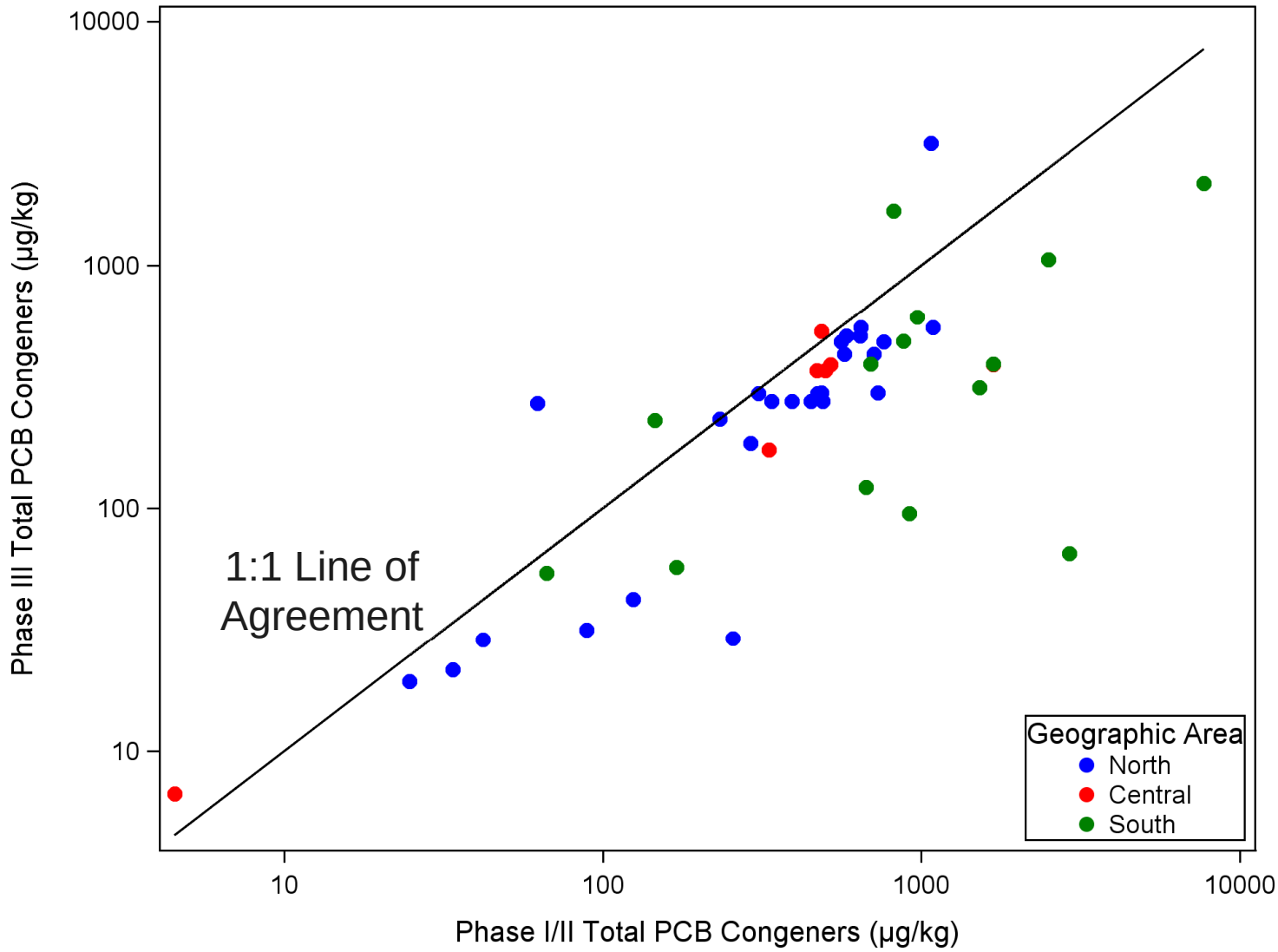
Notes:
All observations were detected values.
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
ng/kg = nanograms per kilogram

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

COMPARISON OF CO-LOCATED PHASE I/II AND PHASE III SEDIMENT CONCENTRATIONS: 2,3,7,8-TCDD

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-COMP-1



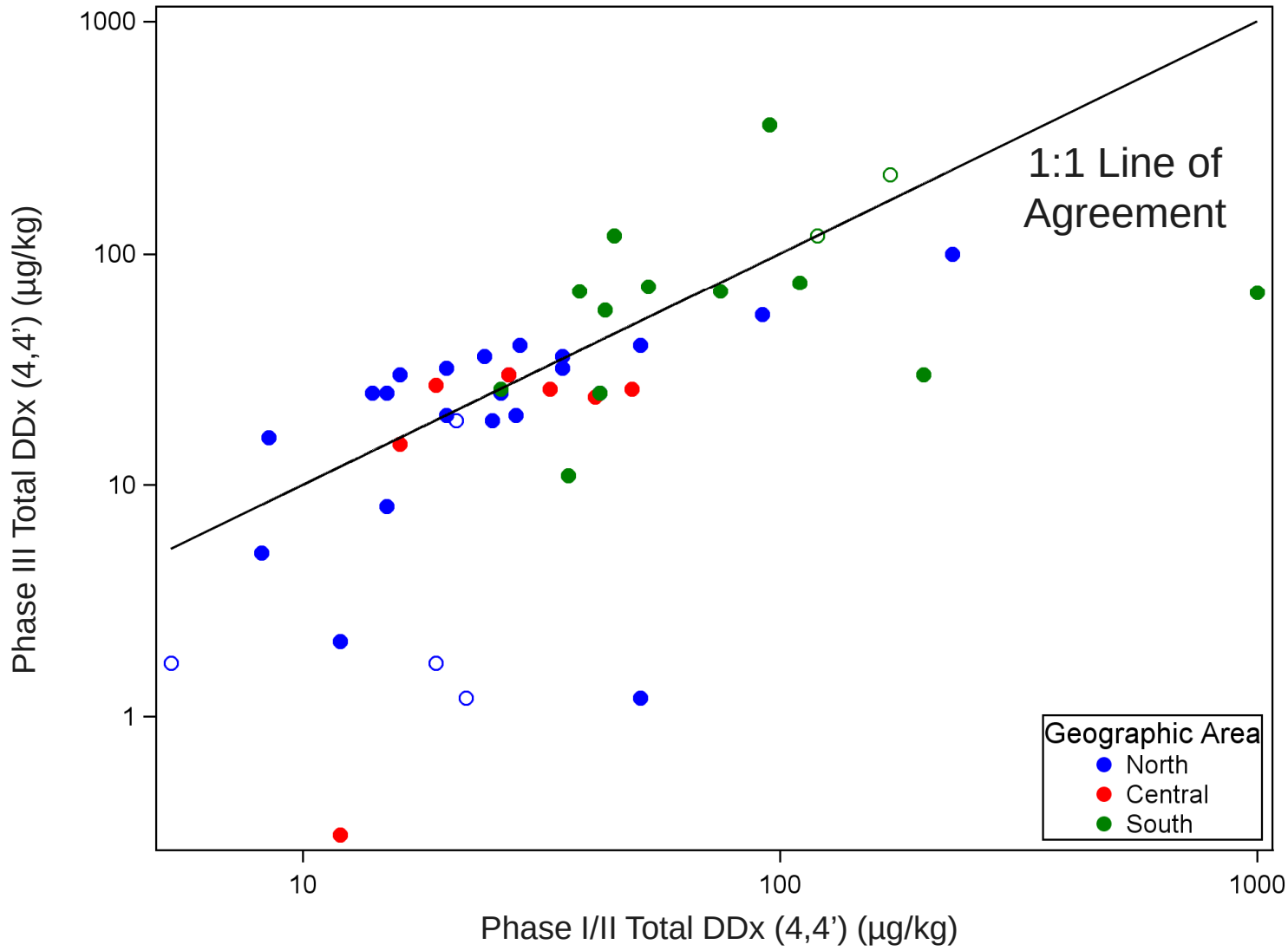
Notes:
All observations were detected values.
PCBs = polychlorinated biphenyls
µg/kg = micrograms per kilogram

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

COMPARISON OF CO-LOCATED PHASE I/II AND PHASE III SEDIMENT CONCENTRATIONS: TOTAL PCBS

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-COMP-2



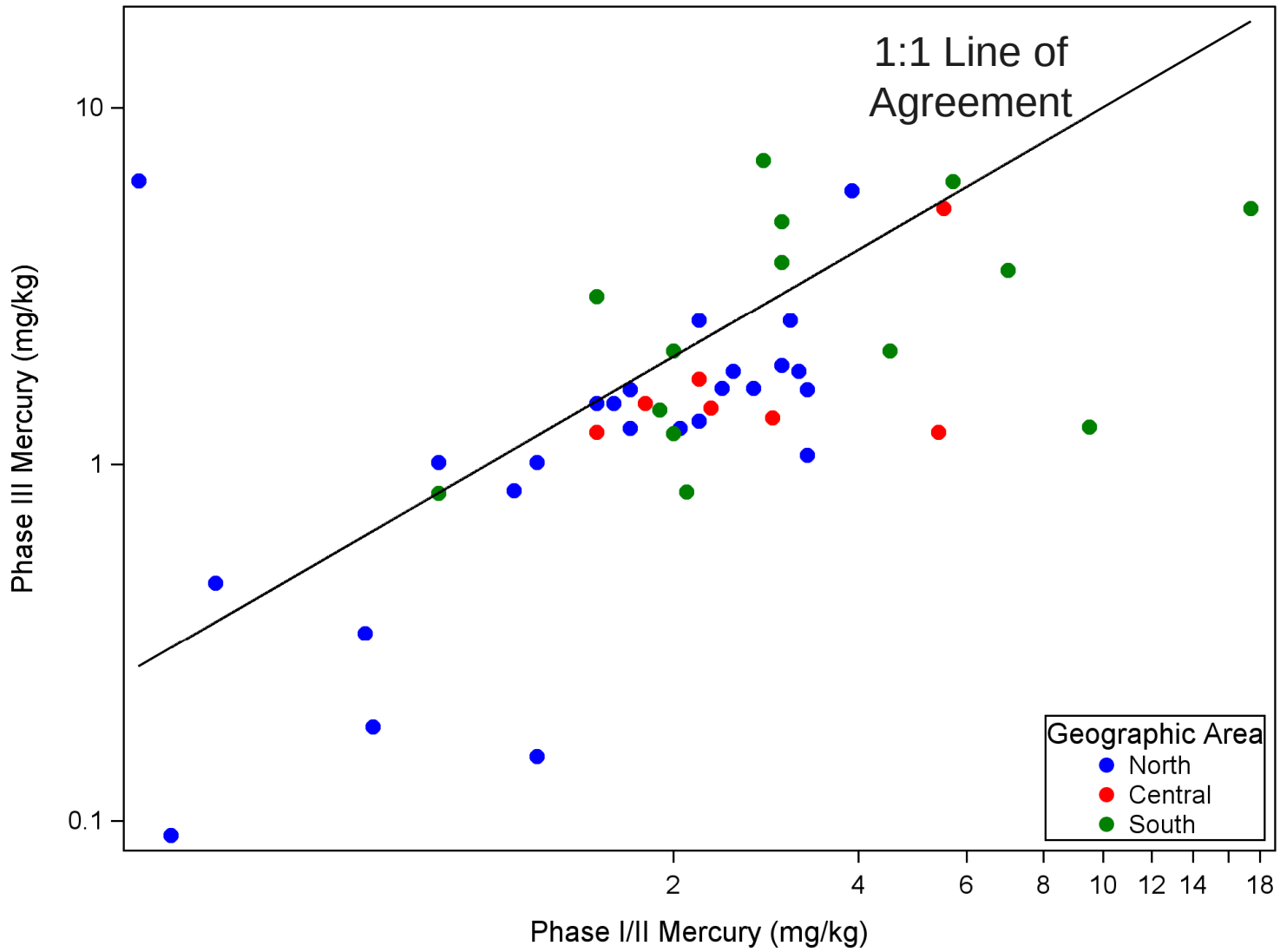
Notes:
Open circles indicate that the Phase I sample (but not Phase III sample) was not detected and is plotted at the value of the Phase I detection limit. All other samples were detected in all programs.
DDx = sum of dichlorodiphenyldichloroethane, dichlorodiphenyldichloroethylene, and dichlorodiphenyltrichloroethane
µg/kg = micrograms per kilogram

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

COMPARISON OF CO-LOCATED PHASE I/II AND PHASE III SEDIMENT CONCENTRATIONS: TOTAL DDX (4,4')

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-COMP-3



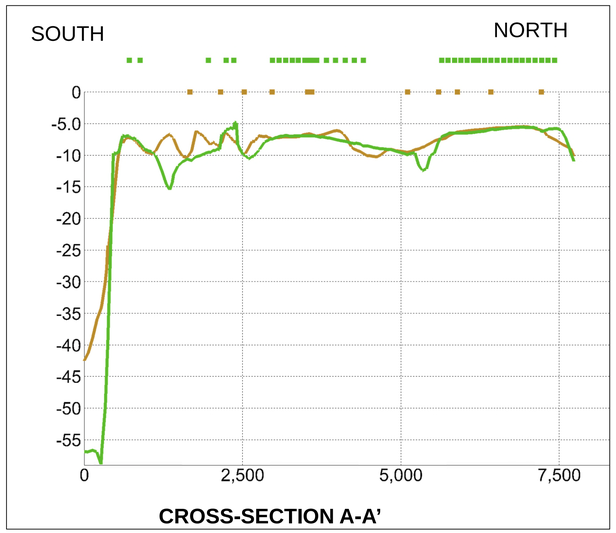
Notes:
All observations were detected values.
mg/kg = milligrams per kilogram

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION (OU3)
REMEDIAL INVESTIGATION REPORT

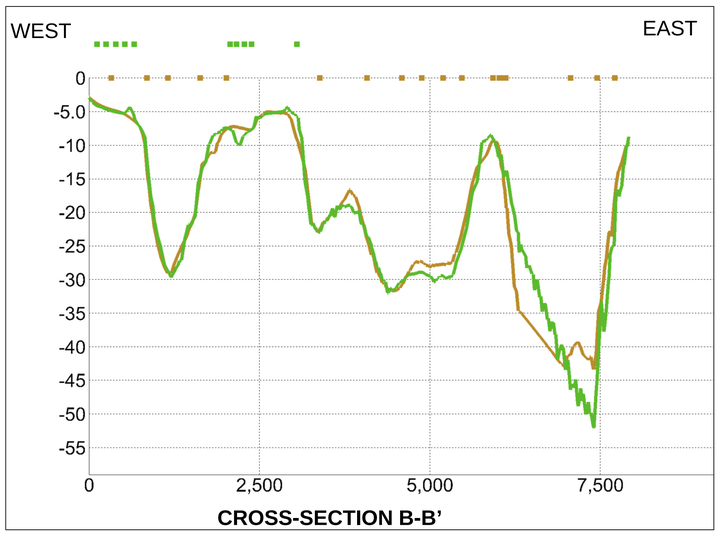
COMPARISON OF CO-LOCATED PHASE I/II AND PHASE III SEDIMENT CONCENTRATIONS: MERCURY

OXY Glenn Springs Holdings, Inc.
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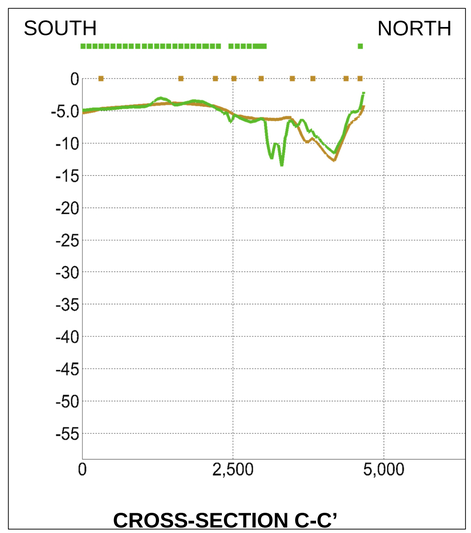
FIGURE
5-COMP-4



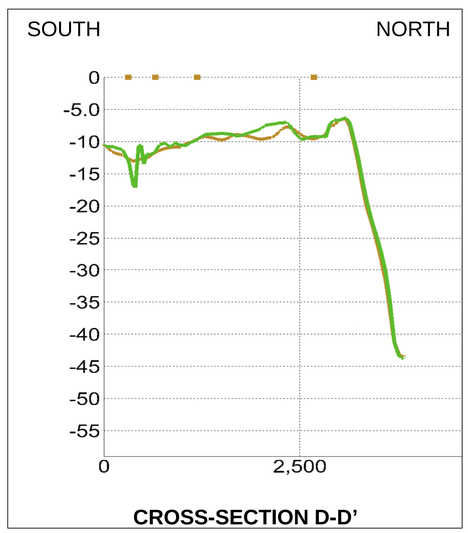
CROSS-SECTION A-A’



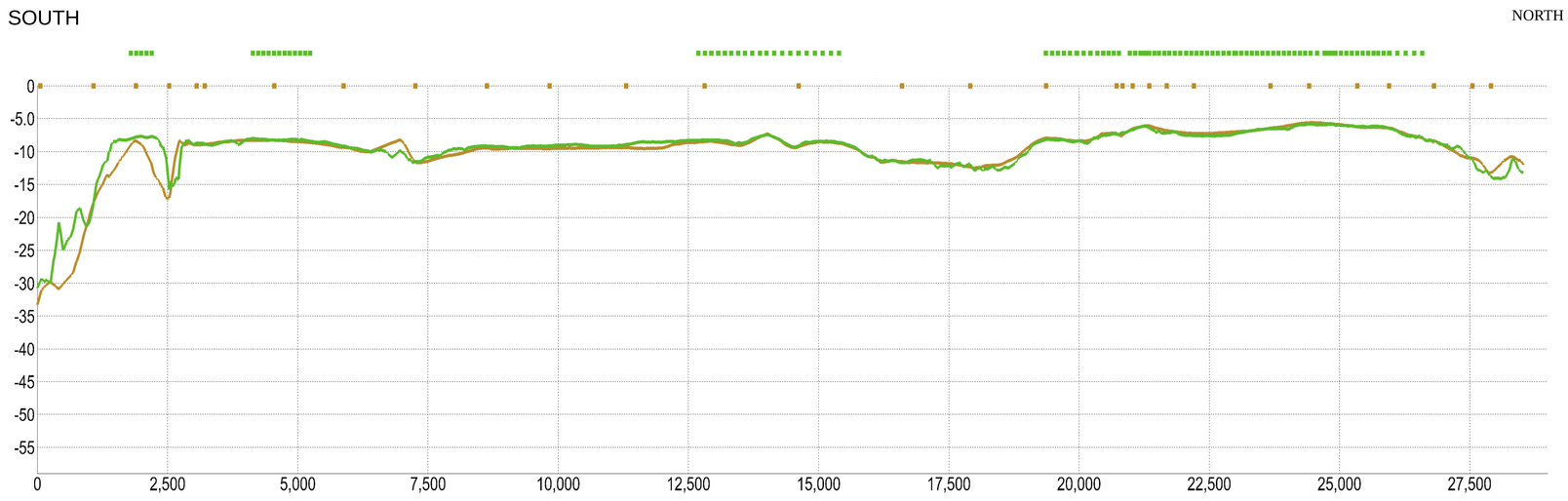
CROSS-SECTION B-B’



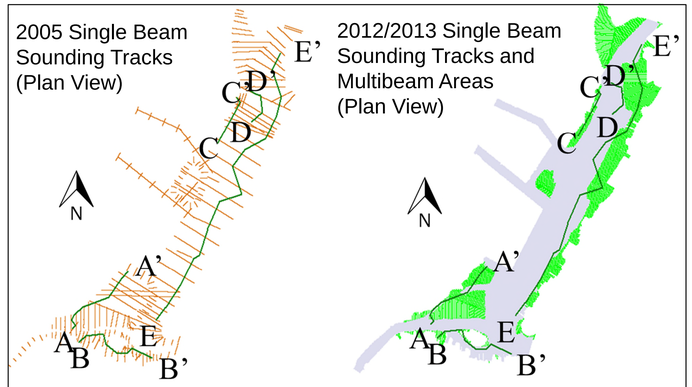
CROSS-SECTION C-C’



CROSS-SECTION D-D’



CROSS-SECTION E-E’



Inset Legend:
2005 Single Beam Sounding Tracks
2012/2013 Single Beam Sounding Tracks
Area of “Multi-Beam” Sounding Coverage (2012-2013)
Cross Section Traces

Cross-Sections Legend:
2005 Bathymetry (modeled surface)
2012 Bathymetry (modeled surface)
Note:
Lines show interpolated model bathymetry surface.
Dots show where single-beam sounding tracks were crossed.

Notes:
1.Vertical Exaggeration = 100X.
2.Samples up to 400 feet from cross-section trace project at native elevation.
3.Some sample locations shifted in display to avoid label overruns..

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

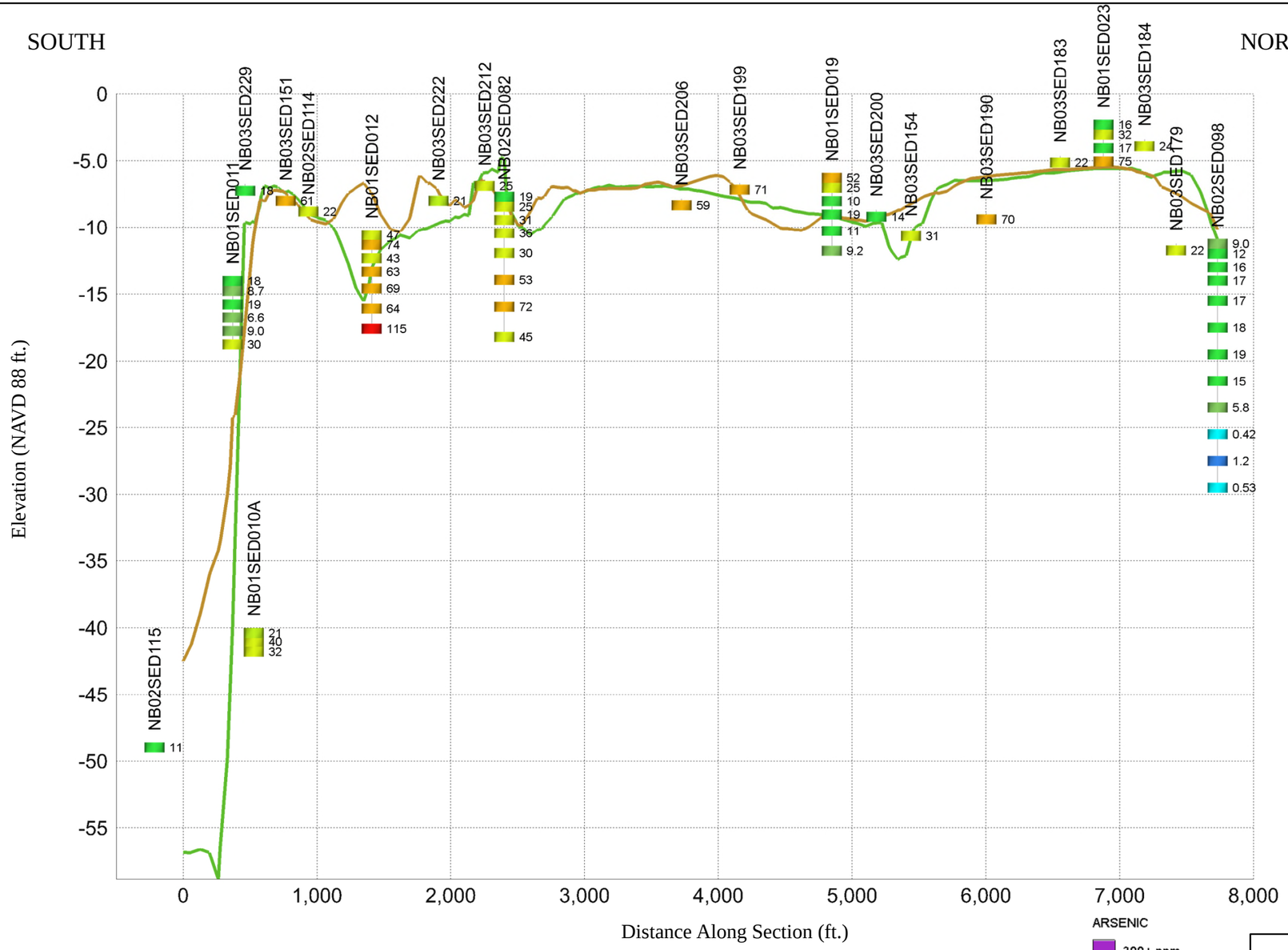
INTERSECTIONS WITH SINGLE BEAM SOUNDING TRACKS ALL CROSS-SECTIONS

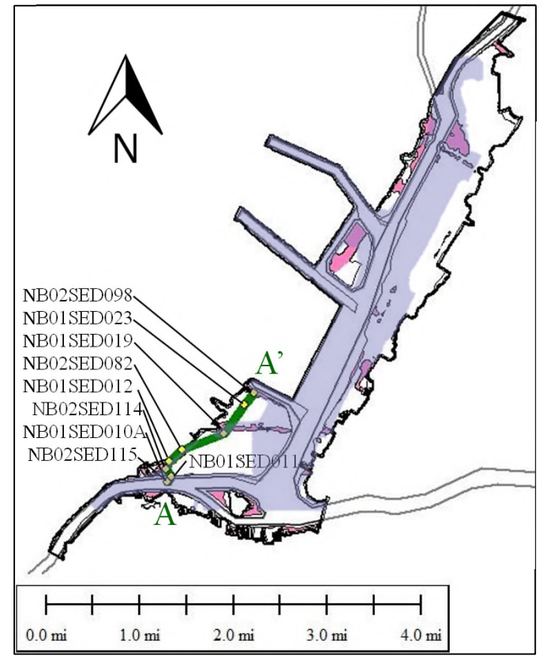
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-CS-1

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206 17

ARSENIC

- 300+ ppm
- 200 - <300 ppm
- 100 - <200 ppm
- 50 - <100 ppm
- 20 - <50 ppm
- 10 - <20 ppm
- 5 - <10 ppm
- 1 - <5 ppm
- <1 ppm
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION A-A' (FACING WEST) – ARSENIC

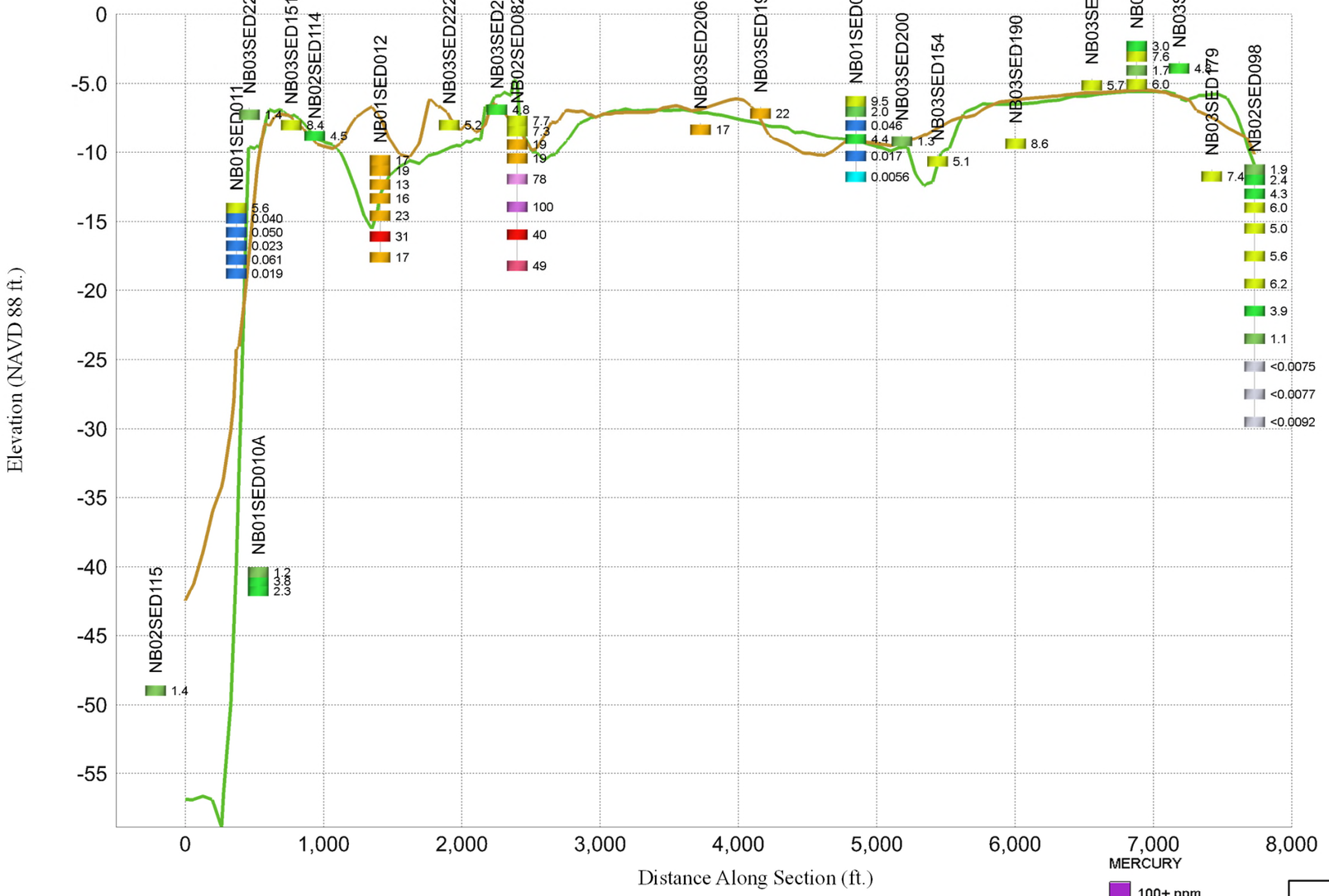
Glenn Springs Holdings, Inc.
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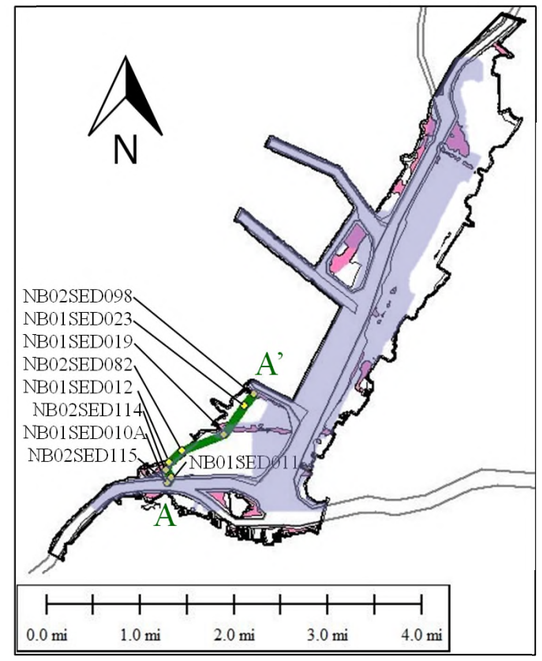
FIGURE

5-CS-2

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

MERCURY

- 100+ ppm
- 50 - <100 ppm
- 25 - <50 ppm
- 10 - <25 ppm
- 5 - <10 ppm
- 2 - <5 ppm
- 1 - <2 ppm
- 0.01 - <1 ppm
- <0.01 ppm
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

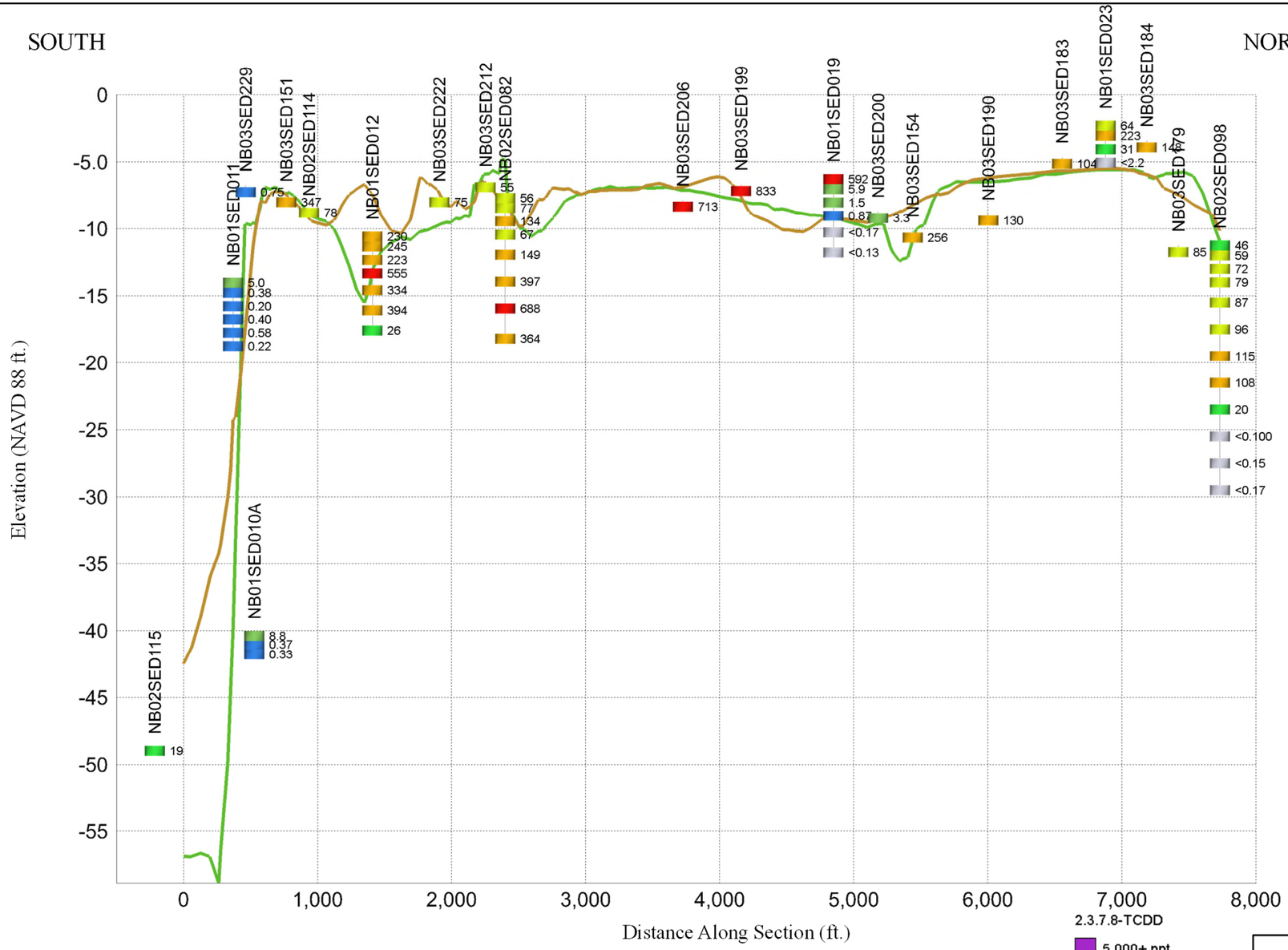
CROSS-SECTION A-A' (FACING WEST) – MERCURY

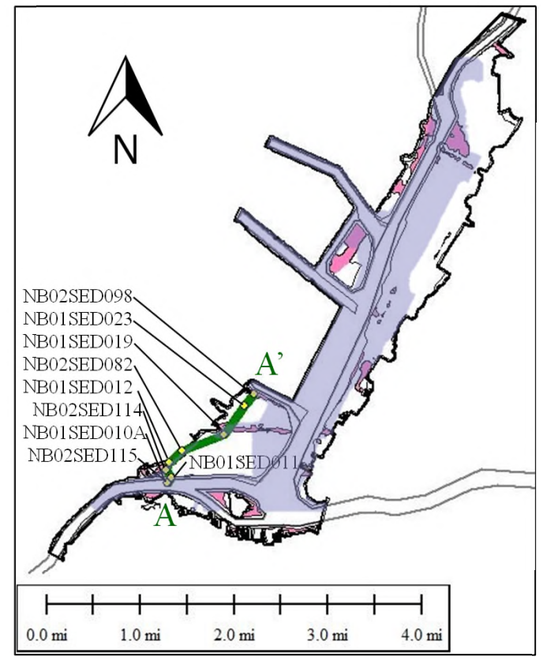
OXY Glenn Springs Holdings, Inc.
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FIGURE
5-CS-3

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

2,3,7,8-TCDD

- 5,000+ ppt
- 1,000 - <5,000 ppt
- 500 - <1,000 ppt
- 100 - <500 ppt
- 50 - <100 ppt
- 10 - <50 ppt
- 1 - <10 ppt
- 0.1 - <1 ppt
- <0.1 ppt
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

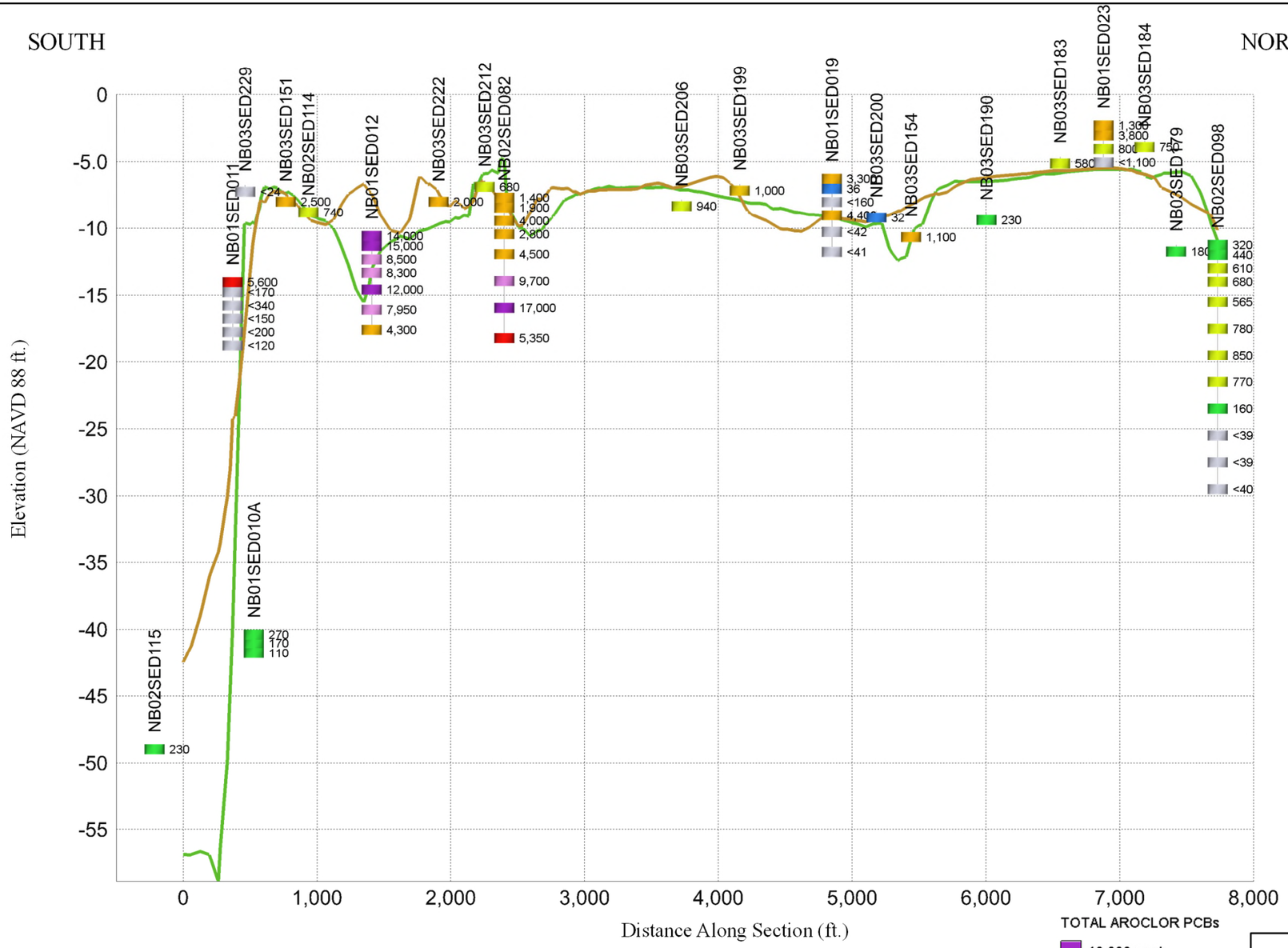
CROSS-SECTION A-A' (FACING WEST) – 2,3,7,8-TCDD

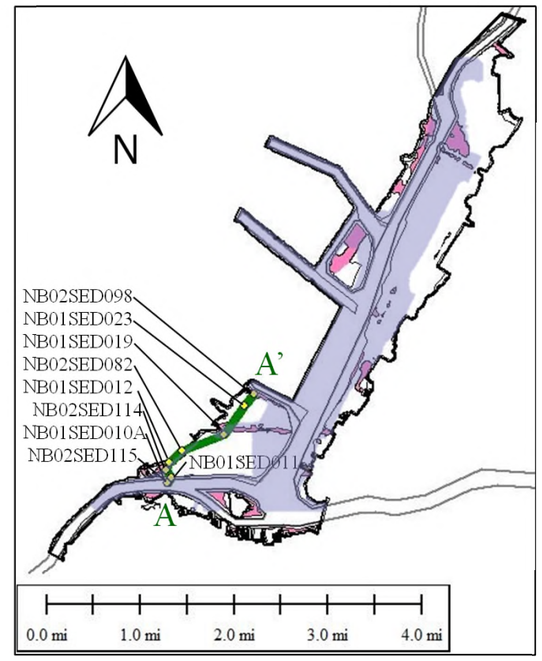
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FIGURE
5-CS-4

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

TOTAL AROCLOR PCBs

- 10,000+ ppb
- 7,500 - <10,000 ppb
- 5,000 - <7,500 ppb
- 1,000 - <5,000 ppb
- 500 - <1,000 ppb
- 100 - <500 ppb
- 50 - <100 ppb
- 10 - <50 ppb
- <10 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION A-A' (FACING WEST)

TOTAL AROCLOR PCBs

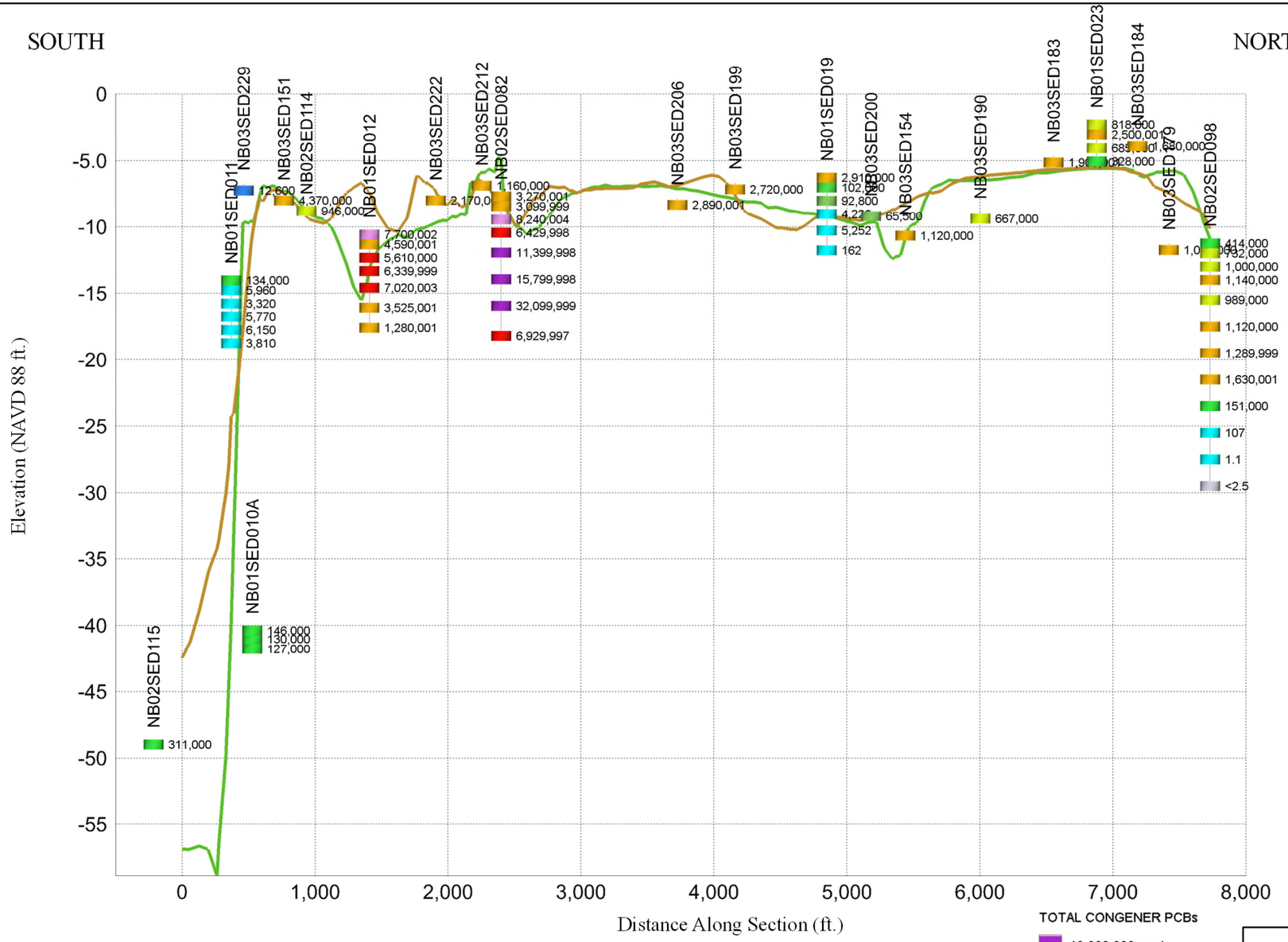
OXY Glenn Springs Holdings, Inc.
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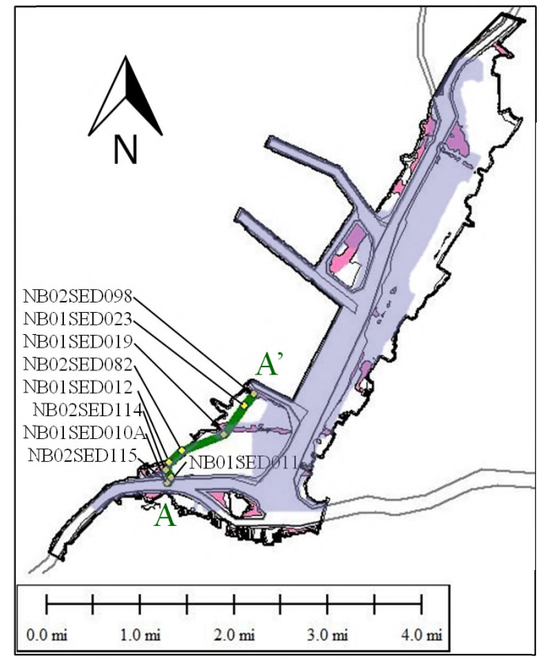
FIGURE

5-CS-5

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample — NB03SED206 — 17

TOTAL CONGENER PCBs

- 10,000,000+ ppt
- 7,500,000 - <10,000,000 ppt
- 5,000,000 - <7,500,000 ppt
- 1,000,000 - <5,000,000 ppt
- 500,000 - <1,000,000 ppt
- 100,000 - <500,000 ppt
- 50,000 - <100,000 ppt
- 10,000 - <50,000 ppt
- <10,000 ppt
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION A-A' (FACING WEST)

TOTAL CONGENER PCBs

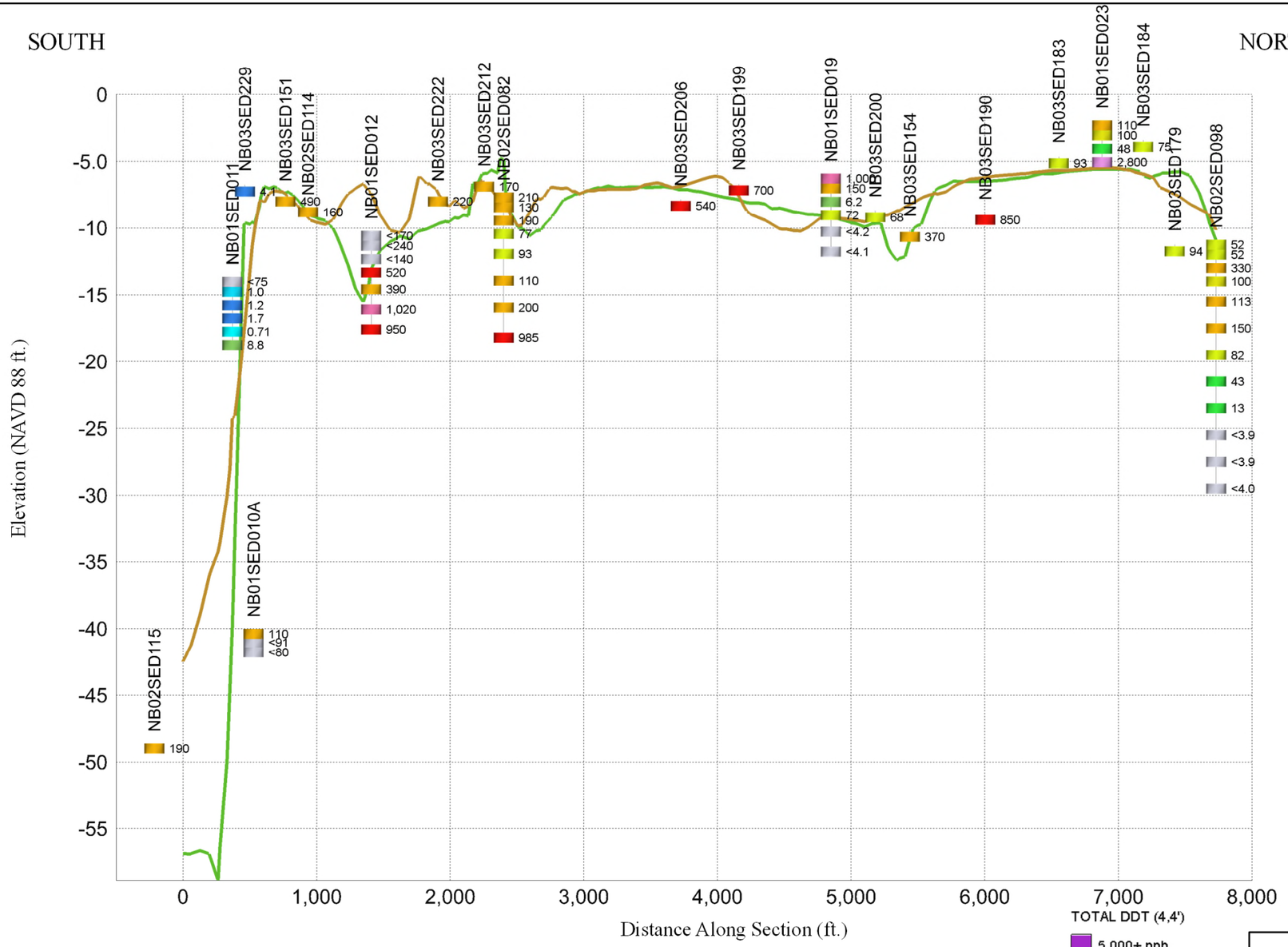
OXY Glenn Springs Holdings, Inc.
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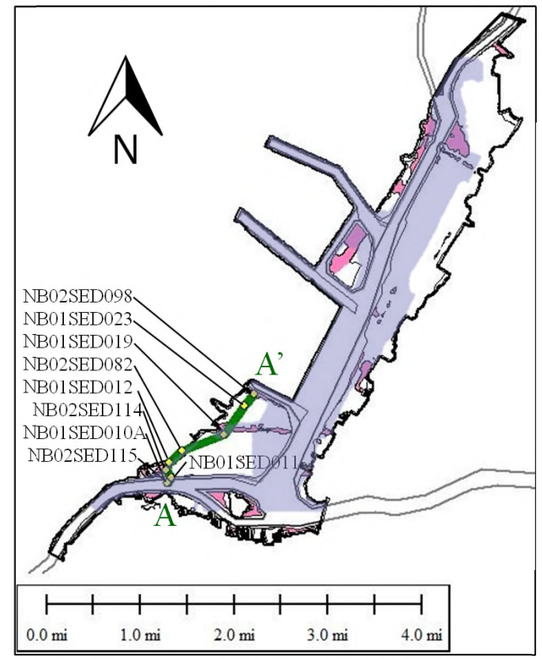
FIGURE

5-CS-6

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

TOTAL DDT (4,4')

- 5,000+ ppb
- 1,000 - <5,000 ppb
- 500 - <1,000 ppb
- 100 - <500 ppb
- 50 - <100 ppb
- 10 - <50 ppb
- 5 - <10 ppb
- 1 - <5 ppb
- <1 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION A-A' (FACING WEST) – TOTAL DDx (4,4')

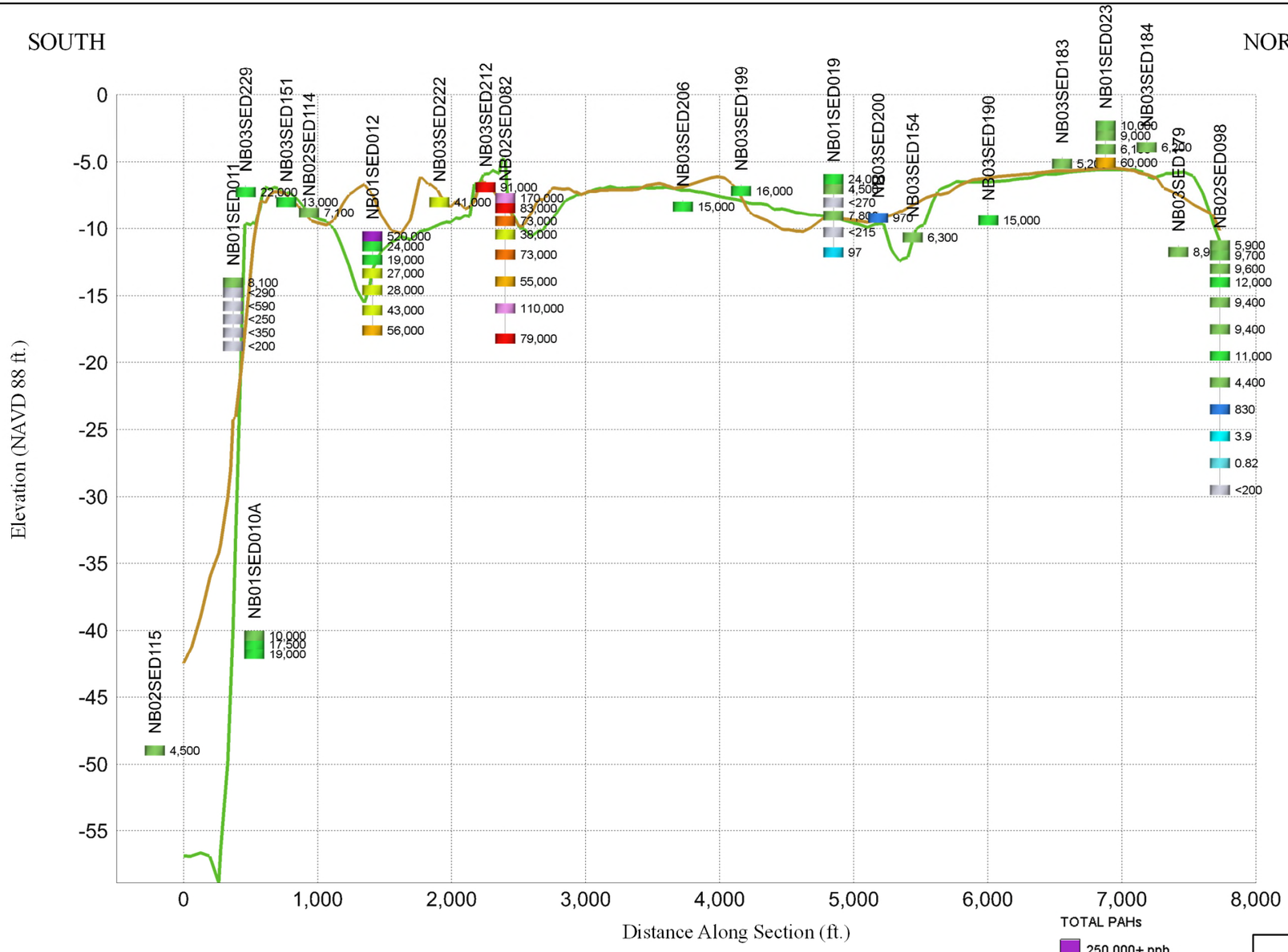
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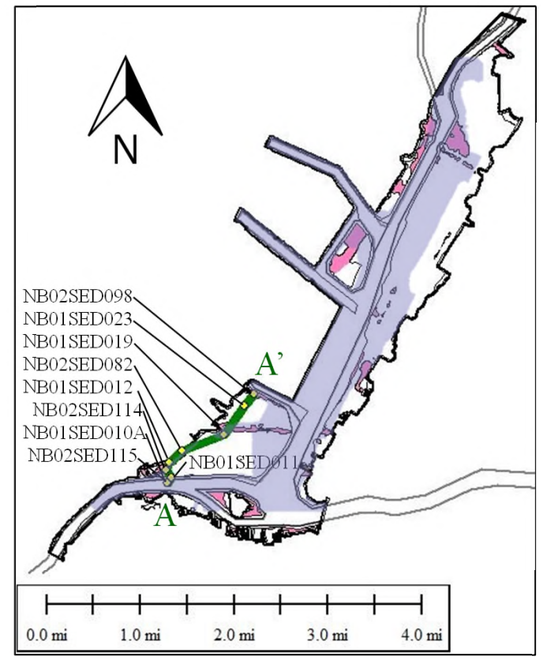
FIGURE

5-CS-7

SOUTH

NORTH





Inset Legend:

- NBSA Study Area Boundary
- Area of "Multi-Beam" Sounding Coverage (2012-2013)
- Cross Section Trace with Primary Borings
- Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

- 2005 Bathymetry
- 2012 Bathymetry
- Soil Boring and Sample (NB03SED206 / 17)

TOTAL PAHs

- 250,000+ ppb
- 100,000 - <250,000 ppb
- 75,000 - <100,000 ppb
- 50,000 - <75,000 ppb
- 25,000 - <50,000 ppb
- 10,000 - <25,000 ppb
- 1,000 - <10,000 ppb
- 100 - <1,000 ppb
- <100 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

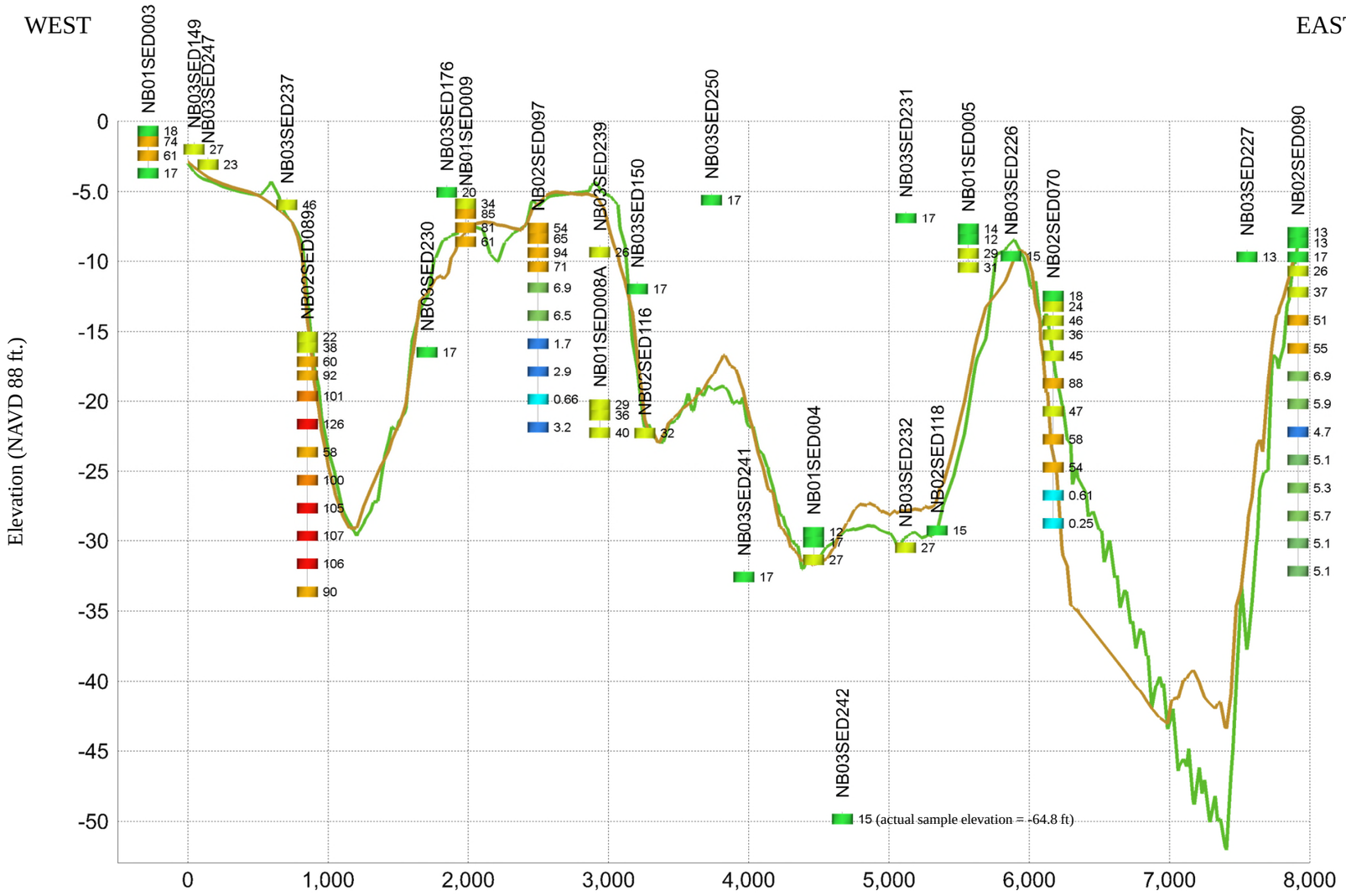
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

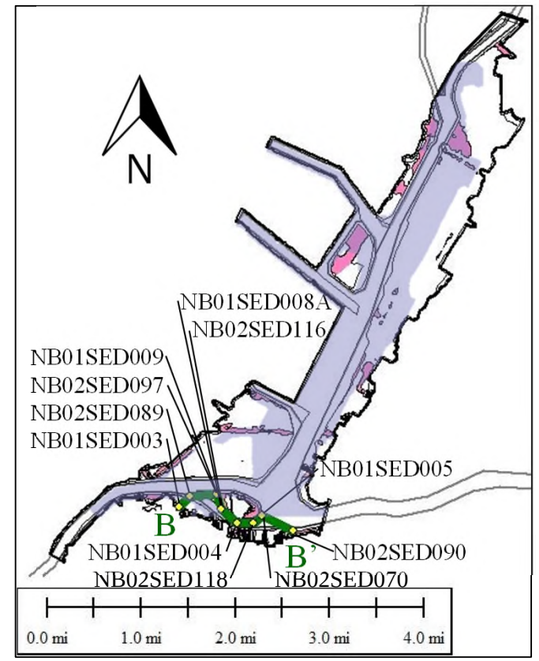
REMEDIAL INVESTIGATION REPORT

CROSS-SECTION A-A' (FACING WEST) – TOTAL PAHs

Glenn Springs Holdings, Inc.
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FIGURE
5-CS-8





Inset Legend:

- NBSA Study Area Boundary
- Area of "Multi-Beam" Sounding Coverage (2012-2013)
- Cross Section Trace with Primary Borings
- Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

- 2005 Bathymetry
- 2012 Bathymetry
- Soil Boring and Sample (NB03SED206, 17)

ARSENIC

- 300+ ppm
- 200 - <300 ppm
- 100 - <200 ppm
- 50 - <100 ppm
- 20 - <50 ppm
- 10 - <20 ppm
- 5 - <10 ppm
- 1 - <5 ppm
- <1 ppm
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

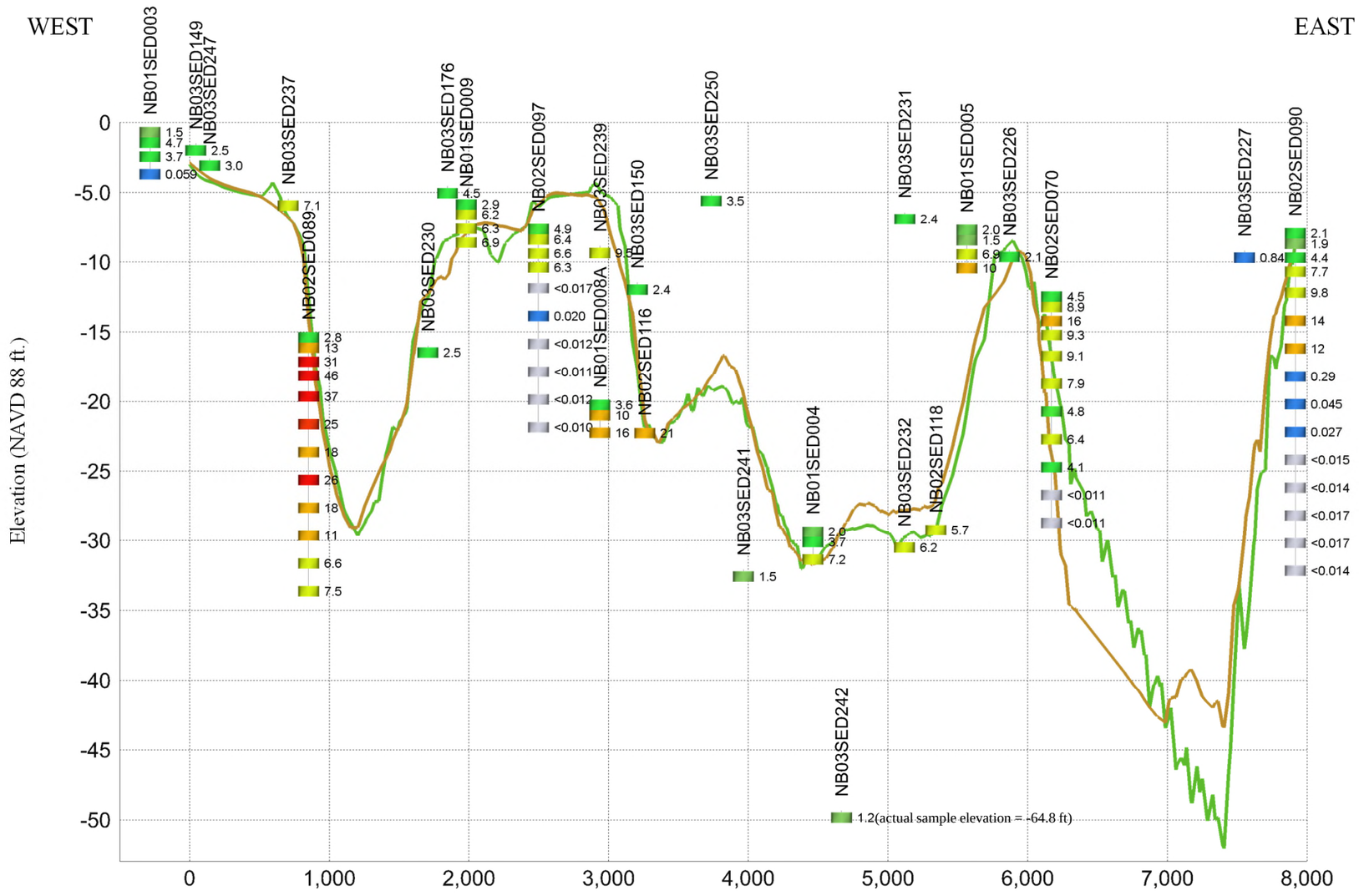
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

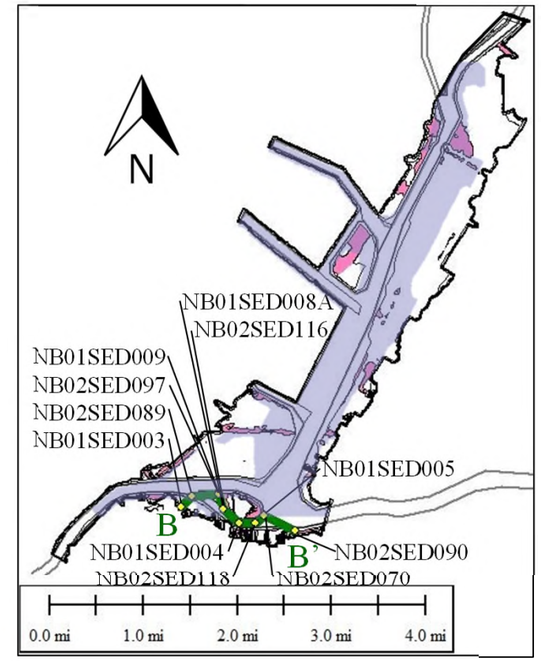
REMEDIAL INVESTIGATION REPORT

CROSS-SECTION B-B' (FACING NORTH) – ARSENIC

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-CS-9





Inset Legend:

- NBSA Study Area Boundary
- Area of "Multi-Beam" Sounding Coverage (2012-2013)
- Cross Section Trace with Primary Borings
- Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

- 2005 Bathymetry
- 2012 Bathymetry
- Soil Boring and Sample (NB03SED206, 17)

MERCURY

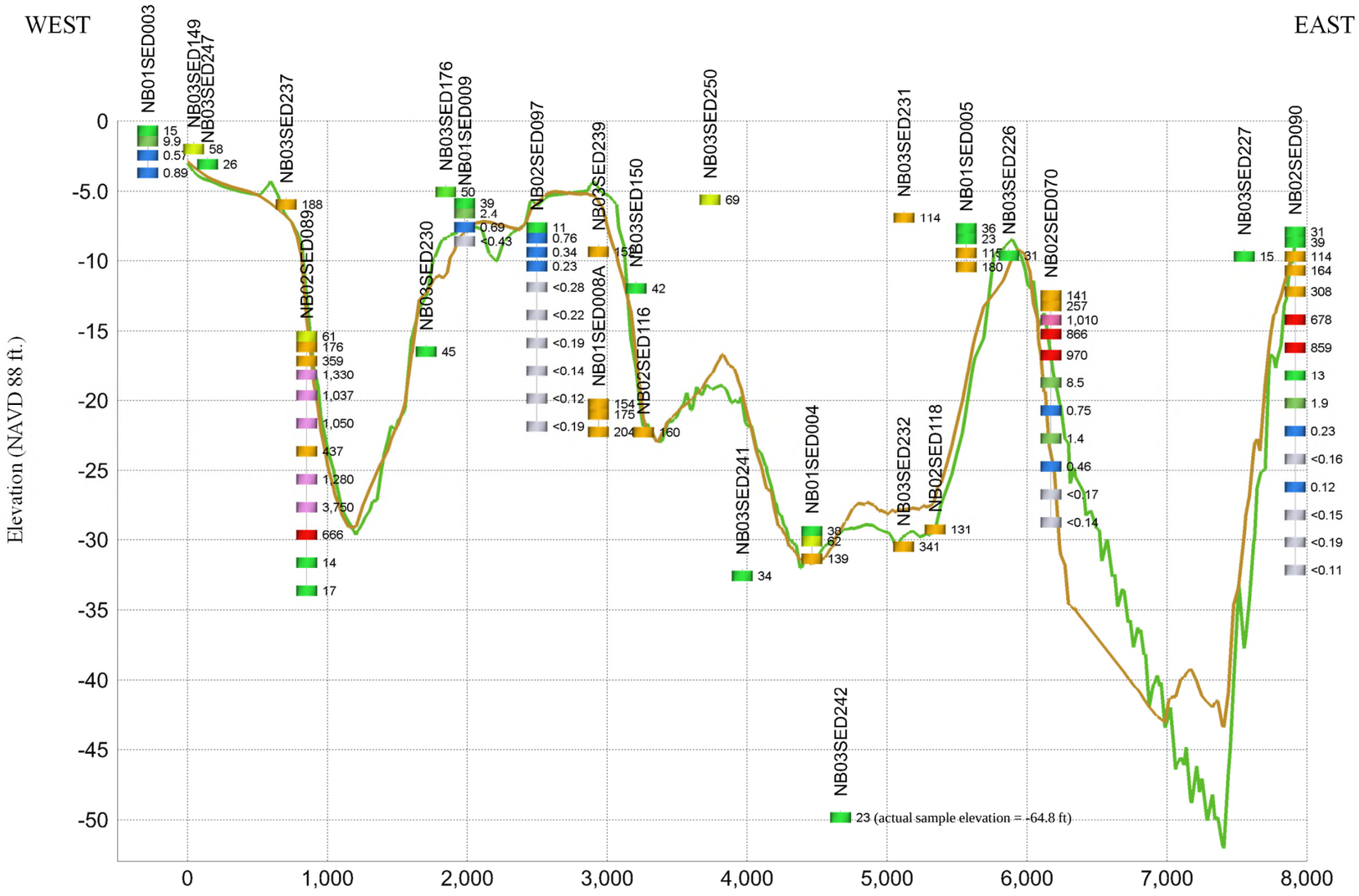
- 100+ ppm
- 50 - <100 ppm
- 25 - <50 ppm
- 10 - <25 ppm
- 5 - <10 ppm
- 2 - <5 ppm
- 1 - <2 ppm
- 0.01 - <1 ppm
- <0.01 ppm
- Non-detect

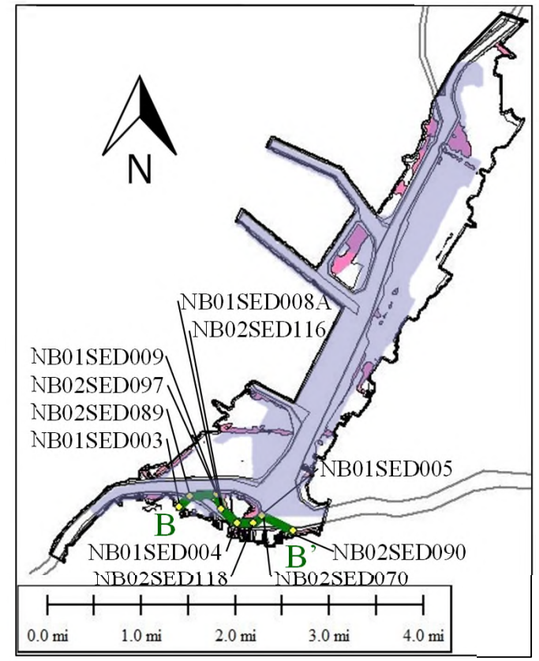
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CROSS-SECTION B-B' (FACING NORTH) – MERCURY

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-CS-10





Inset Legend:

- NBSA Study Area Boundary
- Area of "Multi-Beam" Sounding Coverage (2012-2013)
- Cross Section Trace with Primary Borings
- Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

- 2005 Bathymetry
- 2012 Bathymetry
- Soil Boring and Sample (NB03SED206, 17)

2.3.7.8-TCDD

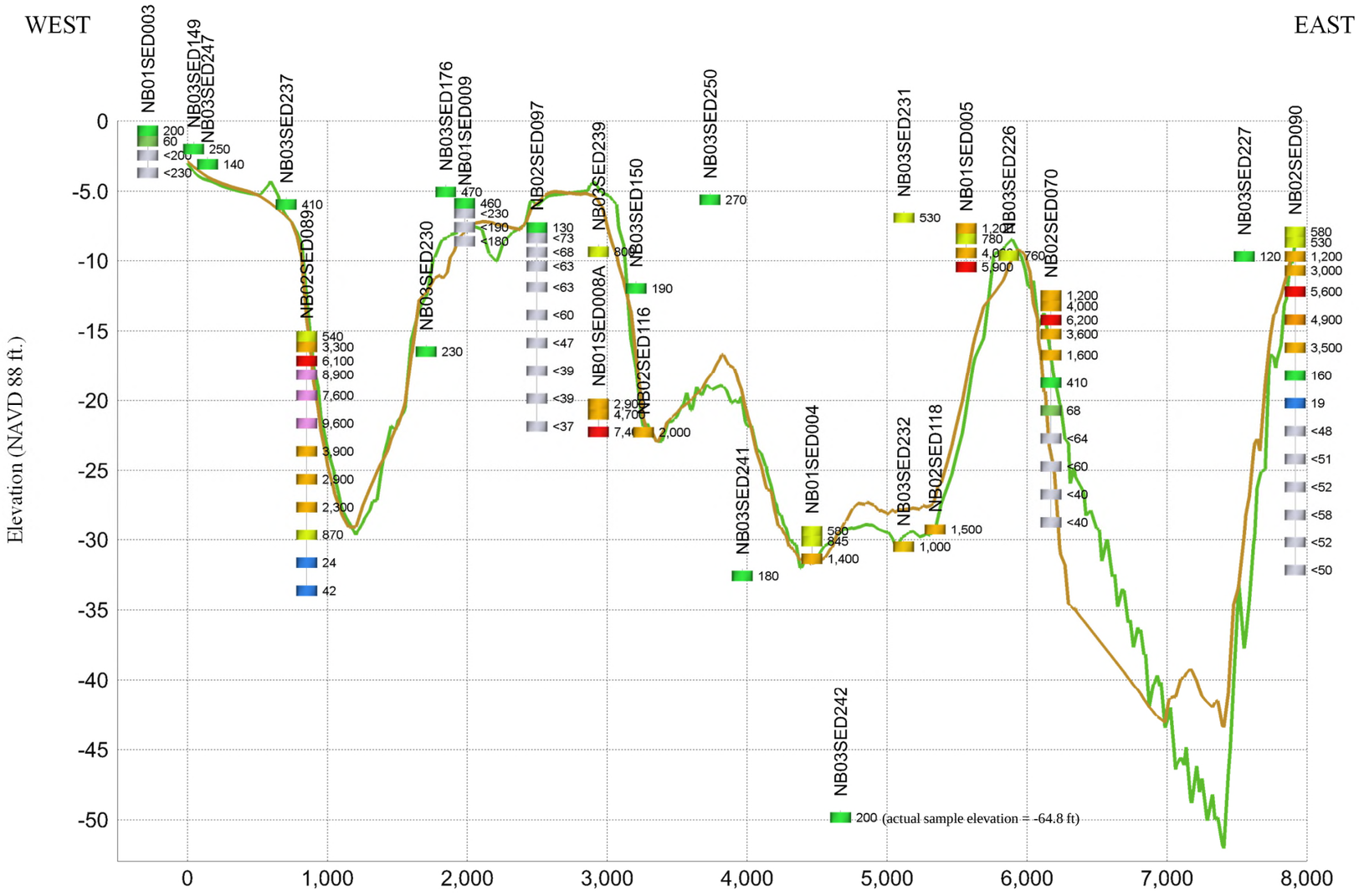
- 5,000+ ppt
- 1,000 - <5,000 ppt
- 500 - <1,000 ppt
- 100 - <500 ppt
- 50 - <100 ppt
- 10 - <50 ppt
- 1 - <10 ppt
- 0.1 - <1 ppt
- <0.1 ppt
- Non-detect

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

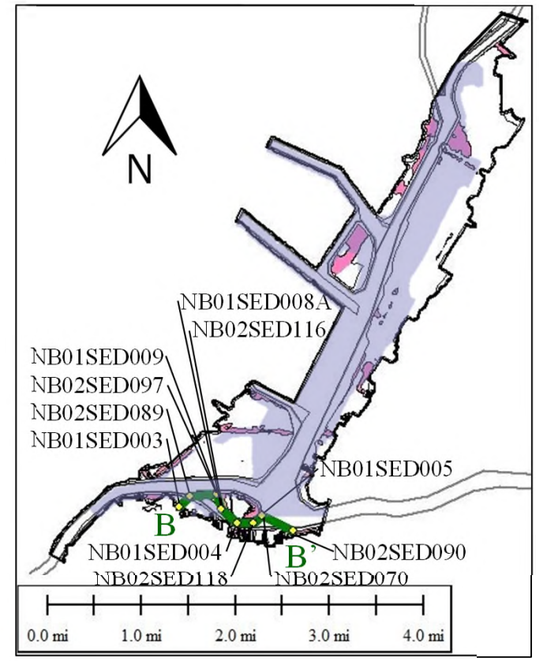
CROSS-SECTION B-B' (FACING NORTH) – 2,3,7,8-TCDD

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FIGURE
5-CS-11



Distance Along Section (ft.)



Inset Legend:

- NBSA Study Area Boundary
- Area of "Multi-Beam" Sounding Coverage (2012-2013)
- Cross Section Trace with Primary Borings
- Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

- 2005 Bathymetry
- 2012 Bathymetry
- Soil Boring and Sample (NB03SED206, 17)

TOTAL AROCLOR PCBs

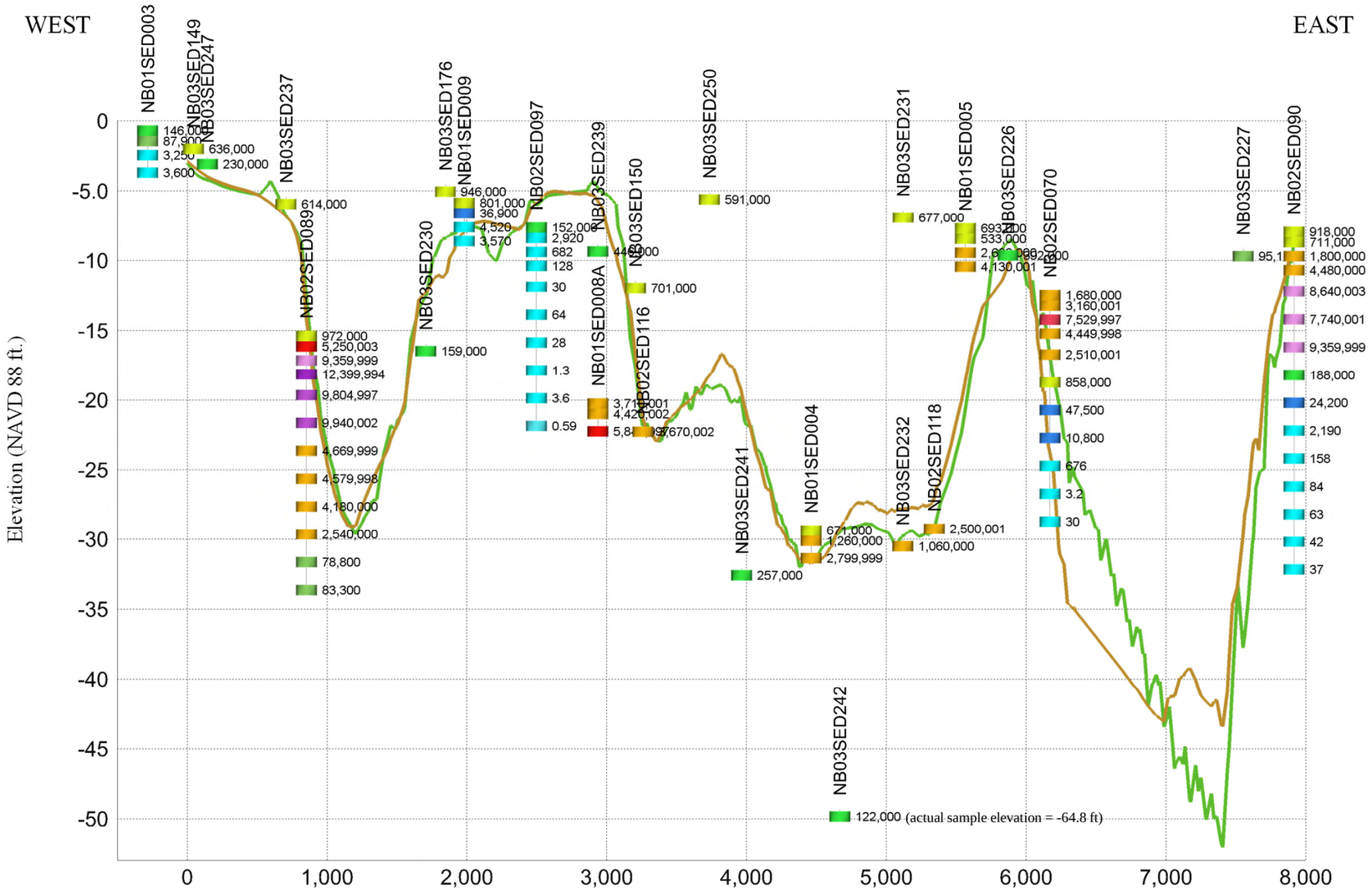
- 10,000+ ppb
- 7,500 - <10,000 ppb
- 5,000 - <7,500 ppb
- 1,000 - <5,000 ppb
- 500 - <1,000 ppb
- 100 - <500 ppb
- 50 - <100 ppb
- 10 - <50 ppb
- <10 ppb
- Non-detect

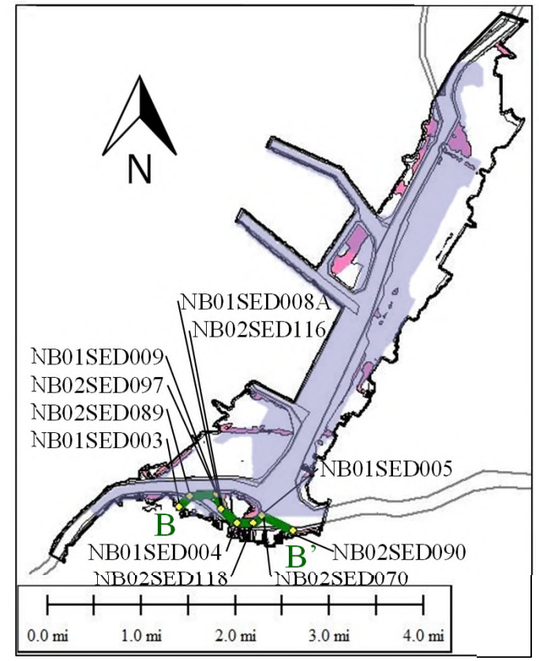
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CROSS-SECTION B-B' (FACING NORTH)
TOTAL AROCLOR PCBs

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-CS-12





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

TOTAL CONGENER PCBs

- 10,000,000+ ppt
- 7,500,000 - <10,000,000 ppt
- 5,000,000 - <7,500,000 ppt
- 1,000,000 - <5,000,000 ppt
- 500,000 - <1,000,000 ppt
- 100,000 - <500,000 ppt
- 50,000 - <100,000 ppt
- 10,000 - <50,000 ppt
- <10,000 ppt
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

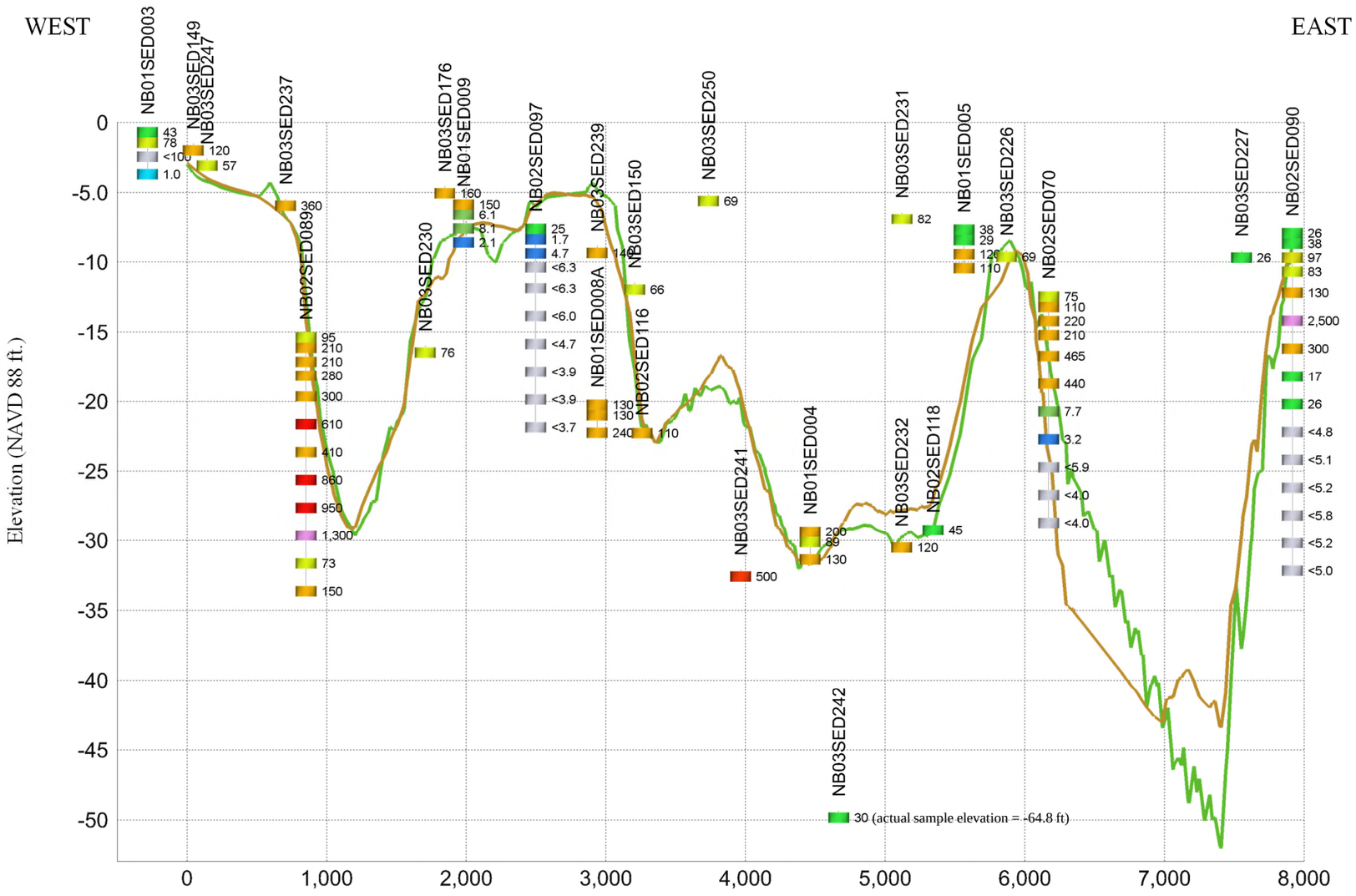
CROSS-SECTION B-B' (FACING NORTH)

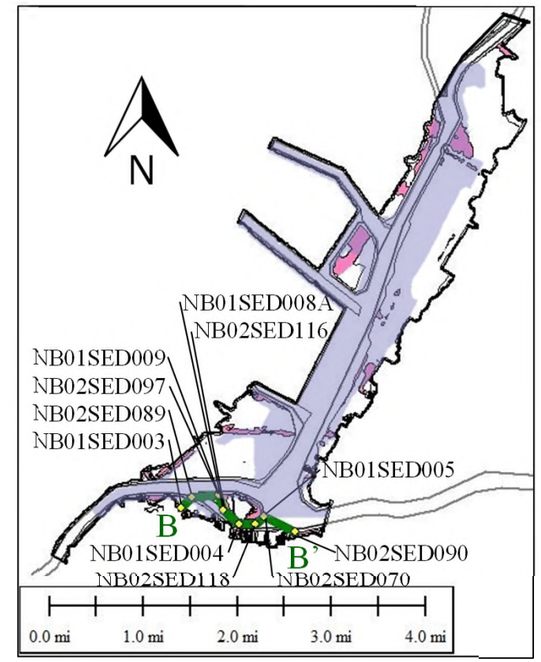
TOTAL CONGENER PCBs

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE

5-CS-13





Inset Legend:

- NBSA Study Area Boundary
- Area of "Multi-Beam" Sounding Coverage (2012-2013)
- Cross Section Trace with Primary Borings
- Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

- 2005 Bathymetry
- 2012 Bathymetry
- Soil Boring and Sample (NB03SED206, 17)

TOTAL DDT (4,4')

- 5,000+ ppb
- 1,000 - <5,000 ppb
- 500 - <1,000 ppb
- 100 - <500 ppb
- 50 - <100 ppb
- 10 - <50 ppb
- 5 - <10 ppb
- 1 - <5 ppb
- <1 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

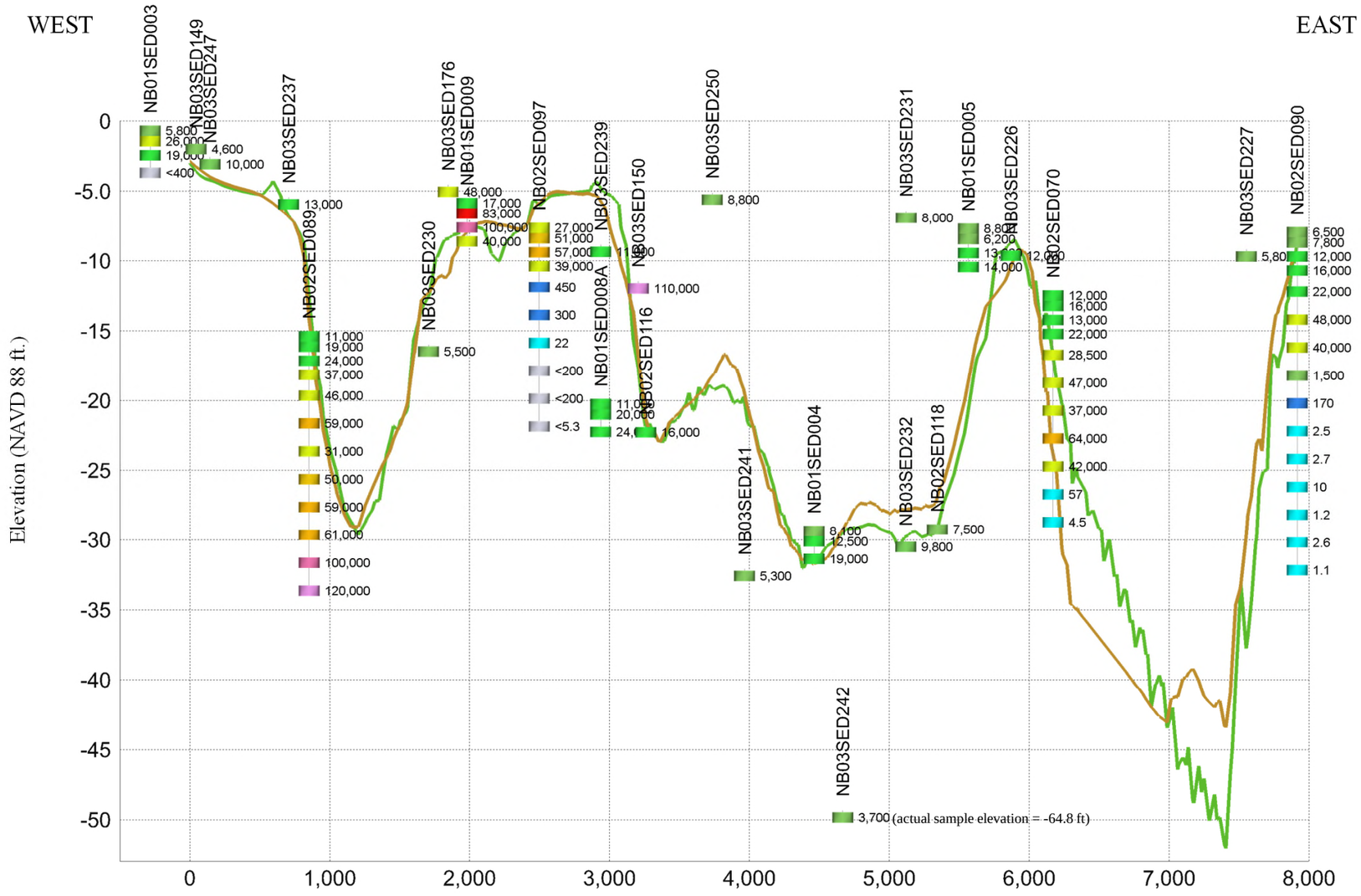
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

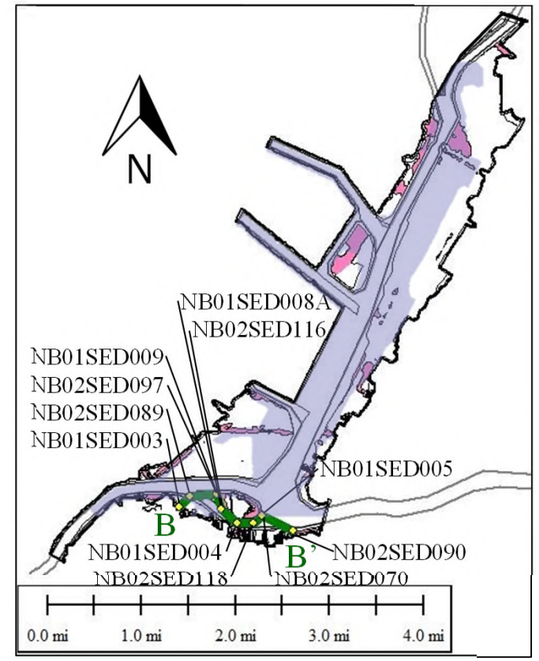
REMEDIAL INVESTIGATION REPORT

CROSS-SECTION B-B' (FACING NORTH) – TOTAL DDx (4,4')

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-CS-14





Inset Legend:

- NBSA Study Area Boundary
- Area of "Multi-Beam" Sounding Coverage (2012-2013)
- Cross Section Trace with Primary Borings
- Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

- 2005 Bathymetry
- 2012 Bathymetry
- Soil Boring and Sample (NB03SED206, 17)

TOTAL PAHs

- 250,000+ ppb
- 100,000 - <250,000 ppb
- 75,000 - <100,000 ppb
- 50,000 - <75,000 ppb
- 25,000 - <50,000 ppb
- 10,000 - <25,000 ppb
- 1,000 - <10,000 ppb
- 100 - <1,000 ppb
- <100 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

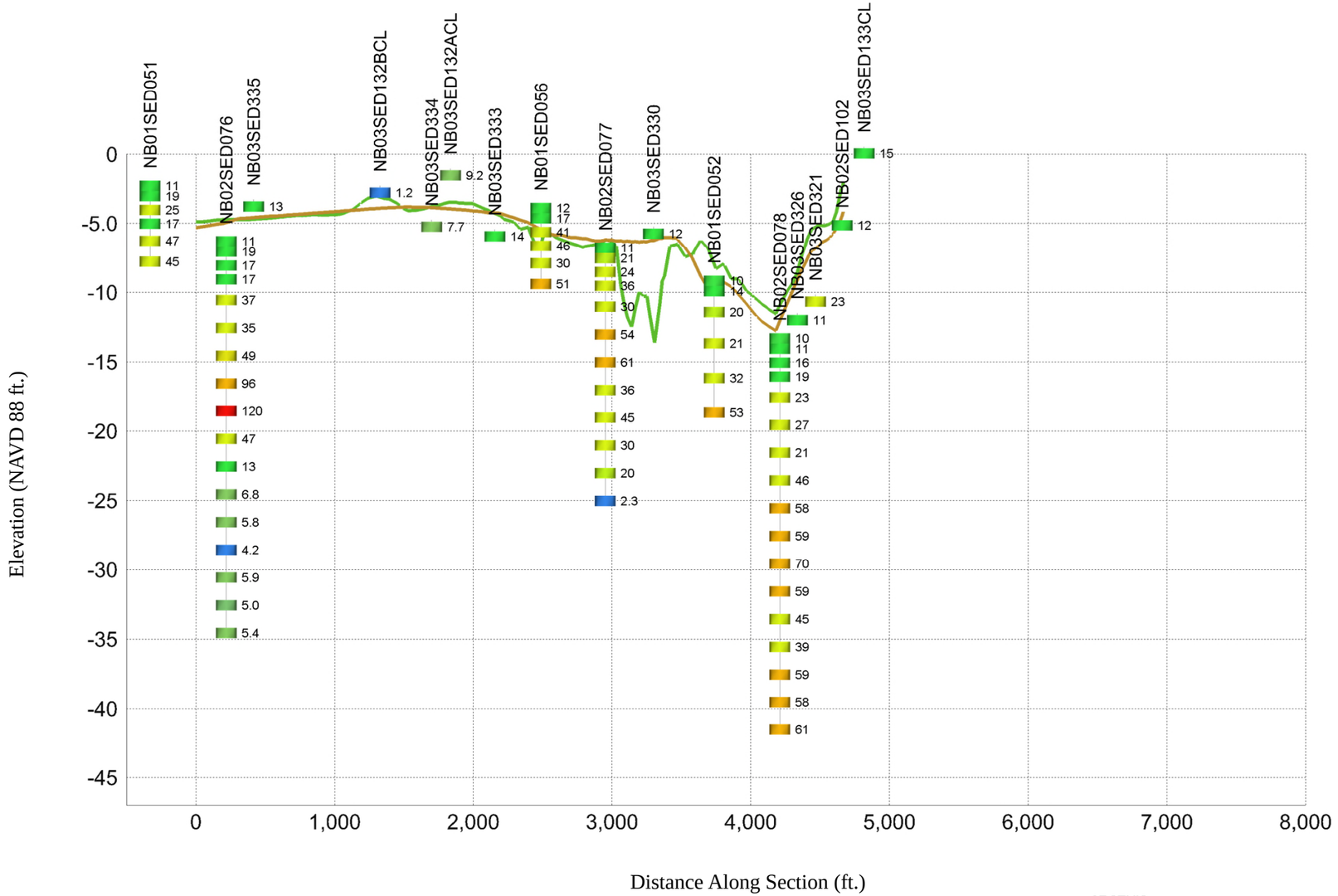
CROSS-SECTION B-B' (FACING NORTH) – TOTAL PAHs

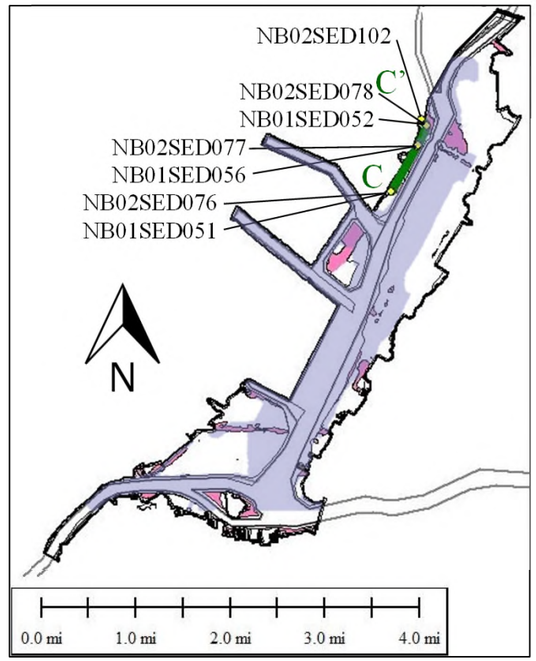
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-CS-15

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206
17

ARSENIC

- 300+ ppm
- 200 - <300 ppm
- 100 - <200 ppm
- 50 - <100 ppm
- 20 - <50 ppm
- 10 - <20 ppm
- 5 - <10 ppm
- 1 - <5 ppm
- <1 ppm
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION C-C' (FACING WEST) – ARSENIC

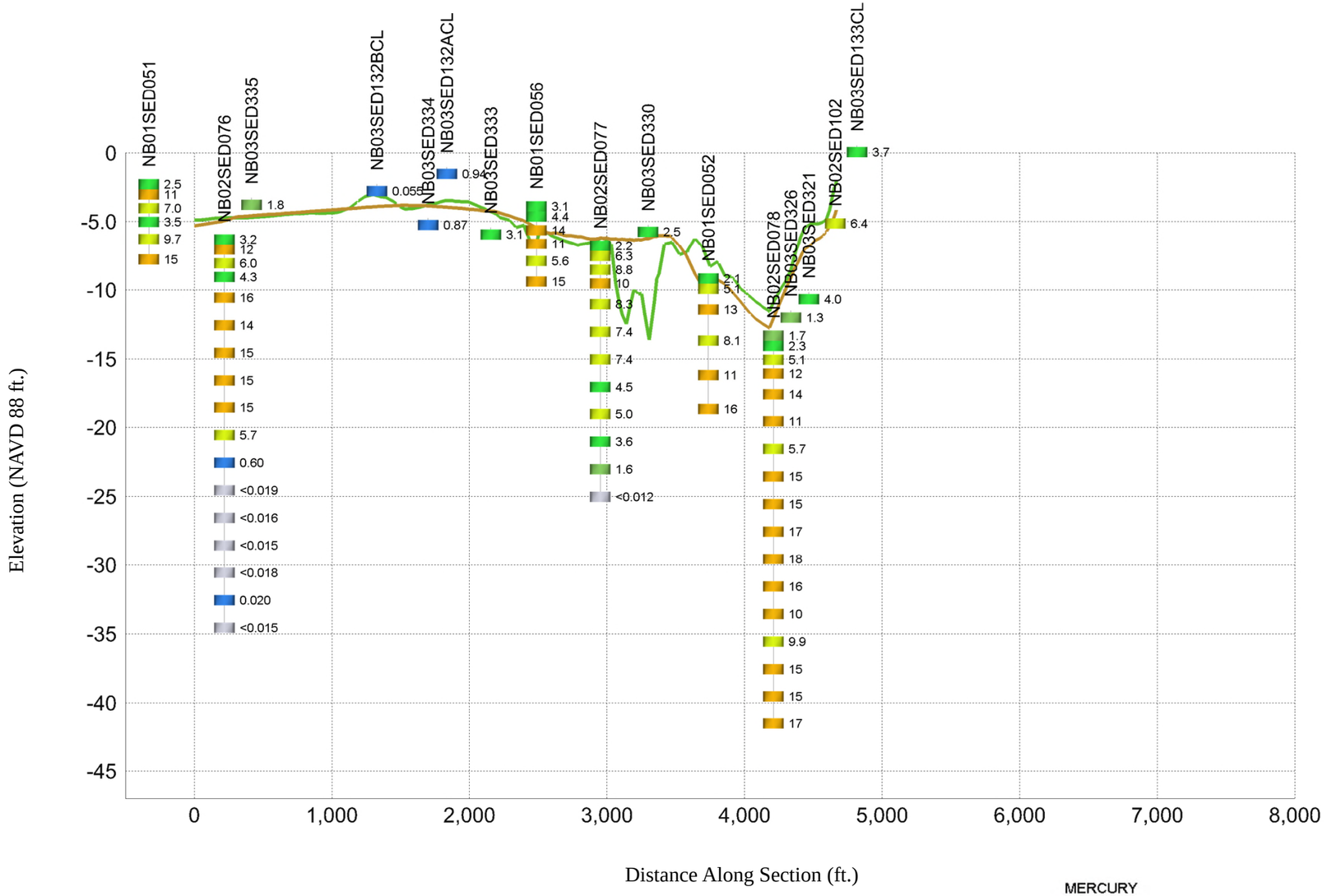
OXY Glenn Springs Holdings, Inc.
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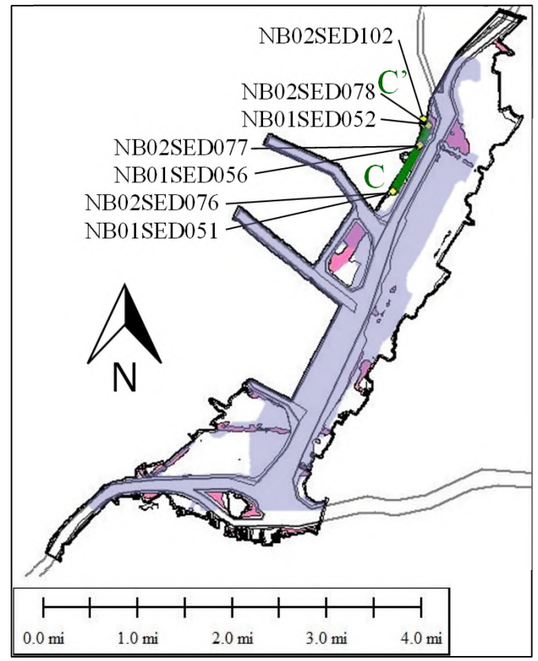
FIGURE

5-CS-16

SOUTH

NORTH





Inset Legend:

- NBSA Study Area Boundary
- Area of "Multi-Beam" Sounding Coverage (2012-2013)
- Cross Section Trace with Primary Borings
- Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

- 2005 Bathymetry
- 2012 Bathymetry
- Soil Boring and Sample (NB03SED206, 17)

MERCURY

- 100+ ppm
- 50 - <100 ppm
- 25 - <50 ppm
- 10 - <25 ppm
- 5 - <10 ppm
- 2 - <5 ppm
- 1 - <2 ppm
- 0.01 - <1 ppm
- <0.01 ppm
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION C-C' (FACING WEST) – MERCURY

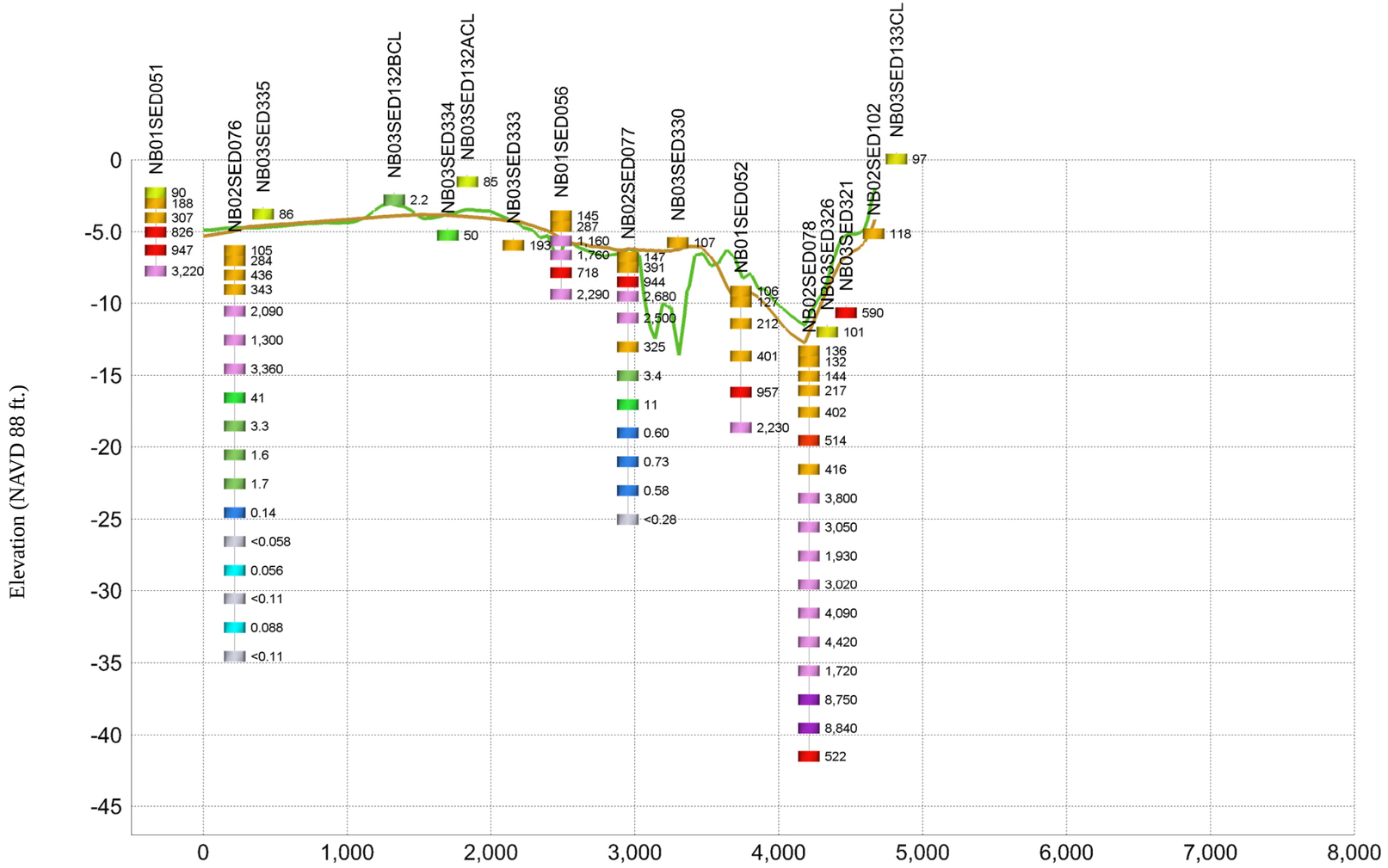
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

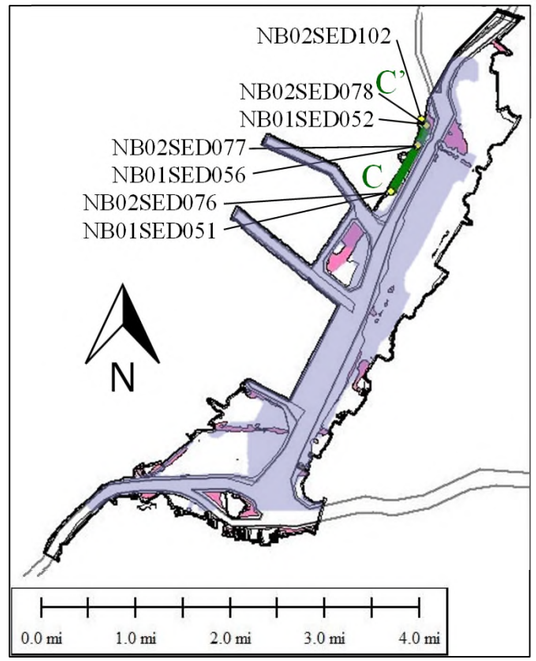
FIGURE

5-CS-17

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206

17

2.3.7.8-TCDD

- 5,000+ ppt
- 1,000 - <5,000 ppt
- 500 - <1,000 ppt
- 100 - <500 ppt
- 50 - <100 ppt
- 10 - <50 ppt
- 1 - <10 ppt
- 0.1 - <1 ppt
- <0.1 ppt
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION C-C' (FACING WEST) – 2,3,7,8-TCDD

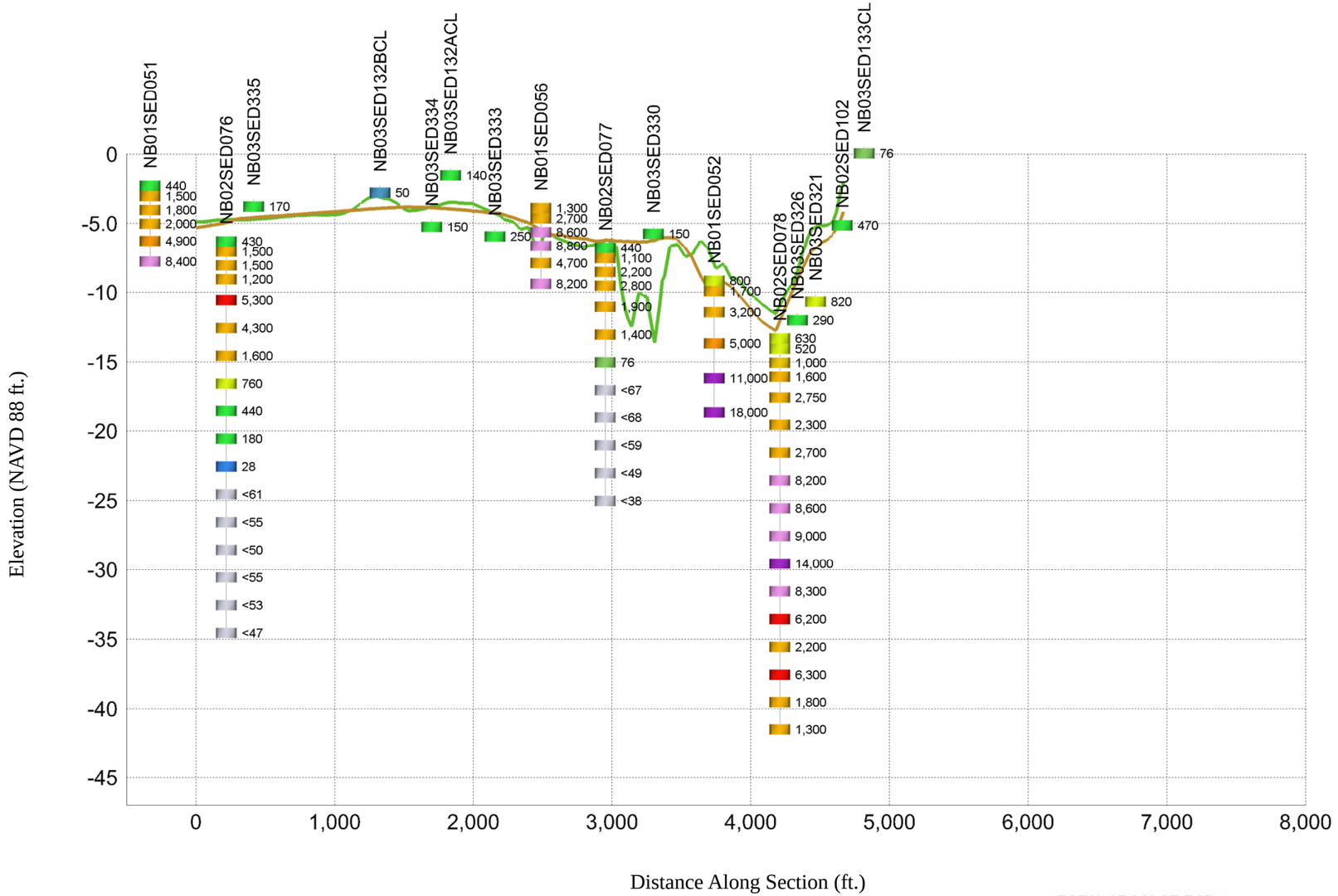
OXY Glenn Springs Holdings, Inc.
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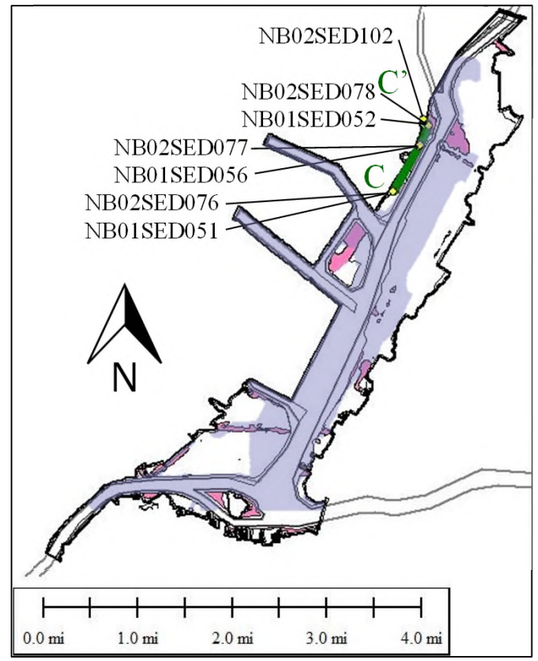
FIGURE

5-CS-18

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206

17

TOTAL AROCLOR PCBs

- 10,000+ ppb
- 7,500 - <10,000 ppb
- 5,000 - <7,500 ppb
- 1,000 - <5,000 ppb
- 500 - <1,000 ppb
- 100 - <500 ppb
- 50 - <100 ppb
- 10 - <50 ppb
- <10 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION C-C' (FACING WEST)

TOTAL AROCLOR PCBs

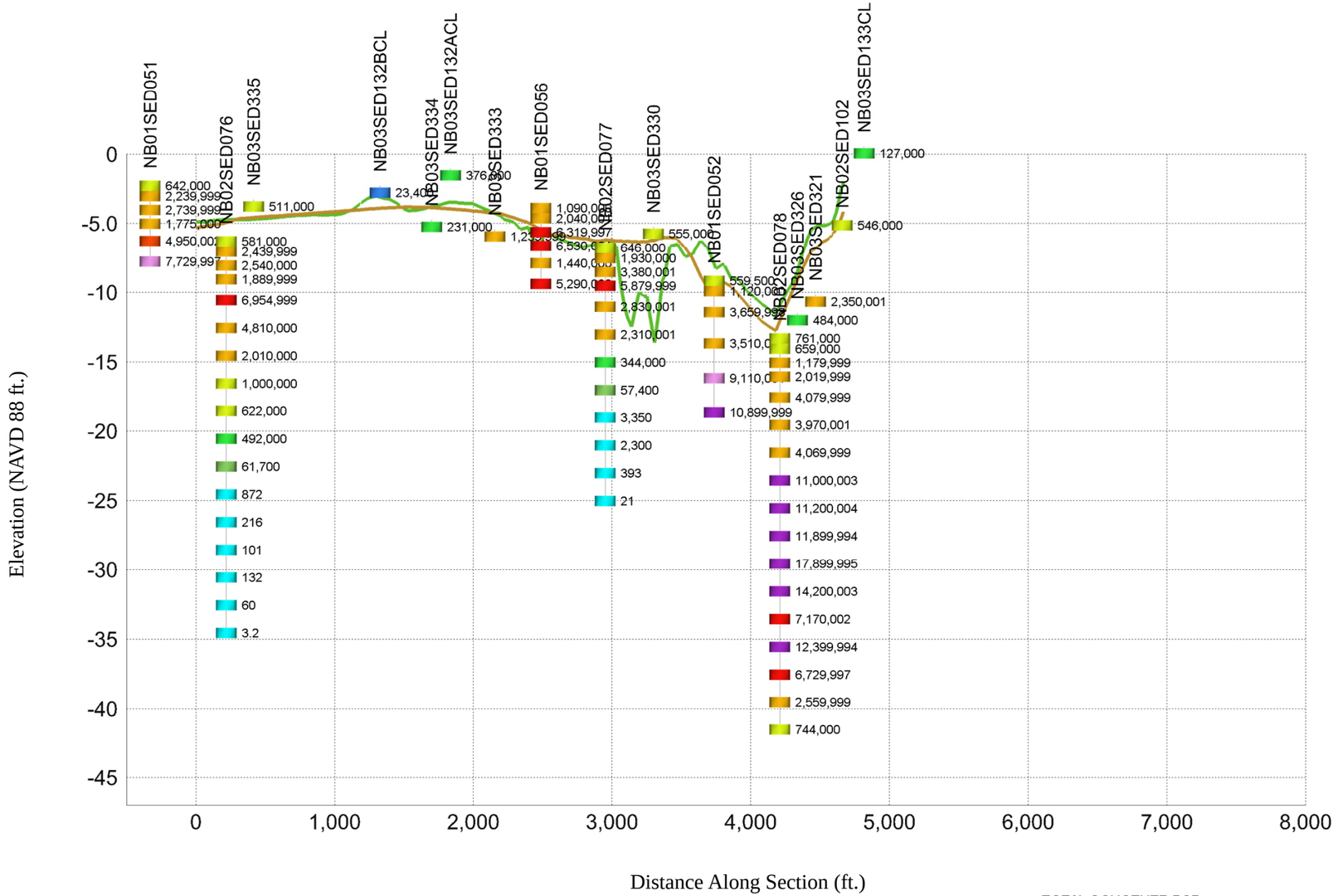
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

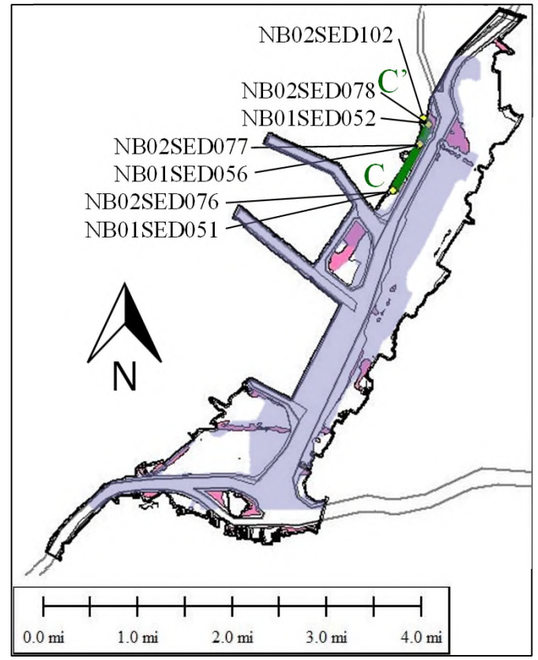
FIGURE

5-CS-19

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206

17

TOTAL CONGENER PCBs

- 10,000,000+ ppt
- 7,500,000 - <10,000,000 ppt
- 5,000,000 - <7,500,000 ppt
- 1,000,000 - <5,000,000 ppt
- 500,000 - <1,000,000 ppt
- 100,000 - <500,000 ppt
- 50,000 - <100,000 ppt
- 10,000 - <50,000 ppt
- <10,000 ppt
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION C-C' (FACING WEST)

TOTAL CONGENER PCBs

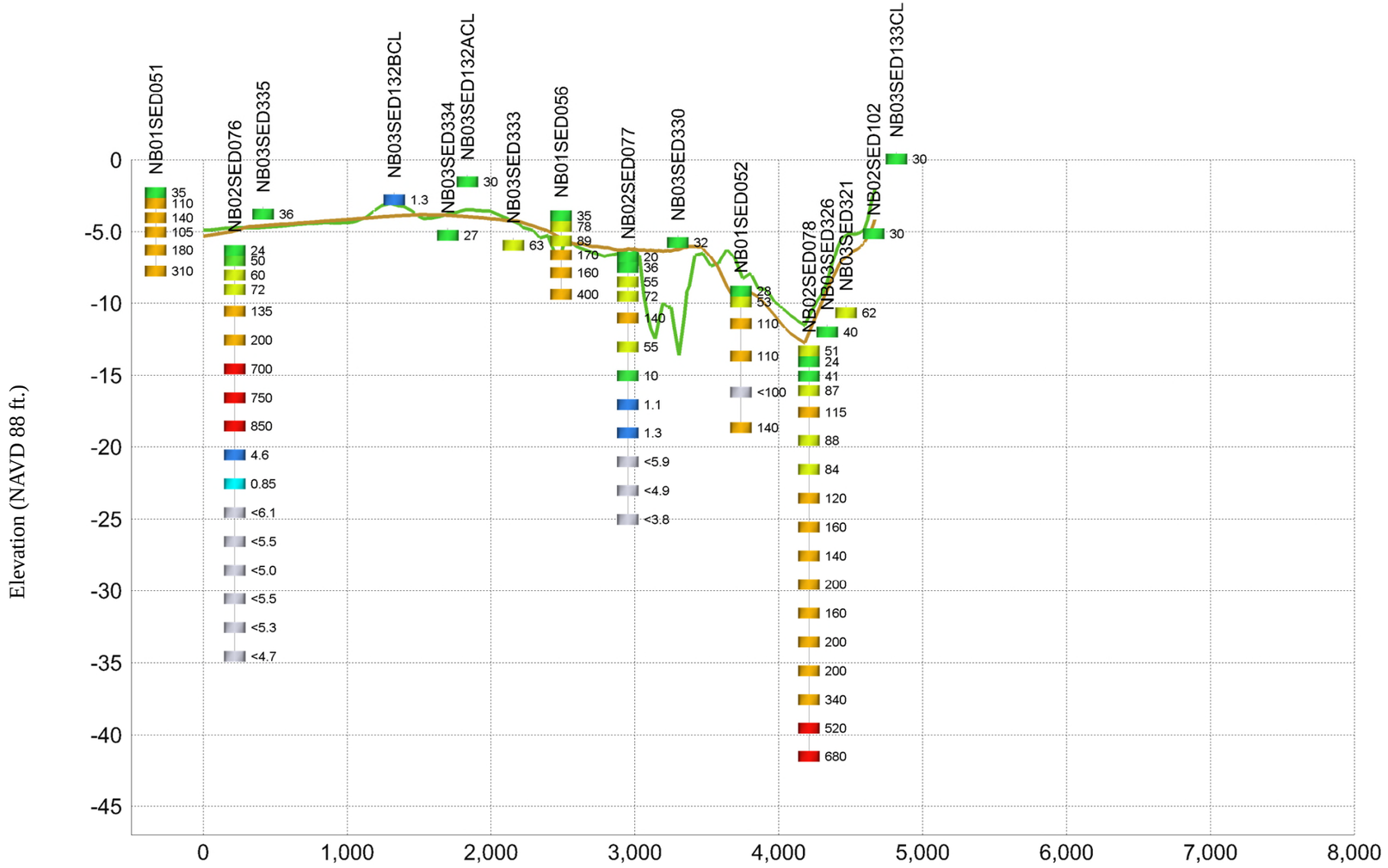
OXY Glenn Springs Holdings, Inc.
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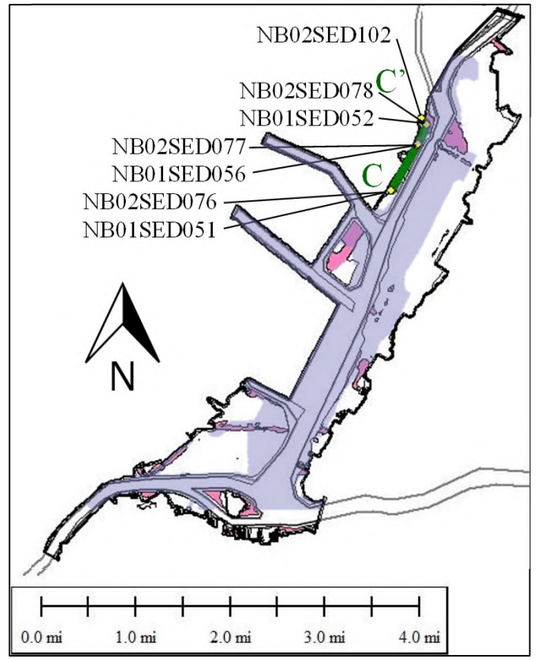
FIGURE

5-CS-20

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206

17

TOTAL DDT (4,4')

- 5,000+ ppb
- 1,000 - <5,000 ppb
- 500 - <1,000 ppb
- 100 - <500 ppb
- 50 - <100 ppb
- 10 - <50 ppb
- 5 - <10 ppb
- 1 - <5 ppb
- <1 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION C-C' (FACING WEST) – TOTAL DDx (4,4')

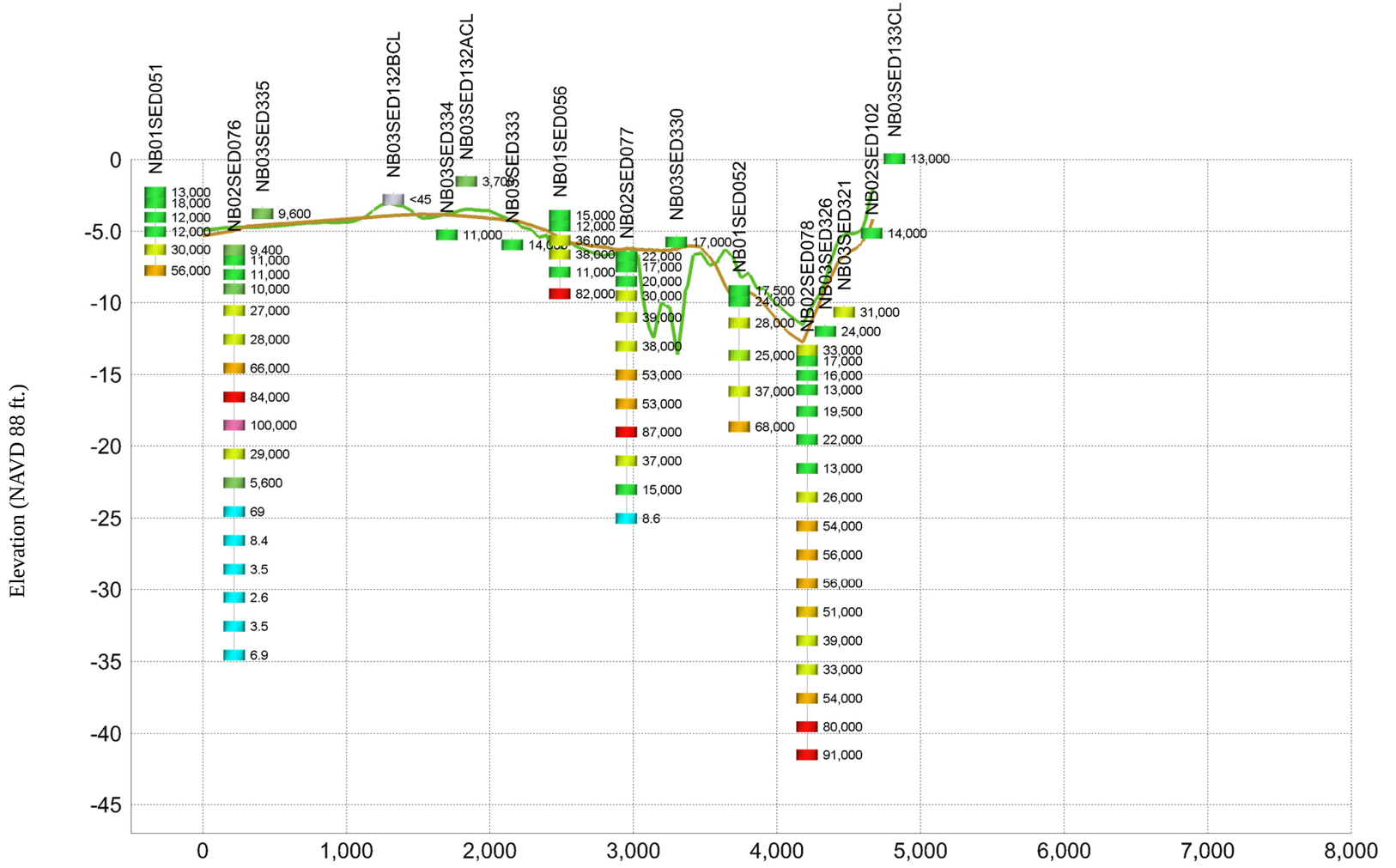
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE

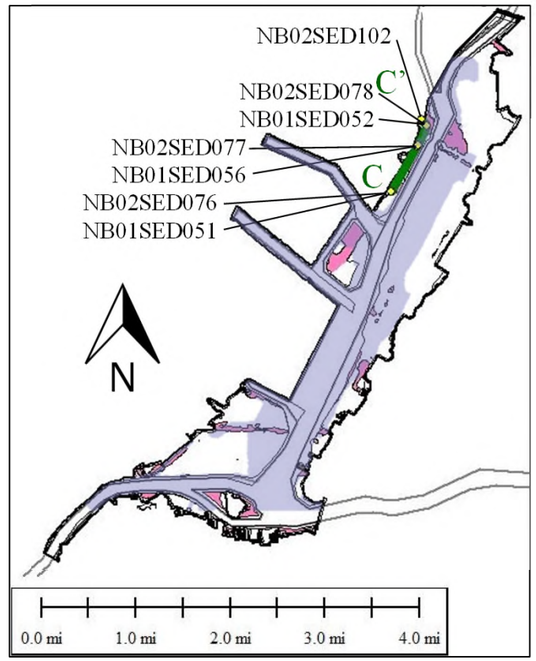
5-CS-21

SOUTH

NORTH



Distance Along Section (ft.)



Inset Legend:

- NBSA Study Area Boundary
- Area of "Multi-Beam" Sounding Coverage (2012-2013)
- Cross Section Trace with Primary Borings
- Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

- 2005 Bathymetry
- 2012 Bathymetry
- Soil Boring and Sample (NB03SED206 / 17)

TOTAL PAHs

- 250,000+ ppb
- 100,000 - <250,000 ppb
- 75,000 - <100,000 ppb
- 50,000 - <75,000 ppb
- 25,000 - <50,000 ppb
- 10,000 - <25,000 ppb
- 1,000 - <10,000 ppb
- 100 - <1,000 ppb
- <100 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION C-C' (FACING WEST) – TOTAL PAHs

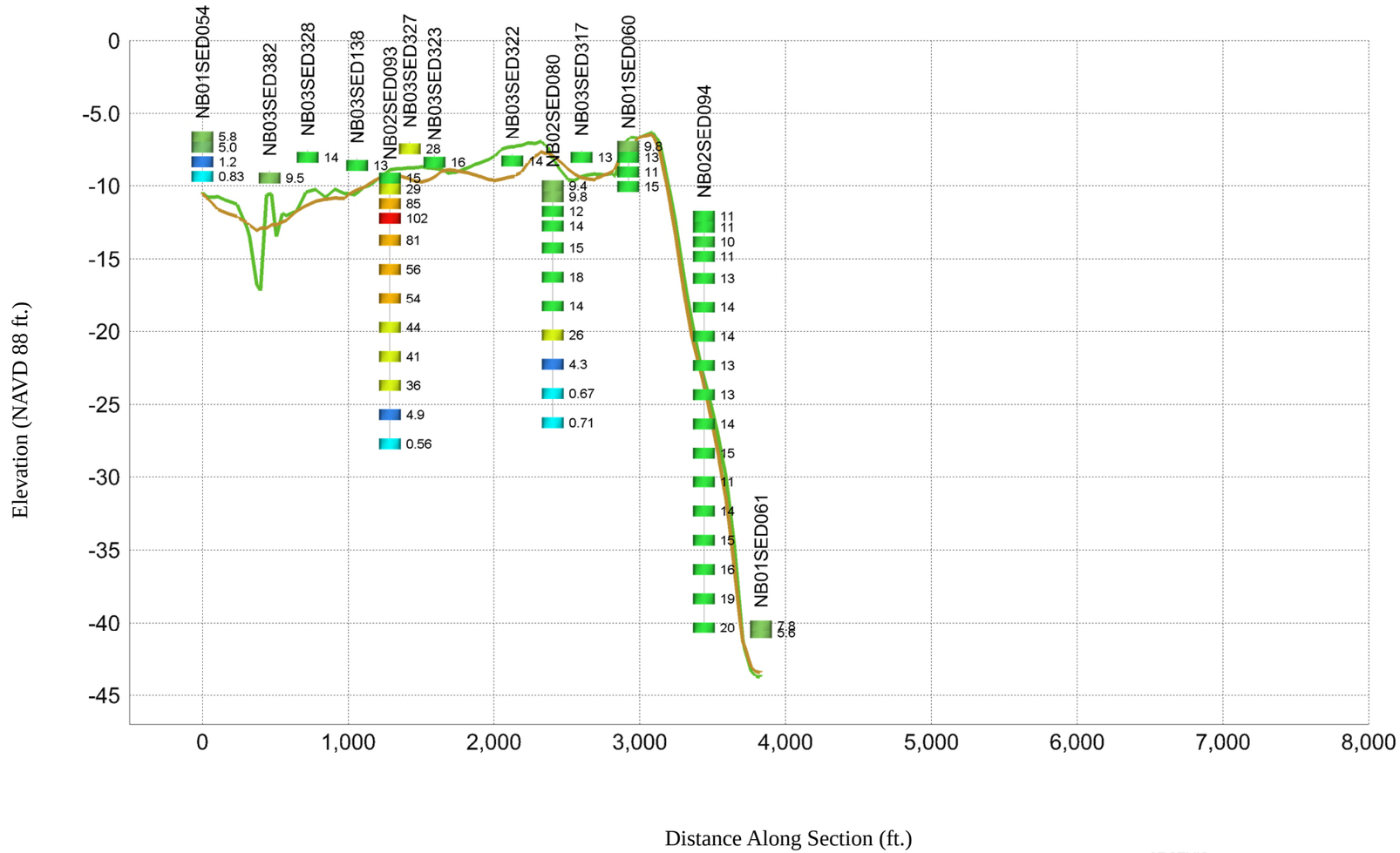
Glenn Springs Holdings, Inc.
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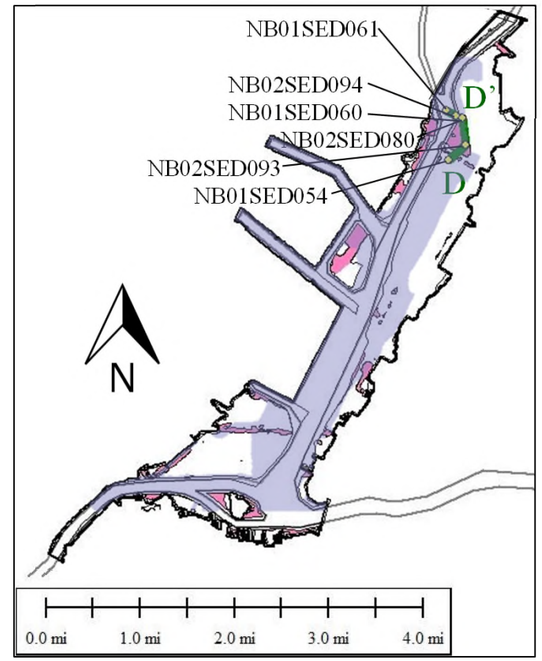
FIGURE

5-CS-22

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206

17

ARSENIC

- 300+ ppm
- 200 - <300 ppm
- 100 - <200 ppm
- 50 - <100 ppm
- 20 - <50 ppm
- 10 - <20 ppm
- 5 - <10 ppm
- 1 - <5 ppm
- <1 ppm
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION D-D' (FACING WEST) – ARSENIC

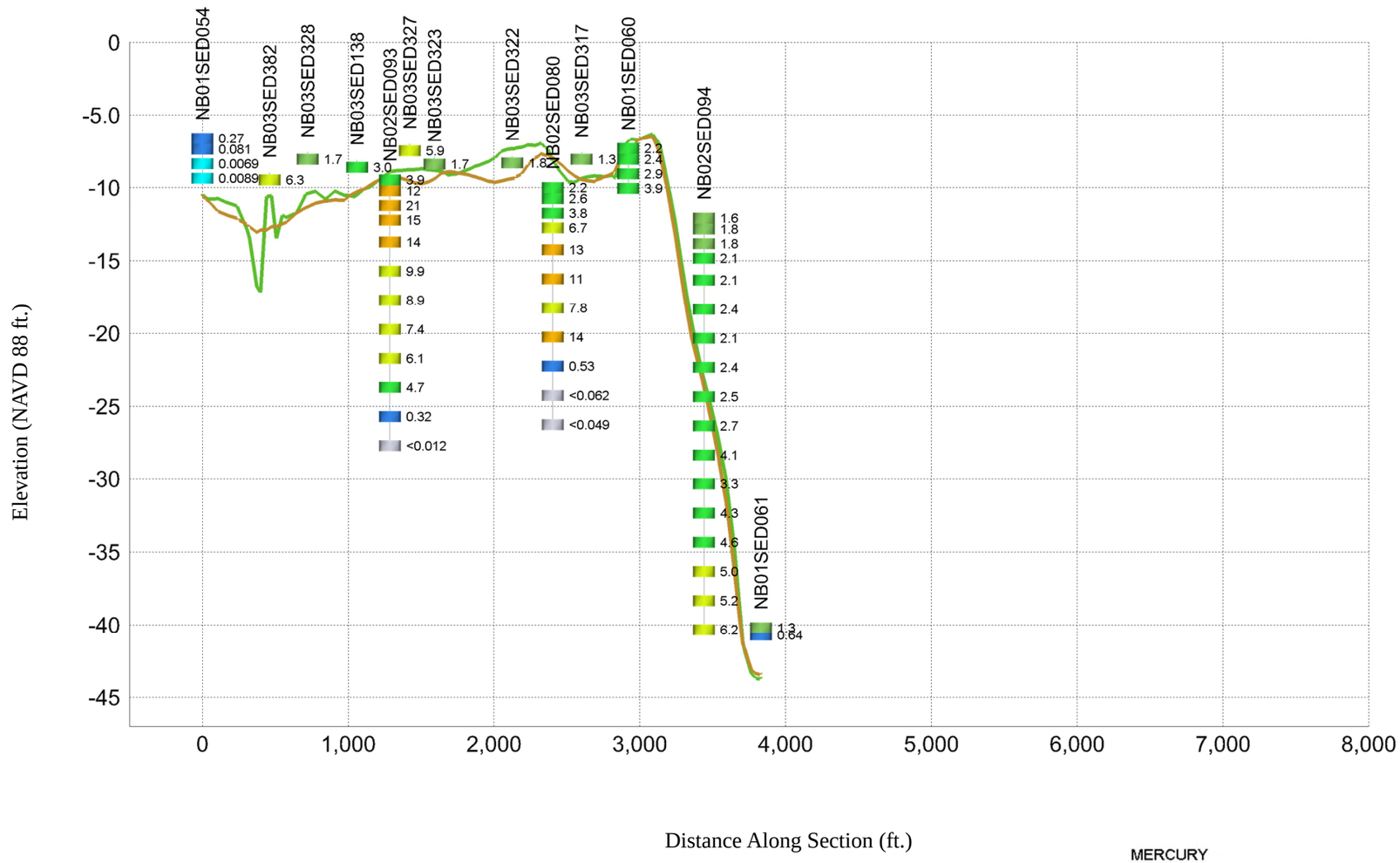
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

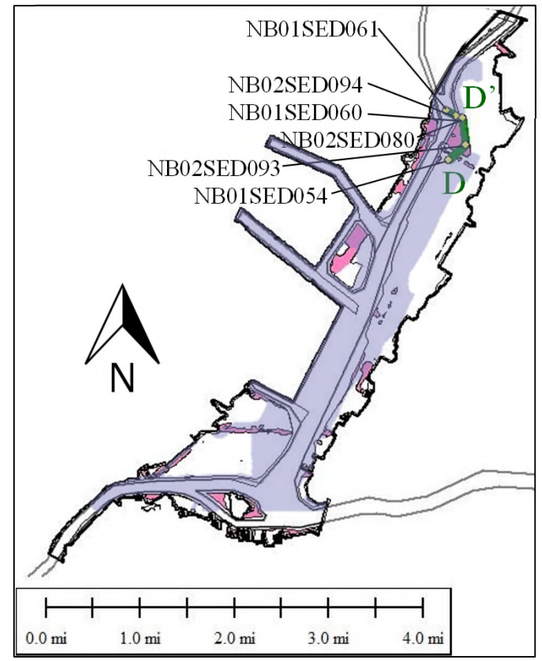
FIGURE

5-CS-23

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206

17

MERCURY

- 100+ ppm
- 50 - <100 ppm
- 25 - <50 ppm
- 10 - <25 ppm
- 5 - <10 ppm
- 2 - <5 ppm
- 1 - <2 ppm
- 0.01 - <1 ppm
- <0.01 ppm
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION D-D' (FACING WEST) – MERCURY

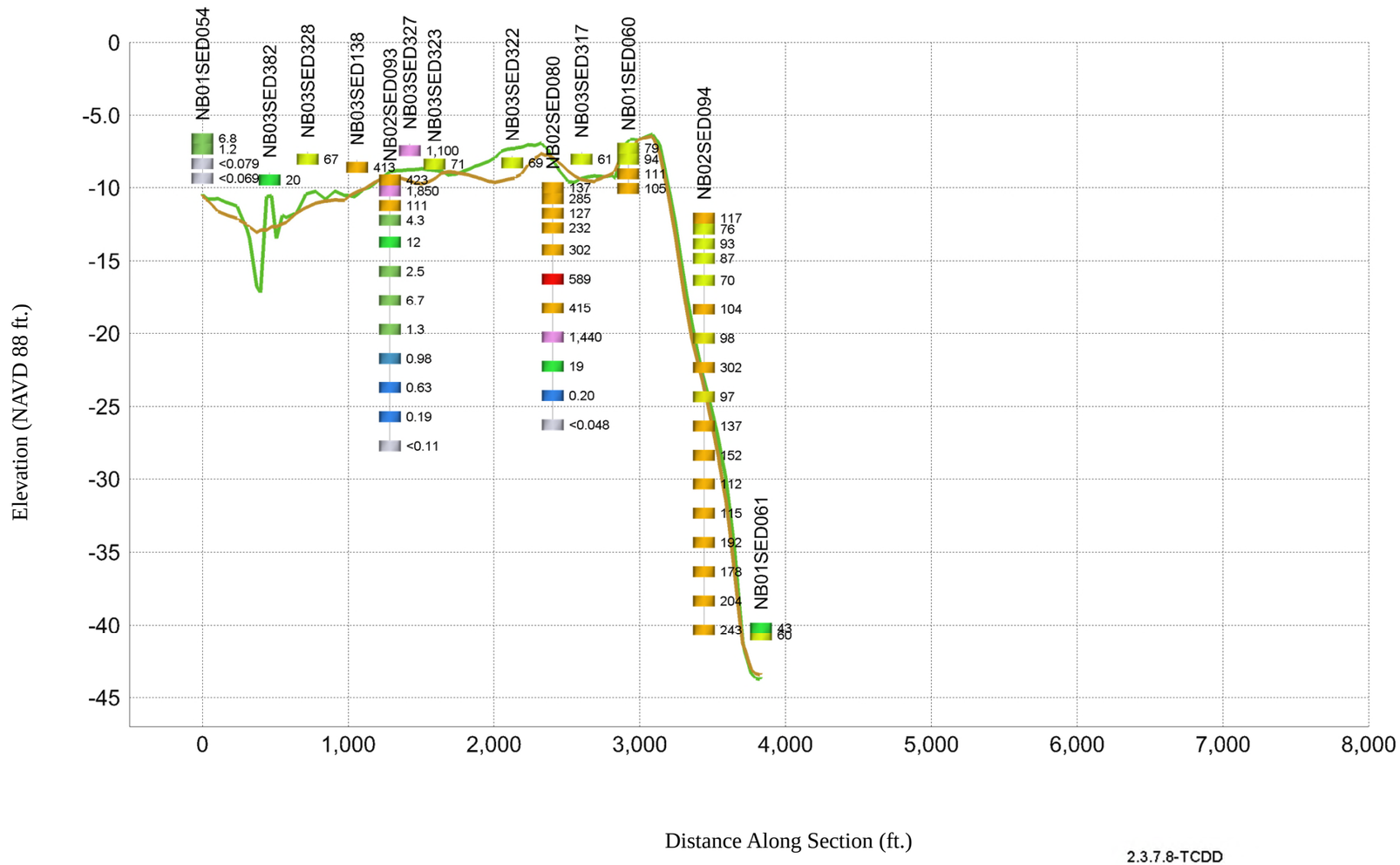
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

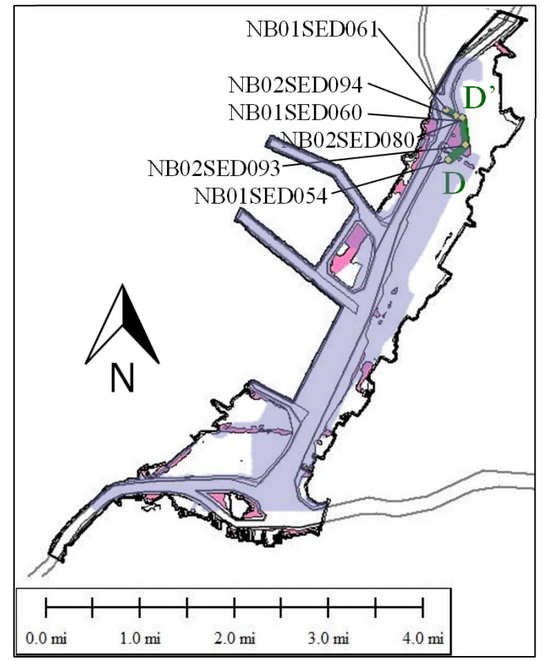
FIGURE

5-CS-24

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206
17

2.3.7.8-TCDD

- 5,000+ ppt
- 1,000 - <5,000 ppt
- 500 - <1,000 ppt
- 100 - <500 ppt
- 50 - <100 ppt
- 10 - <50 ppt
- 1 - <10 ppt
- 0.1 - <1 ppt
- <0.1 ppt
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION D-D' (FACING WEST) – 2,3,7,8-TCDD

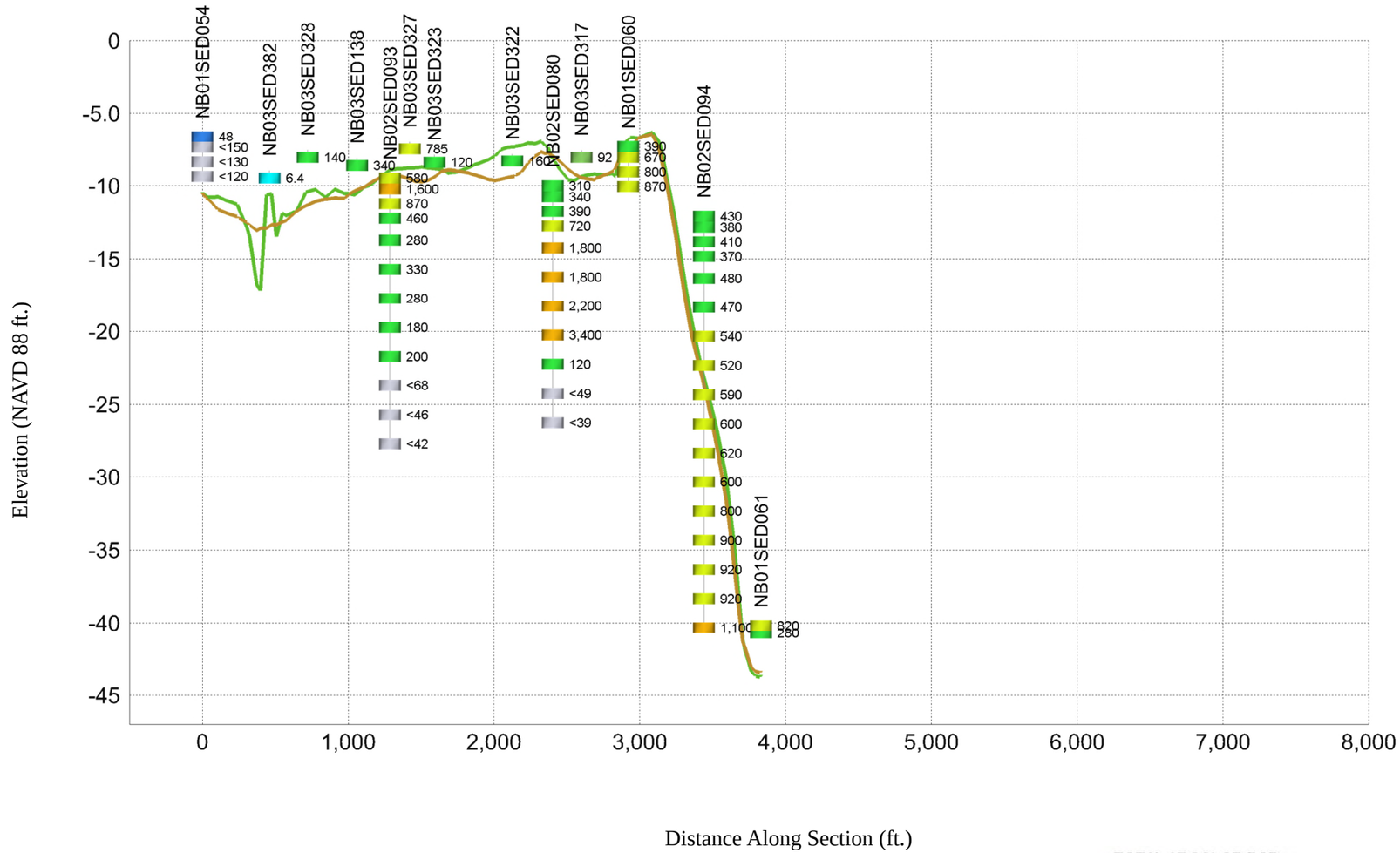
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

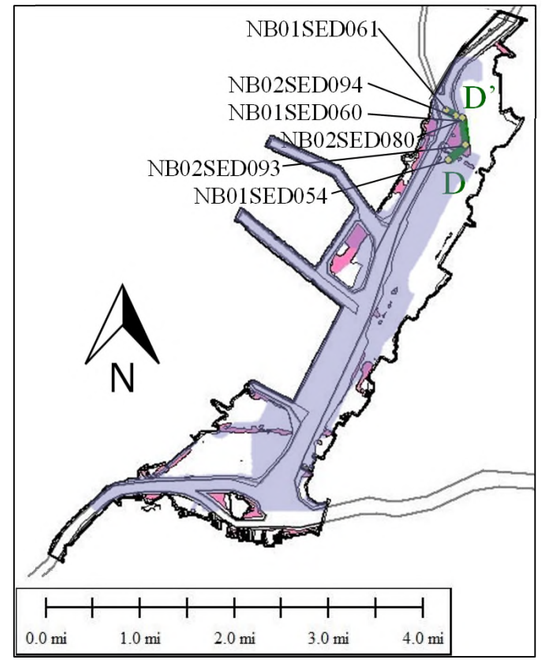
FIGURE

5-CS-25

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206
17

TOTAL AROCLOR PCBs

- 10,000+ ppb
- 7,500 - <10,000 ppb
- 5,000 - <7,500 ppb
- 1,000 - <5,000 ppb
- 500 - <1,000 ppb
- 100 - <500 ppb
- 50 - <100 ppb
- 10 - <50 ppb
- <10 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

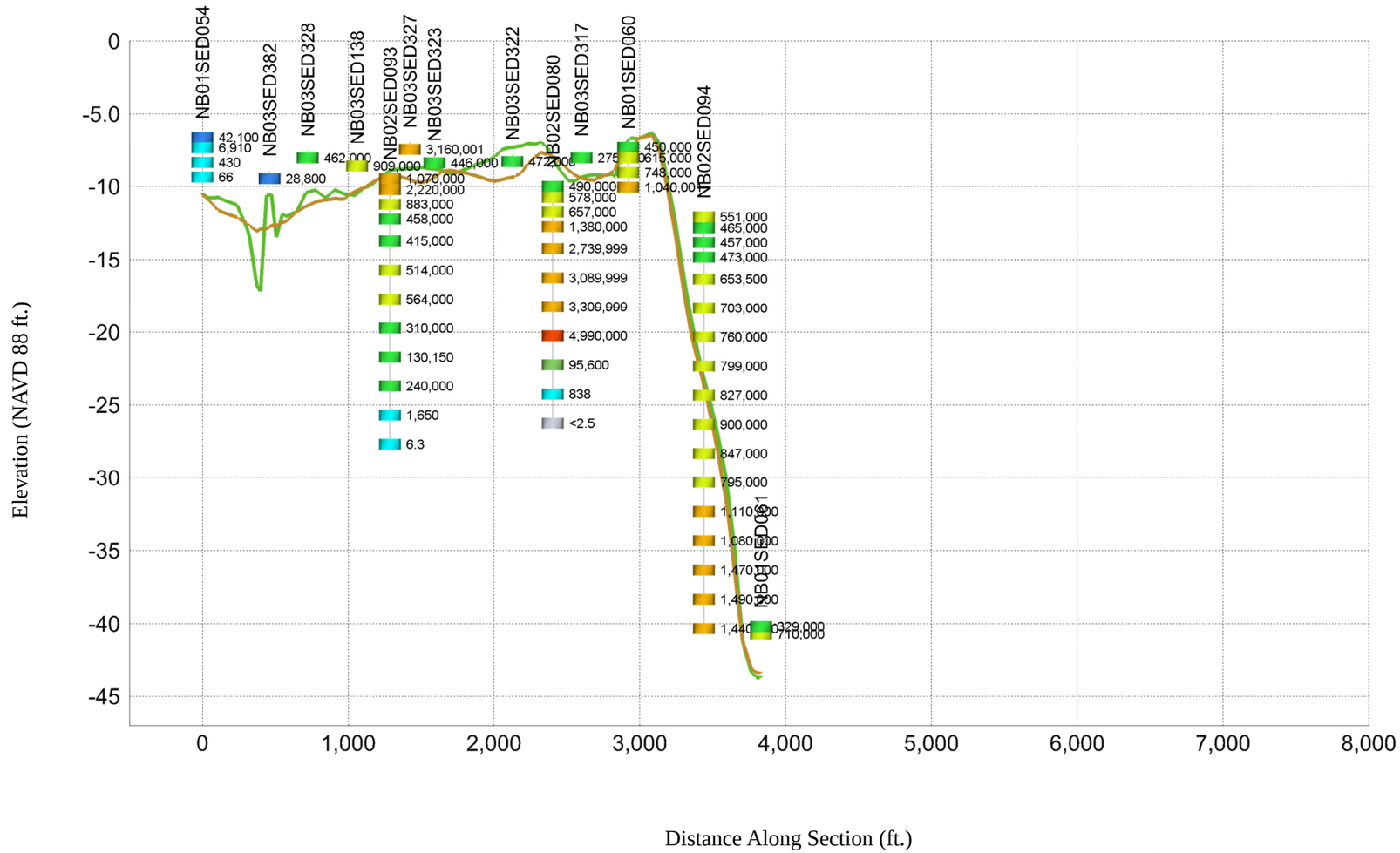
CROSS-SECTION D-D' (FACING WEST)
TOTAL AROCLOR PCBs

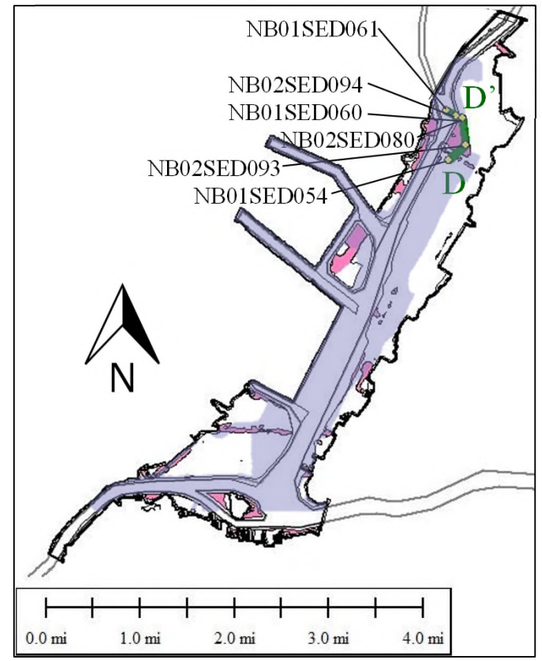
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-CS-26

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206
17

TOTAL CONGENER PCBs

- 10,000,000+ ppt
- 7,500,000 - <10,000,000 ppt
- 5,000,000 - <7,500,000 ppt
- 1,000,000 - <5,000,000 ppt
- 500,000 - <1,000,000 ppt
- 100,000 - <500,000 ppt
- 50,000 - <100,000 ppt
- 10,000 - <50,000 ppt
- <10,000 ppt
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION D-D' (FACING WEST)

TOTAL CONGENER PCBs

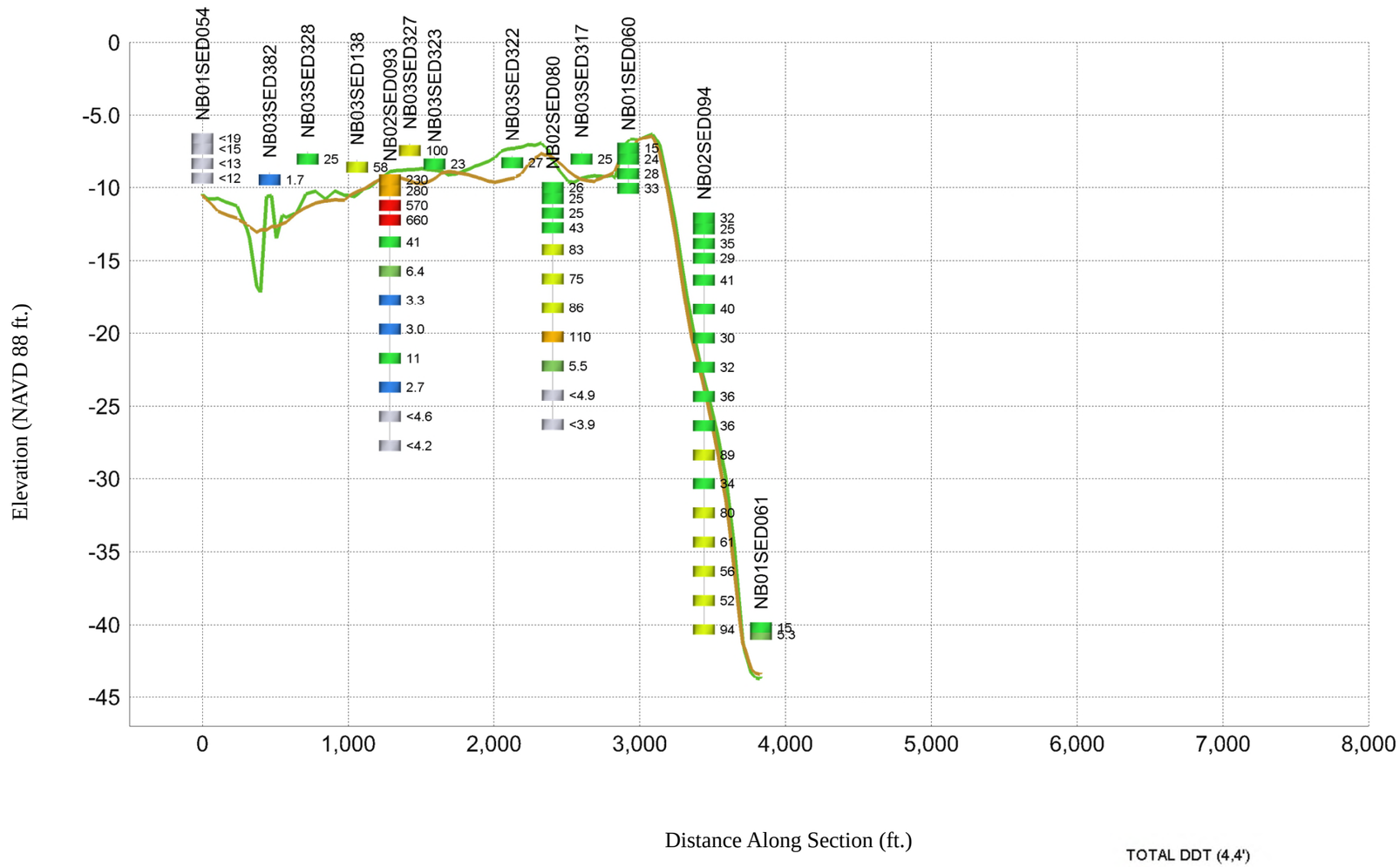
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

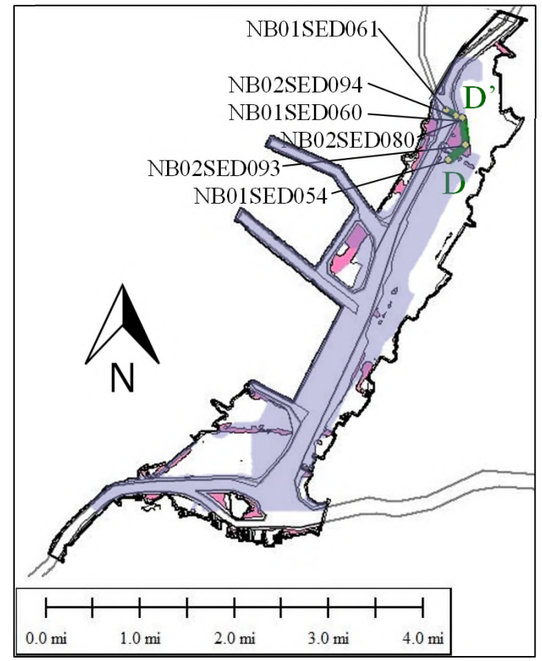
FIGURE

5-CS-27

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206

17

TOTAL DDT (4,4')

- 5,000+ ppb
- 1,000 - <5,000 ppb
- 500 - <1,000 ppb
- 100 - <500 ppb
- 50 - <100 ppb
- 10 - <50 ppb
- 5 - <10 ppb
- 1 - <5 ppb
- <1 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION =D-D' (FACING WEST) – TOTAL DDx (4,4')

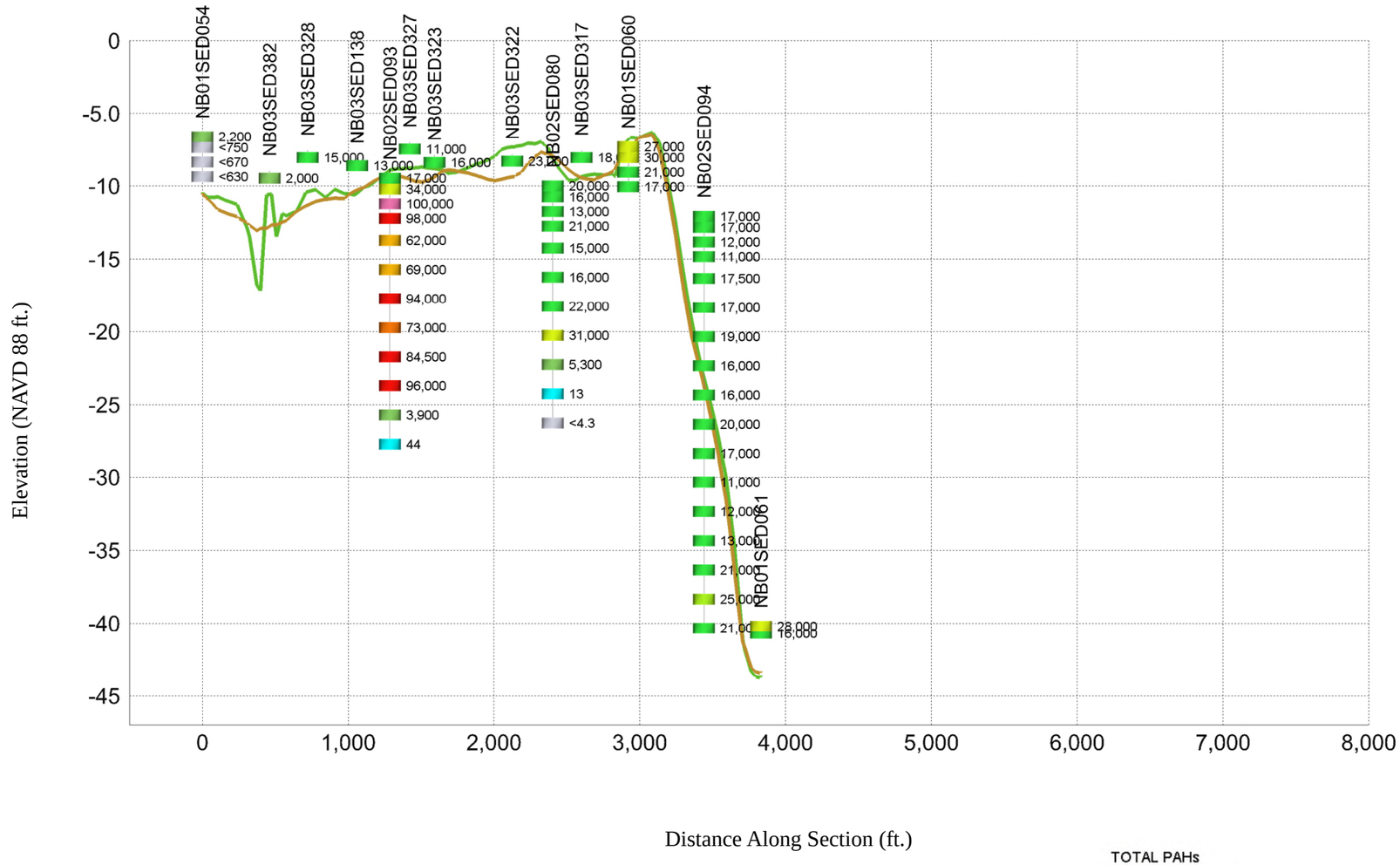
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

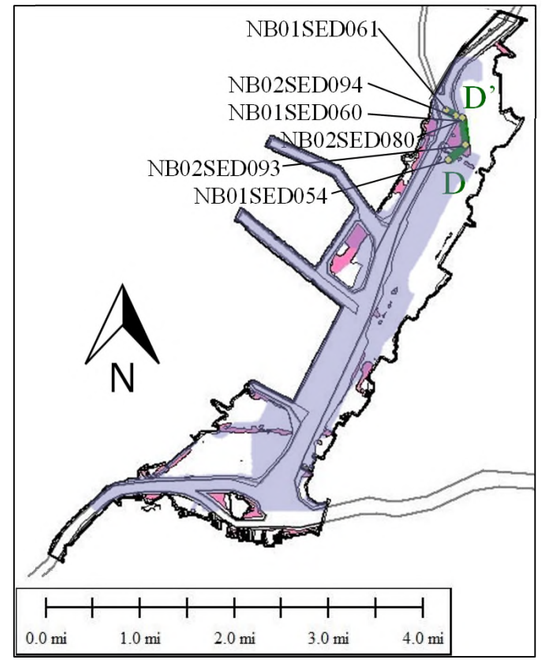
FIGURE

5-CS-28

SOUTH

NORTH





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Notes:

1. Vertical Exaggeration = 100X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample

NB03SED206
17

TOTAL PAHs

- 250,000+ ppb
- 100,000 - <250,000 ppb
- 75,000 - <100,000 ppb
- 50,000 - <75,000 ppb
- 25,000 - <50,000 ppb
- 10,000 - <25,000 ppb
- 1,000 - <10,000 ppb
- 100 - <1,000 ppb
- <100 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

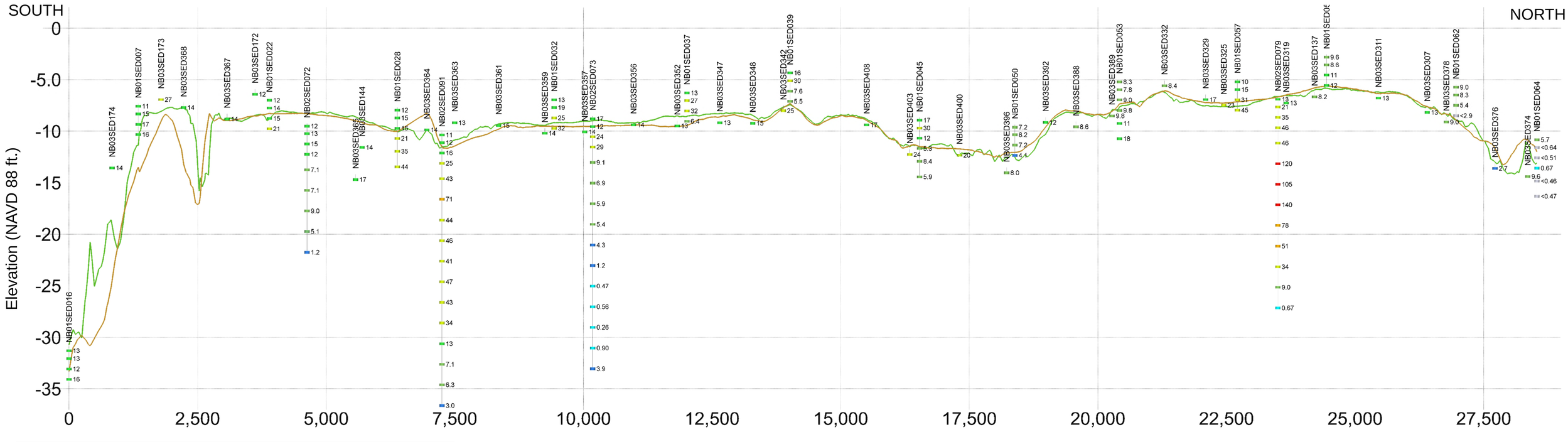
REMEDIAL INVESTIGATION REPORT

CROSS-SECTION D-D' (FACING WEST) – TOTAL PAHs

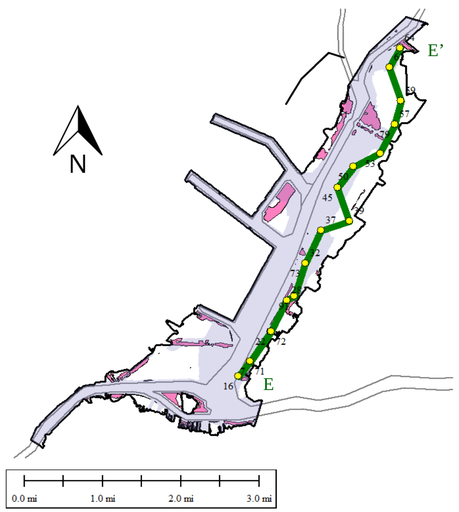
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE

5-CS-29



Distance Along Section (ft.)



Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

Notes:

1. Vertical Exaggeration = 200X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.
4. Projected borings NBO3-SED324 and NO03-SED366 not shown on sections due to display space limitations.

ARSENIC

- 300+ ppm
- 200 - <300 ppm
- 100 - <200 ppm
- 50 - <100 ppm
- 20 - <50 ppm
- 10 - <20 ppm
- 5 - <10 ppm
- 1 - <5 ppm
- <1 ppm
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION E-E' (FACING WEST) – ARSENIC

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE 5-CS-30

SOUTH

NORTH

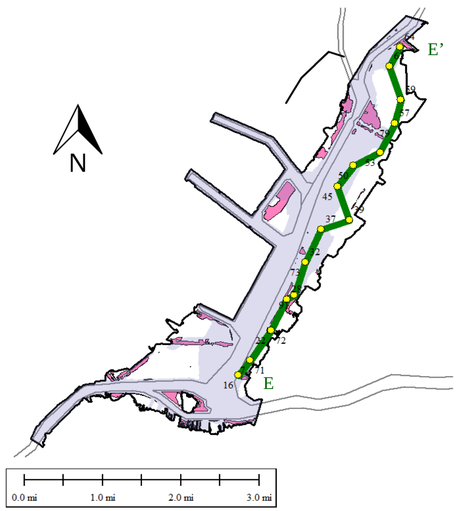
Elevation (NAVD 88 ft.)

0
-5.0
-10
-15
-20
-25
-30
-35

0
2,500
5,000
7,500
10,000
12,500
15,000
17,500
20,000
22,500
25,000
27,500

Distance Along Section (ft.)

NB01SED016 1.0 1.5 1.3 1.5
NB03SED174 1.3
NB01SED007 1.1 1.6 2.6 3.3
NB03SED173 3.0
NB03SED368 1.4
NB03SED367 1.5
NB03SED172 1.3
NB01SED022 1.4 1.7 2.3 3.1
NB02SED072 1.4 2.1 3.4 2.4 0.049 0.018 <0.017 <0.010 <0.0097
NB03SED385 2.0
NB03SED144 2.4
NB01SED028 1.4 2.0 2.3 6.9 7.2 2.5
NB03SED364 1.4
NB02SED091 2.3 2.9 2.5 5.0 5.9 8.1 3.4 3.3 2.8 1.6 1.4 2.5 0.66 0.26 0.040 <0.012
NB03SED363 1.5
NB03SED361 1.5
NB03SED359 1.5 4.6 7.0 7.4 1.2
NB01SED032
NB03SED357 5.4 2.2 9.3 8.0 0.42 0.060 0.028 <0.015 <0.018 <0.012 <0.010 <0.011 <0.011 <0.011 <0.014
NB02SED073 1.7
NB03SED356 1.4
NB03SED352 2.2 8.2 6.6 0.012 1.7
NB01SED037
NB03SED347 1.8
NB03SED348 1.9
NB03SED342 1.8 2.3 0.22 0.016 1.5
NB01SED039
NB03SED408 2.0
NB03SED403 3.0 2.3 1.2 0.021 1.9 0.028 0.020
NB01SED045
NB03SED400 0.51
NB03SED396 0.36 0.049 0.023 0.0087 0.46
NB01SED050
NB03SED392 0.67
NB03SED388 0.34
NB03SED389 0.65 0.056 0.047 0.038 0.18 0.032 0.029
NB01SED053
NB03SED332 1.1
NB03SED329 1.8
NB03SED325 1.6
NB01SED057 2.4 5.9 12 11
NB02SED079 2.7 1.0 9.8 13 14 13 17 18 18 13 8.7 4.0 0.35 <0.013
NB03SED319
NB03SED137 1.7
NB01SED05
1.0 0.099 0.024 0.018
NB03SED311 2.6
NB03SED307 0.40
NB03SED378 0.34
NB01SED062 0.63 0.22 0.019 0.019
NB03SED376 0.11
NB03SED374 0.091
NB01SED064 0.30 0.012 0.0080 <0.0027 0.0035 <0.0024



Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

Notes:

1. Vertical Exaggeration = 200X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.
4. Projected borings NBO3-SED324 and NO03-SED366 not shown on sections due to display space limitations.

MERCURY

- 100+ ppm
- 50 - <100 ppm
- 25 - <50 ppm
- 10 - <25 ppm
- 5 - <10 ppm
- 2 - <5 ppm
- 1 - <2 ppm
- 0.01 - <1 ppm
- <0.01 ppm
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

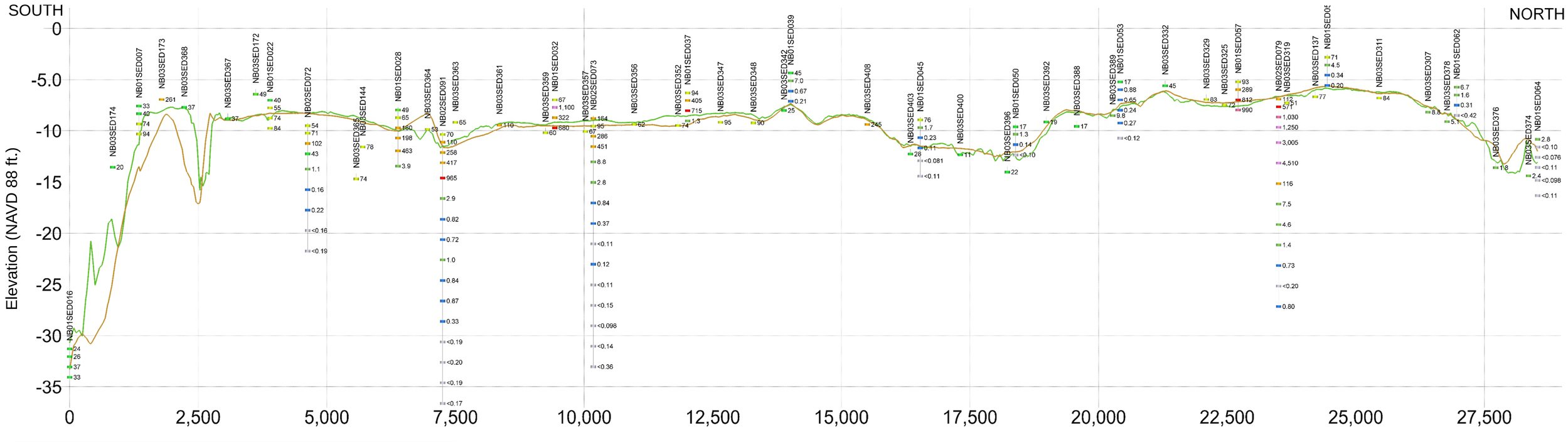
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

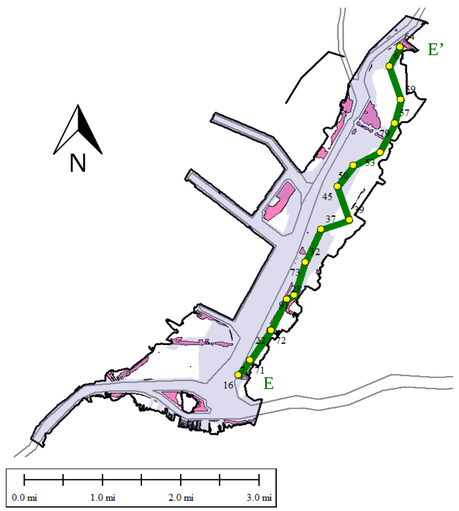
REMEDIAL INVESTIGATION REPORT

CROSS-SECTION E-E' (FACING WEST) – MERCURY

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE 5-CS-31





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

Notes:

1. Vertical Exaggeration = 200X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.
4. Projected borings NBO3-SED324 and NO03-SED366 not shown on sections due to display space limitations.

2.3.7.8-TCDD

- 5,000+ ppt
- 1,000 - <5,000 ppt
- 500 - <1,000 ppt
- 100 - <500 ppt
- 50 - <100 ppt
- 10 - <50 ppt
- 1 - <10 ppt
- 0.1 - <1 ppt
- <0.1 ppt
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

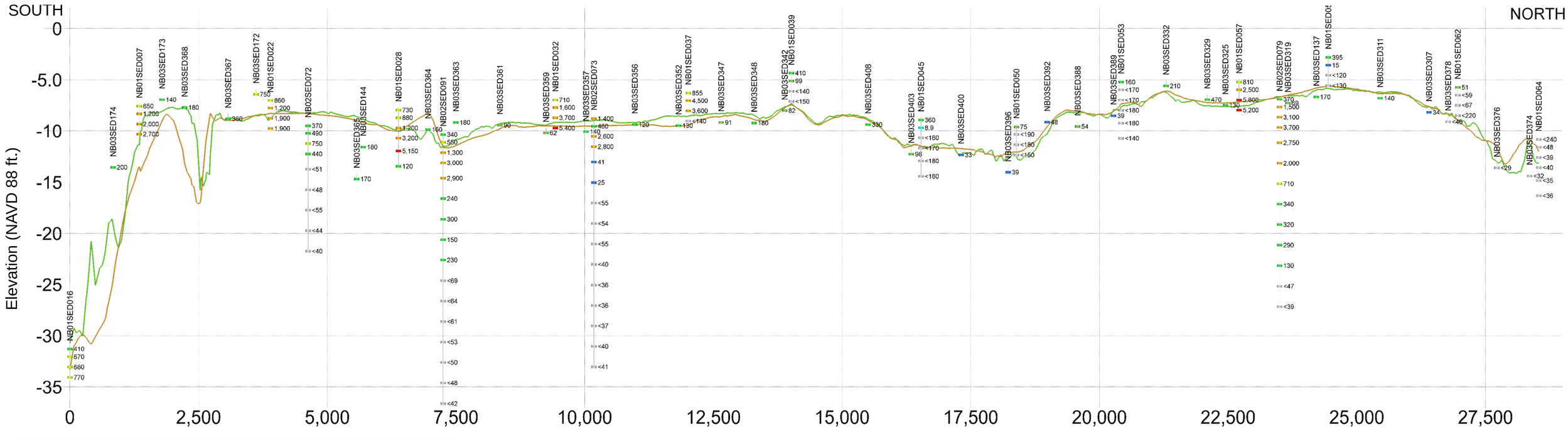
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

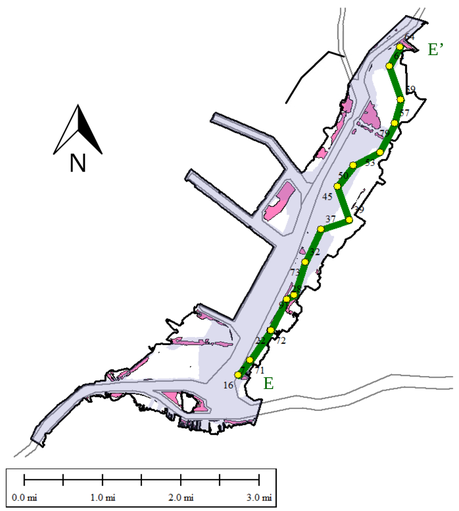
CROSS-SECTION E-E' (FACING WEST) – 2,3,7,8-TCDD

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-CS-32



Distance Along Section (ft.)



Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

Notes:

1. Vertical Exaggeration = 200X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.
4. Projected borings NBO3-SED324 and NO03-SED366 not shown on sections due to display space limitations.

TOTAL AROCLOR PCBs

- 10,000+ ppb
- 7,500 - <10,000 ppb
- 5,000 - <7,500 ppb
- 1,000 - <5,000 ppb
- 500 - <1,000 ppb
- 100 - <500 ppb
- 50 - <100 ppb
- 10 - <50 ppb
- <10 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

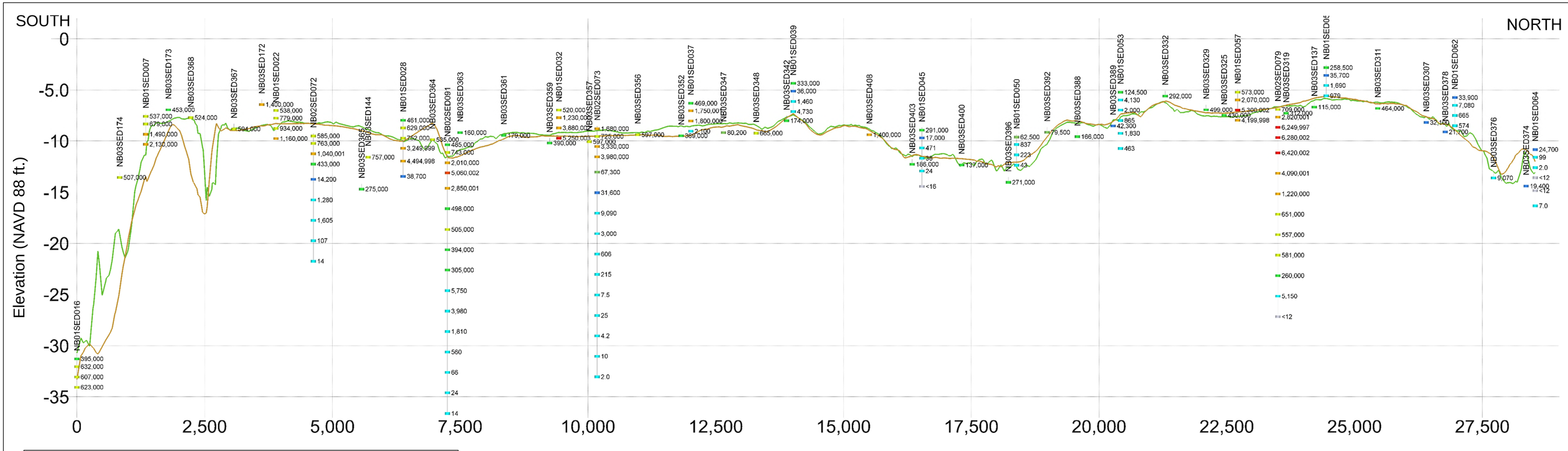
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

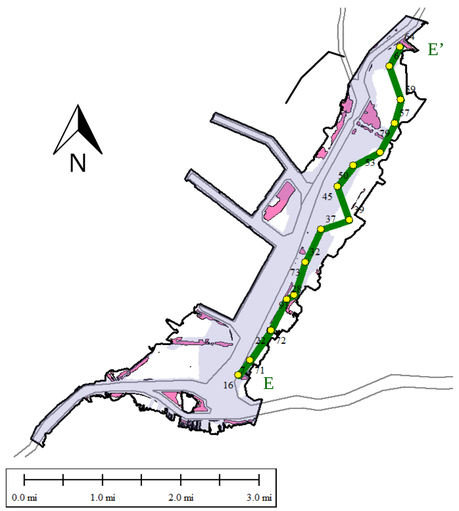
REMEDIAL INVESTIGATION REPORT

CROSS-SECTION E-E' (FACING WEST) – TOTAL AROCLOR PCBs

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE 5-CS-33





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

Notes:

1. Vertical Exaggeration = 200X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.
4. Projected borings NBO3-SED324 and NO03-SED366 not shown on sections due to display space limitations.

TOTAL CONGENER PCBs

- 10,000,000+ ppt
- 7,500,000 - <10,000,000 ppt
- 5,000,000 - <7,500,000 ppt
- 1,000,000 - <5,000,000 ppt
- 500,000 - <1,000,000 ppt
- 100,000 - <500,000 ppt
- 50,000 - <100,000 ppt
- 10,000 - <50,000 ppt
- <10,000 ppt
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

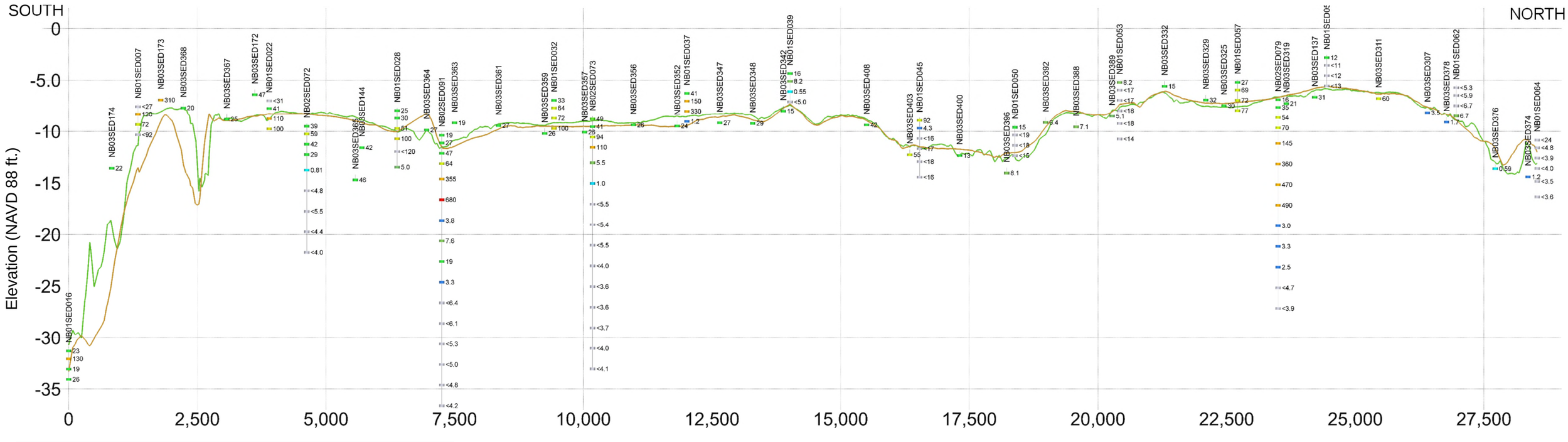
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

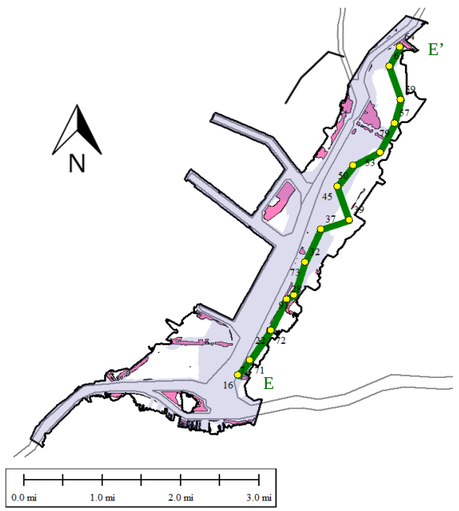
REMEDIAL INVESTIGATION REPORT

CROSS-SECTION E-E' (FACING WEST) – TOTAL CONGENER PCBs

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-CS-34





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

Notes:

1. Vertical Exaggeration = 200X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.
4. Projected borings NBO3-SED324 and NO03-SED366 not shown on sections due to display space limitations.

TOTAL DDT (4,4')

- 5,000+ ppb
- 1,000 - <5,000 ppb
- 500 - <1,000 ppb
- 100 - <500 ppb
- 50 - <100 ppb
- 10 - <50 ppb
- 5 - <10 ppb
- 1 - <5 ppb
- <1 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

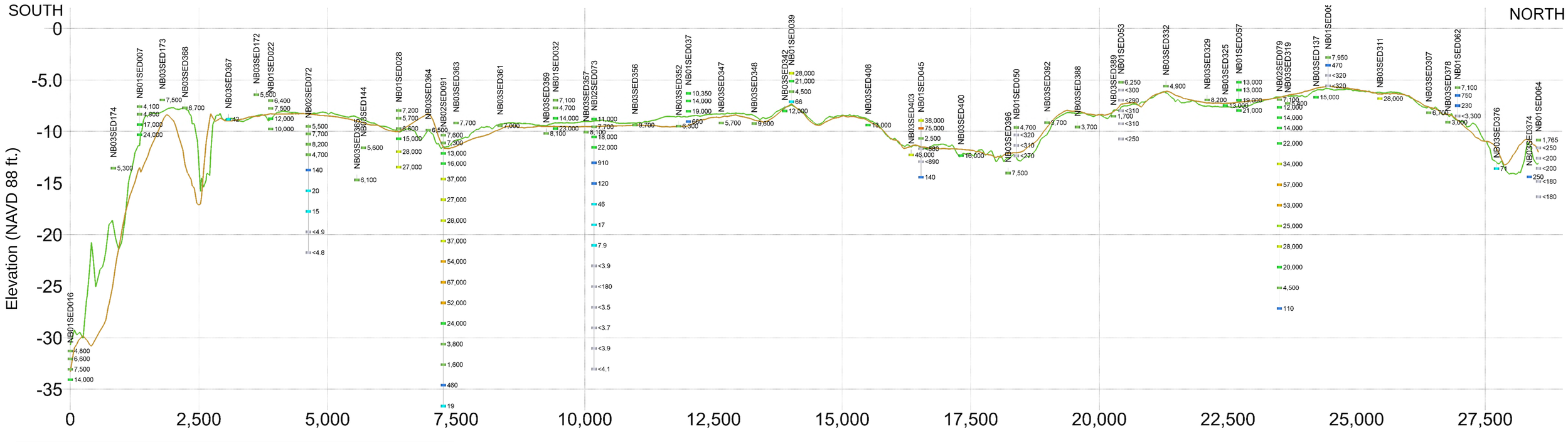
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

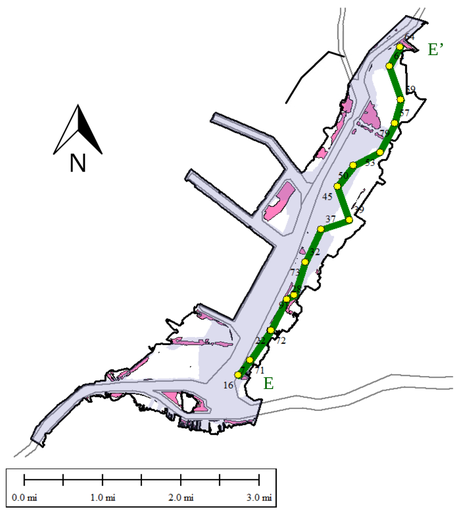
REMEDIAL INVESTIGATION REPORT

CROSS-SECTION E-E' (FACING WEST) – TOTAL DDx (4,4')

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE 5-CS-35





Inset Legend:

NBSA Study Area Boundary

Area of "Multi-Beam" Sounding Coverage (2012-2013)

Cross Section Trace with Primary Borings

Historically Disturbed Subtidal Flats

Cross-Section Legend:

2005 Bathymetry

2012 Bathymetry

Soil Boring and Sample NB03SED206 17

Notes:

1. Vertical Exaggeration = 200X Horizontal.
2. Samples up to 400 feet from cross-section trace project at native elevation.
3. Some sample locations shifted in display to avoid label overruns.
4. Projected borings NBO3-SED324 and NO03-SED366 not shown on sections due to display space limitations.

TOTAL PAHs

- 250,000+ ppb
- 100,000 - <250,000 ppb
- 75,000 - <100,000 ppb
- 50,000 - <75,000 ppb
- 25,000 - <50,000 ppb
- 10,000 - <25,000 ppb
- 1,000 - <10,000 ppb
- 100 - <1,000 ppb
- <100 ppb
- Non-detect

DIAMOND ALKALI SUPERFUND SITE

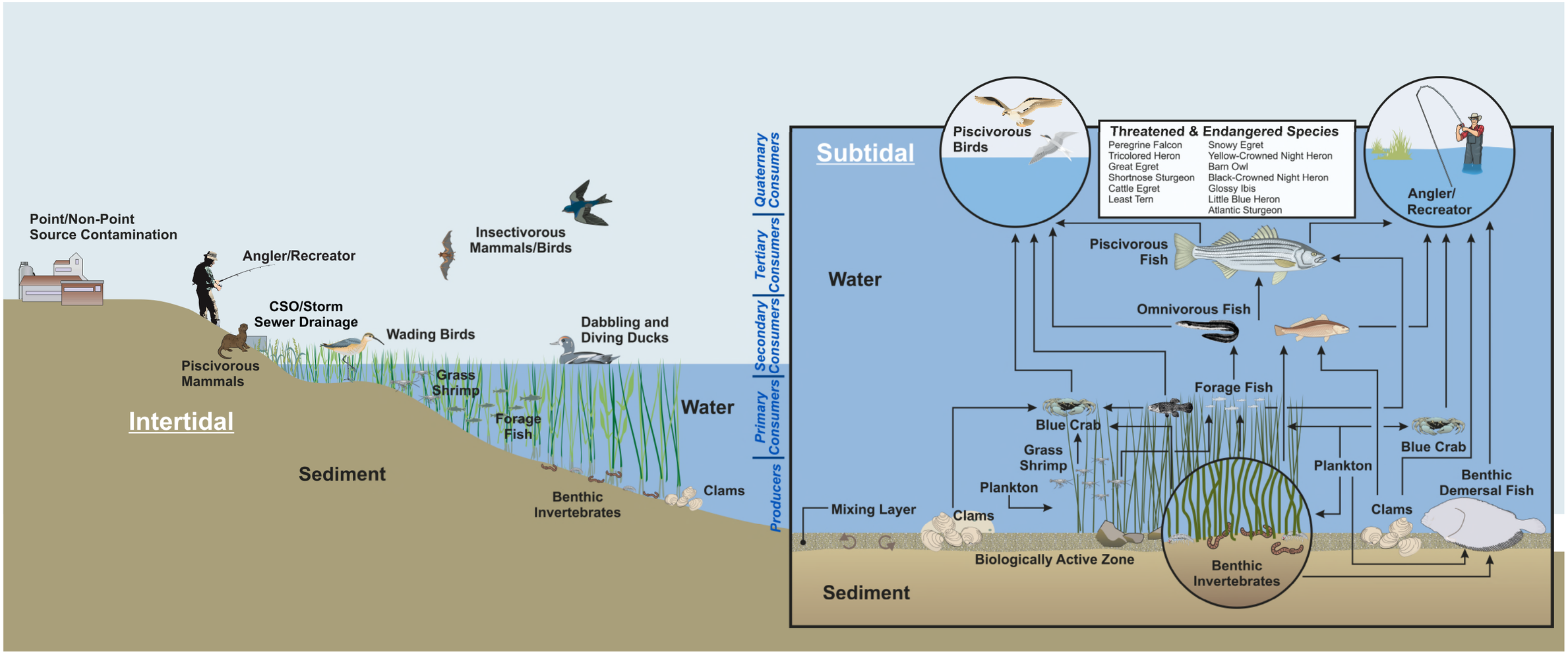
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION

REMEDIAL INVESTIGATION REPORT

CROSS-SECTION E-E' (FACING WEST) – TOTAL PAHs

OXY Glenn Springs Holdings, Inc.
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FIGURE 5-CS-36



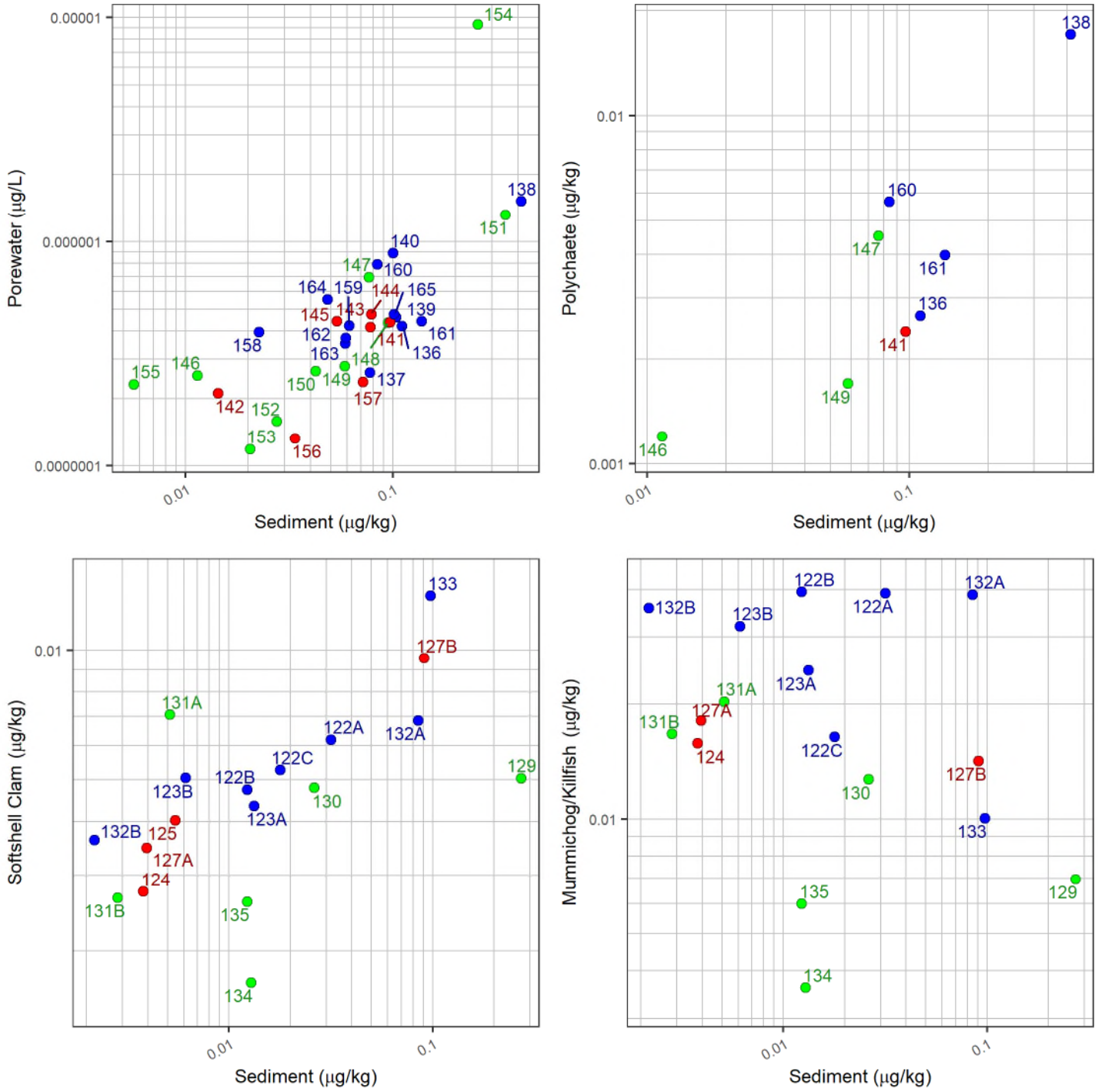
05/30/2013 SYRACUSE, NY-ENV/CAD DJHOWES
B0009989/0023/00003/CDR/09989G12.CDR

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODES OF COPC BIOAVAILABILITY AND EXPOSURE

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
5-BIOAV



Bay Area (color-code)
- North
- Central
- South

- ● Filled Symbol = Both Samples Detected
- ○ Open Symbol = Both Samples Non-detect
- ▲ Filled Symbol = Biota Non-detect and Sediment/Porewater Detect
- ▼ Filled Symbol = Biota Detect and Sediment/Porewater Non-detect

Notes:
Non-detects plotted at the reporting limit.
Measured porewater concentrations were made with passive sampling methods that are intended to measure only freely dissolved concentrations (non-DOC-complexed concentrations).

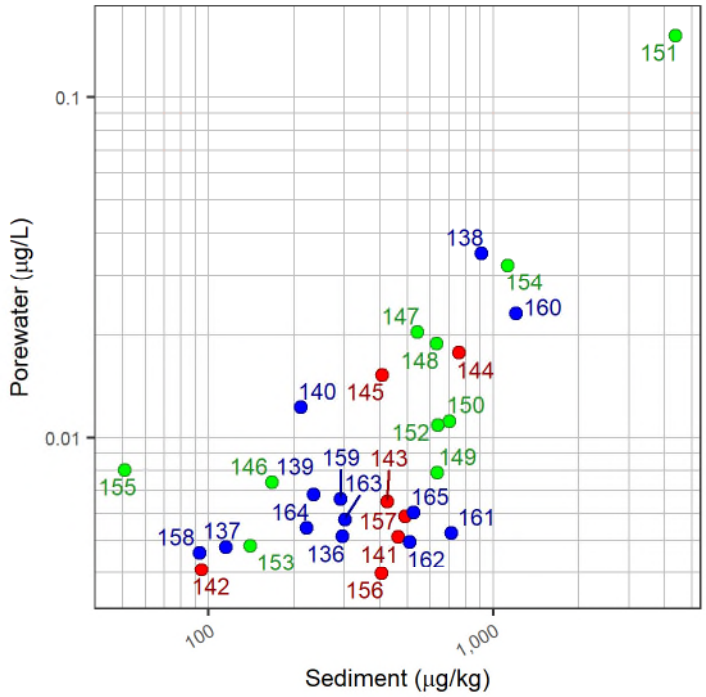
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
µg/kg = micrograms per kilogram
µg/L = micrograms per liter

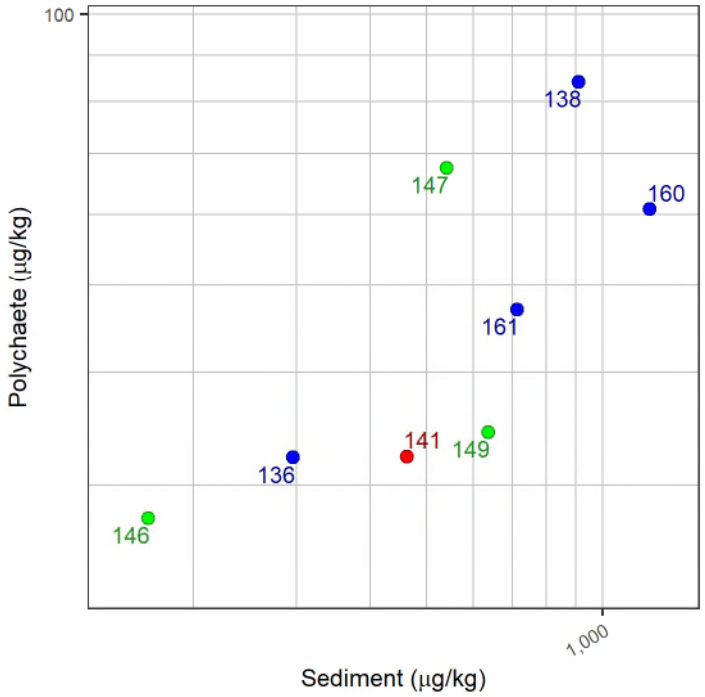
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

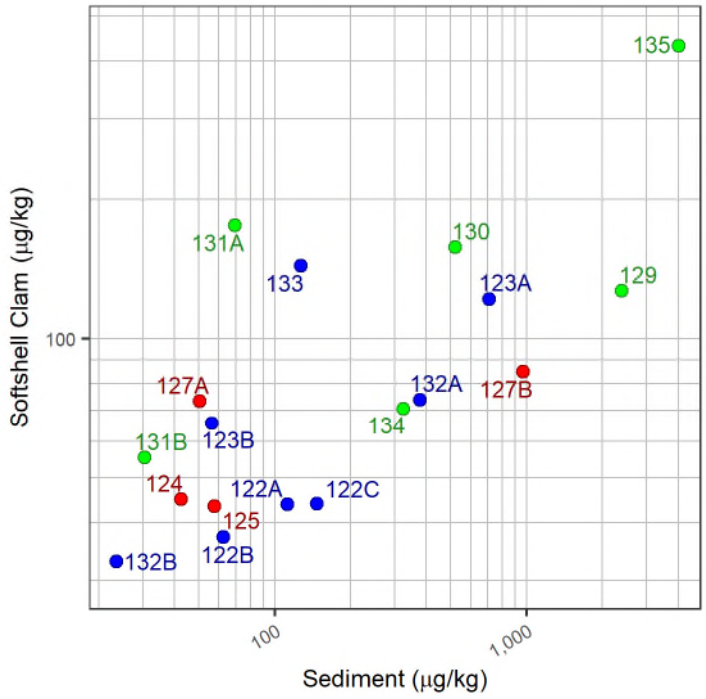
CONCENTRATIONS IN POREWATER AND TISSUE VERSUS SEDIMENT:2,3,7,8-TCDD

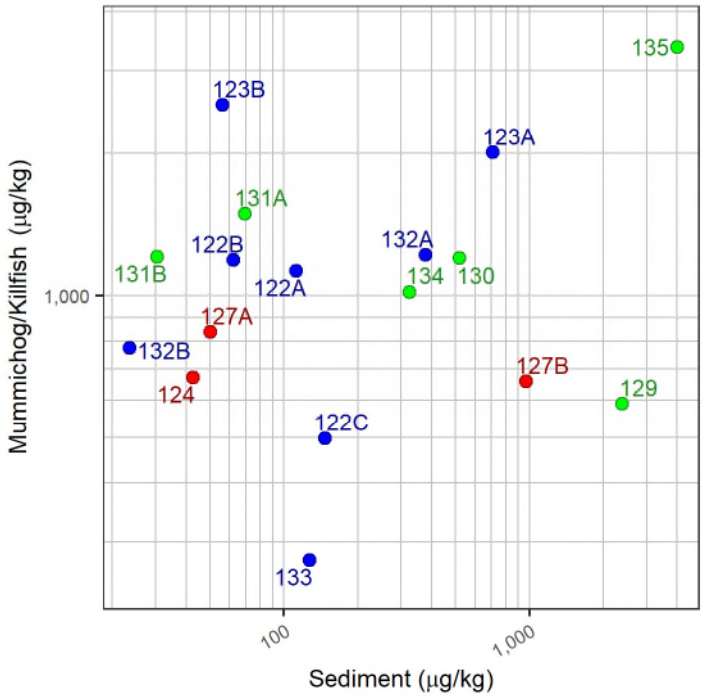
OXY Glenn Springs Holdings, Inc.
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FIGURE
5-BIO-1









Bay Area (color-code)
- North
- Central
- South

- Filled Symbol = Both Samples Detected
- Open Symbol = Both Samples Non-detect
- Filled Symbol = Biota Non-detect and Sediment/Porewater Detect
- Filled Symbol = Biota Detect and Sediment/Porewater Non-detect

Notes:
Non-detects plotted at the reporting limit.
Measured porewater concentrations were made with passive sampling methods that are intended to measure only freely dissolved concentrations (non-DOC-complexed concentrations).

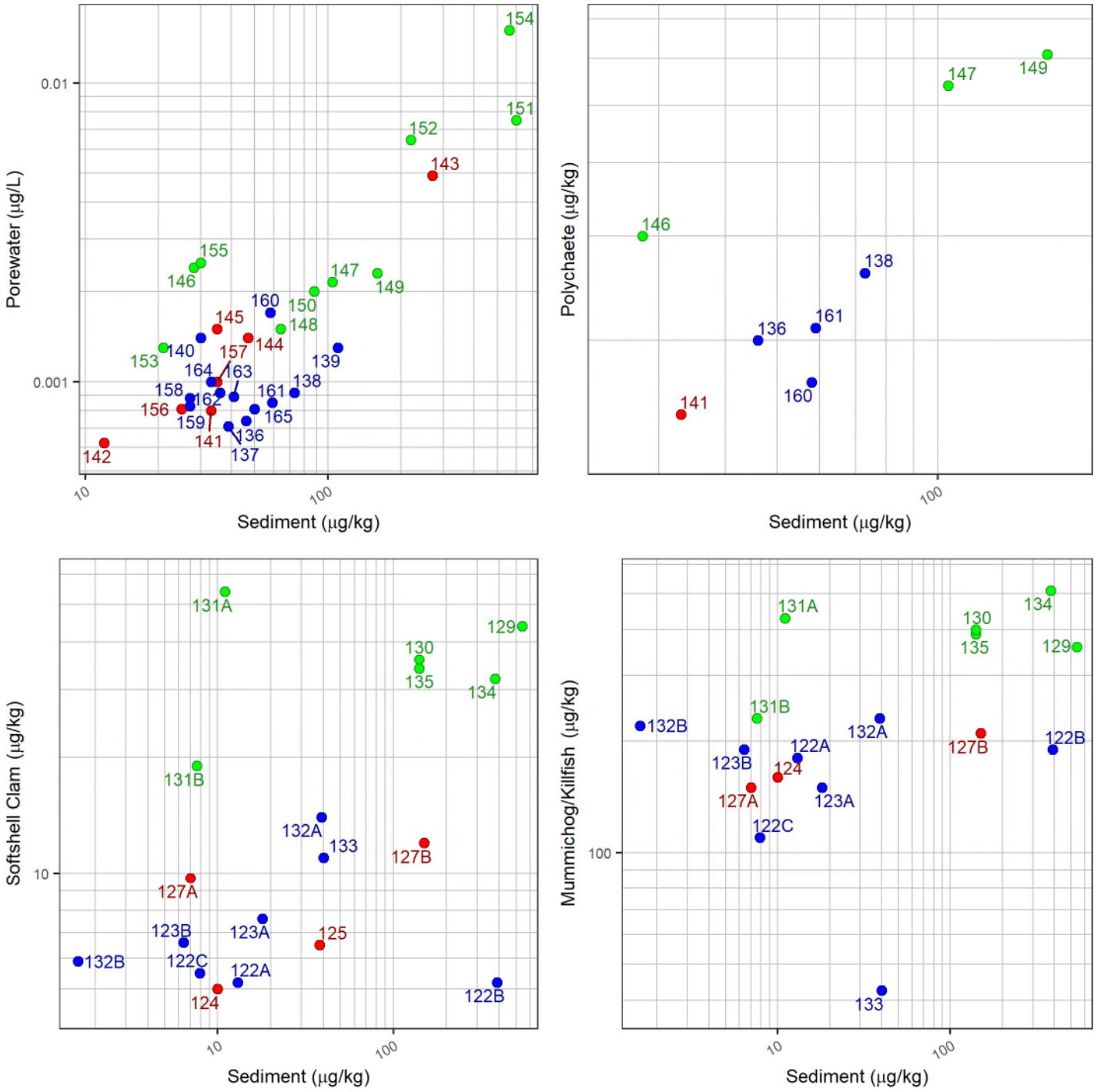
PCBs = polychlorinated biphenyls
µg/kg = micrograms per kilogram
µg/L = micrograms per liter

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CONCENTRATIONS IN POREWATER AND TISSUE VERSUS SEDIMENT:TOTAL PCBS

OXY Glenn Springs Holdings, Inc.
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FIGURE
5-BIO-2



Notes:
Non-detects plotted at the reporting limit.
Measured porewater concentrations were made with passive sampling methods that are intended to measure only freely dissolved concentrations (non-DOC-complexed concentrations).

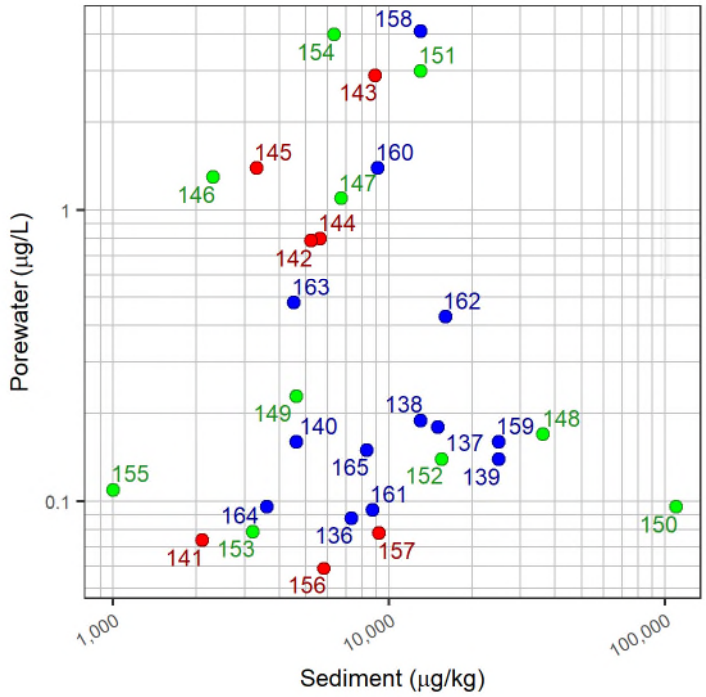
DDx = sum of dichlorodiphenyldichloroethane, dichlorodiphenyldichloroethylene, and dichlorodiphenyltrichloroethane
µg/kg = micrograms per kilogram
µg/L = micrograms per liter

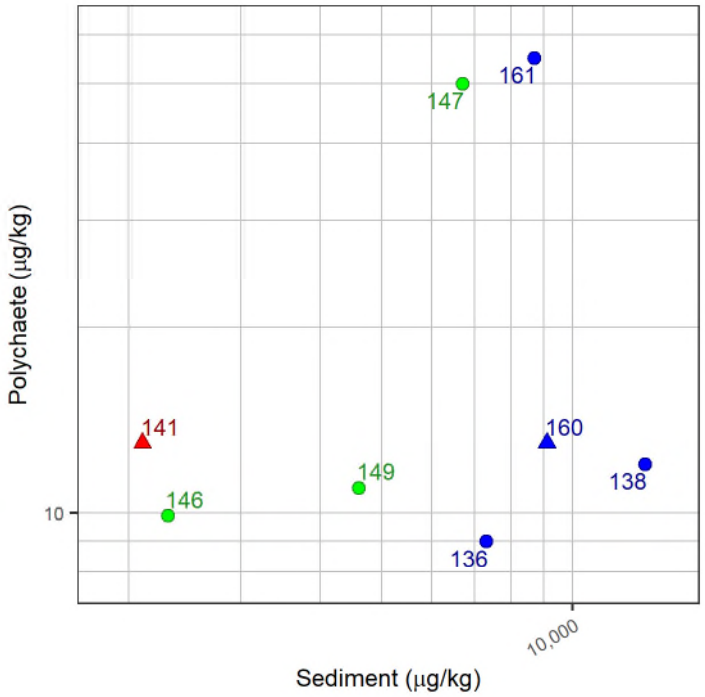
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

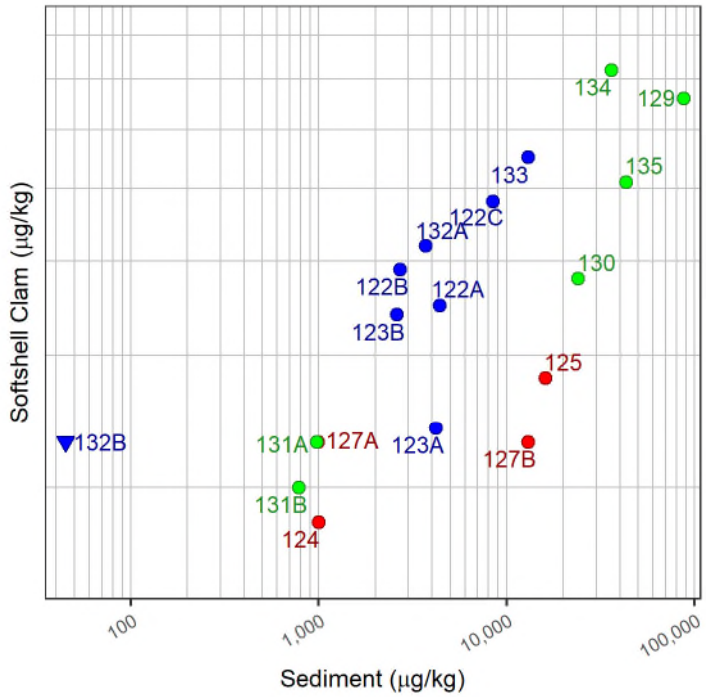
CONCENTRATIONS IN POREWATER AND TISSUE VERSUS SEDIMENT:TOTAL DDX (2,4' & 4,4')

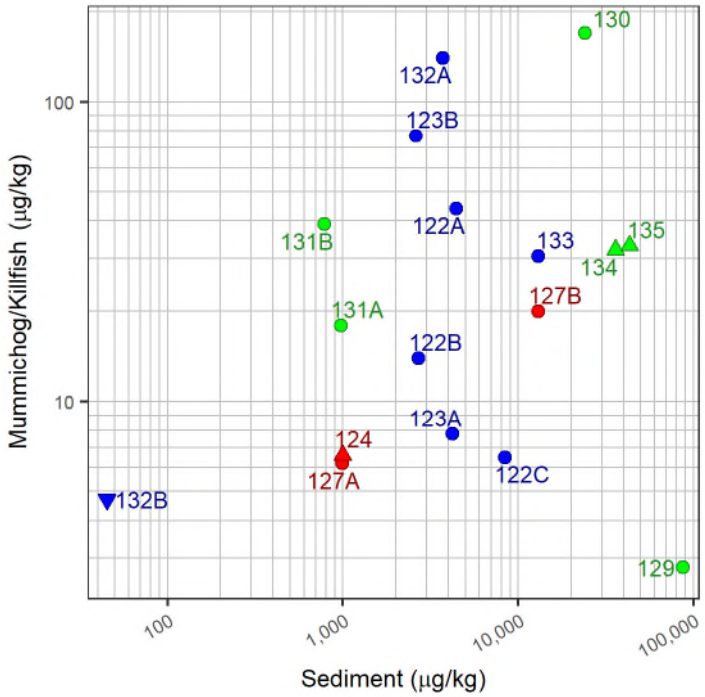
Glenn Springs Holdings, Inc.
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FIGURE
5-BIO-3









Bay Area (color-code)
- North
- Central
- South

- ● Filled Symbol = Both Samples Detected
- ○ Open Symbol = Both Samples Non-detect
- ▲ Filled Symbol = Biota Non-detect and Sediment/Porewater Detect
- ▼ Filled Symbol = Biota Detect and Sediment/Porewater Non-detect

Notes:
Non-detects plotted at the reporting limit.
Measured porewater concentrations were made with passive sampling methods that are intended to measure only freely dissolved concentrations (non-DOC-complexed concentrations).

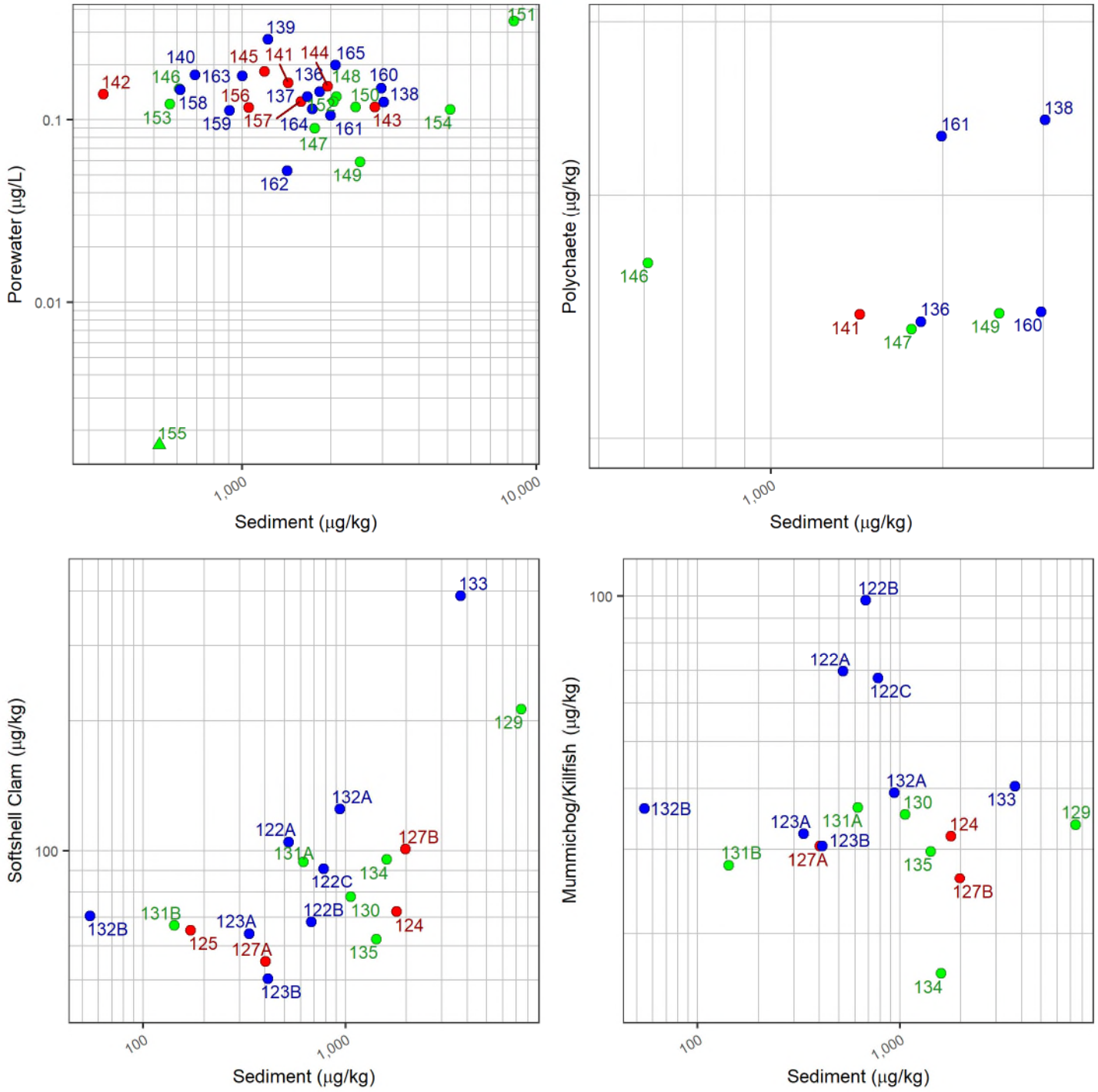
PAHs = polycyclic aromatic hydrocarbons
µg/kg = micrograms per kilogram
µg/L = micrograms per liter

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CONCENTRATIONS IN POREWATER AND TISSUE VERSUS SEDIMENT:TOTAL PAHS

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-BIO-4



Notes:
Non-detects plotted at the reporting limit.
Measured porewater concentrations were made with passive sampling methods that are intended to measure only freely dissolved concentrations (non-DOC-complexed concentrations).

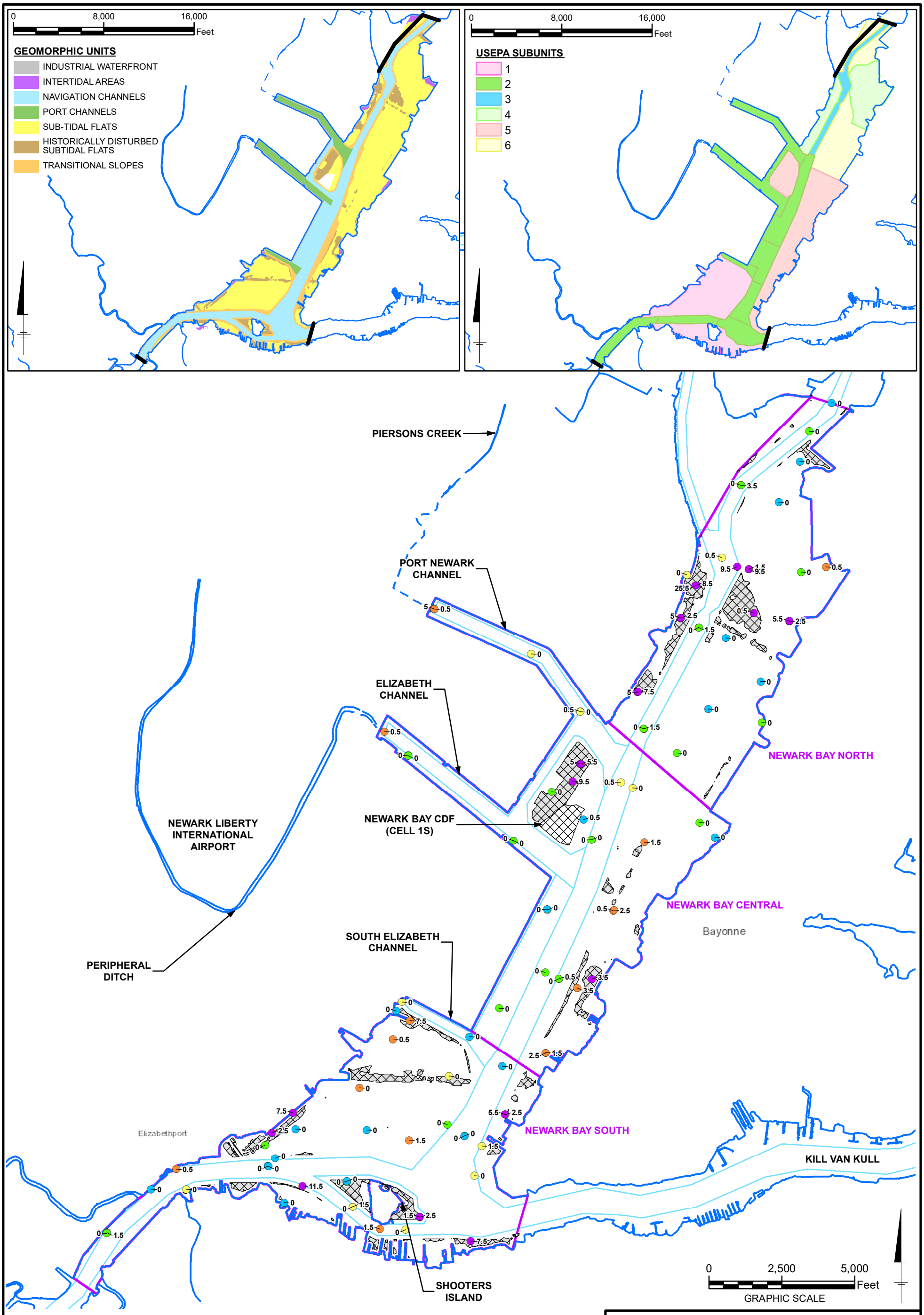
µg/kg = micrograms per kilogram
µg/L = micrograms per liter

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CONCENTRATIONS IN POREWATER AND TISSUE VERSUS SEDIMENT:MERCURY

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-BIO-5



LEGEND

- SHORELINE
- UNDERGROUND TRIBUTARY
- NAVIGATION CHANNEL
- GEOGRAPHIC ZONE BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- CDF Area

TCDD MPA mg/sf

- 0.000 - 0.001
- 0.001 - 0.002
- 0.002 - 0.012
- 0.012 - 0.115
- 0.115 - 4.45

VALUES POSTED AT SAMPLE LOCATIONS SHOW THE DEPTH (FT) OF CORE MAXIMUM CONCENTRATION

NOTE:
1. MASS PER UNIT AREA (MPA) BIN RANGES ARE SHOWN BY QUANTILE,AND REPORTED IN MILLIGRAMS (MG) PER SQUARE FOOT (SF).
2. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
3. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
4. GEOGRAPHIC ZONE BOUNDARIES ARE USED TO DIVIDE THE STUDY AREA INTO NORTH, CENTRAL, AND SOUTH ZONES.

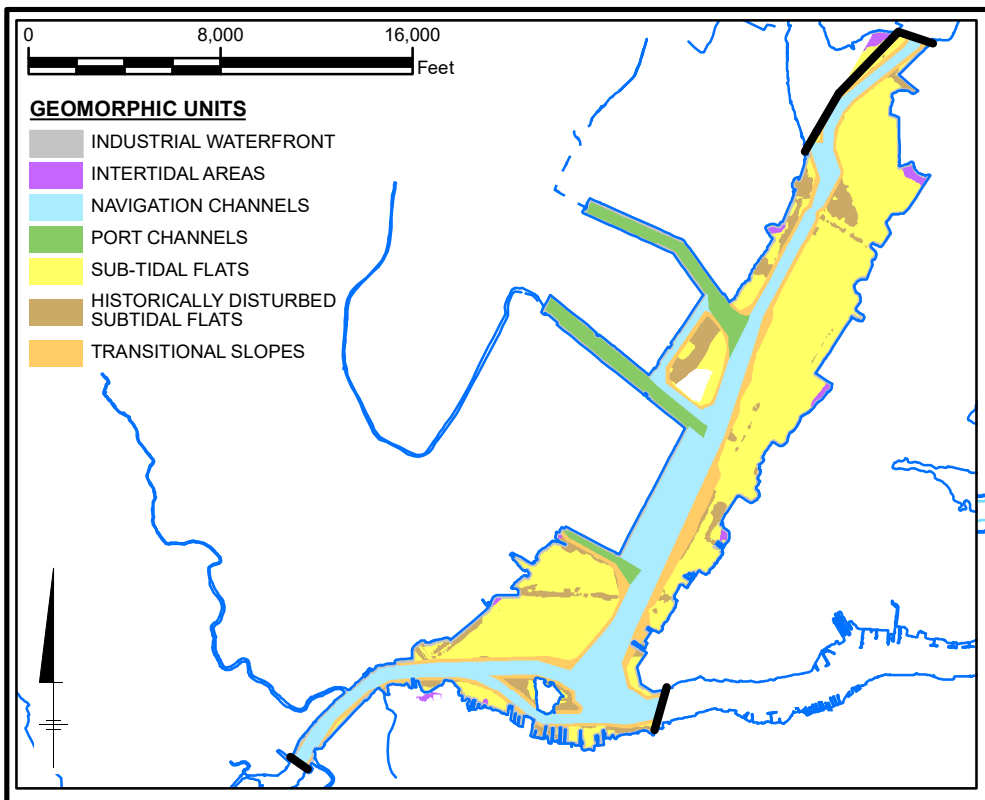
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

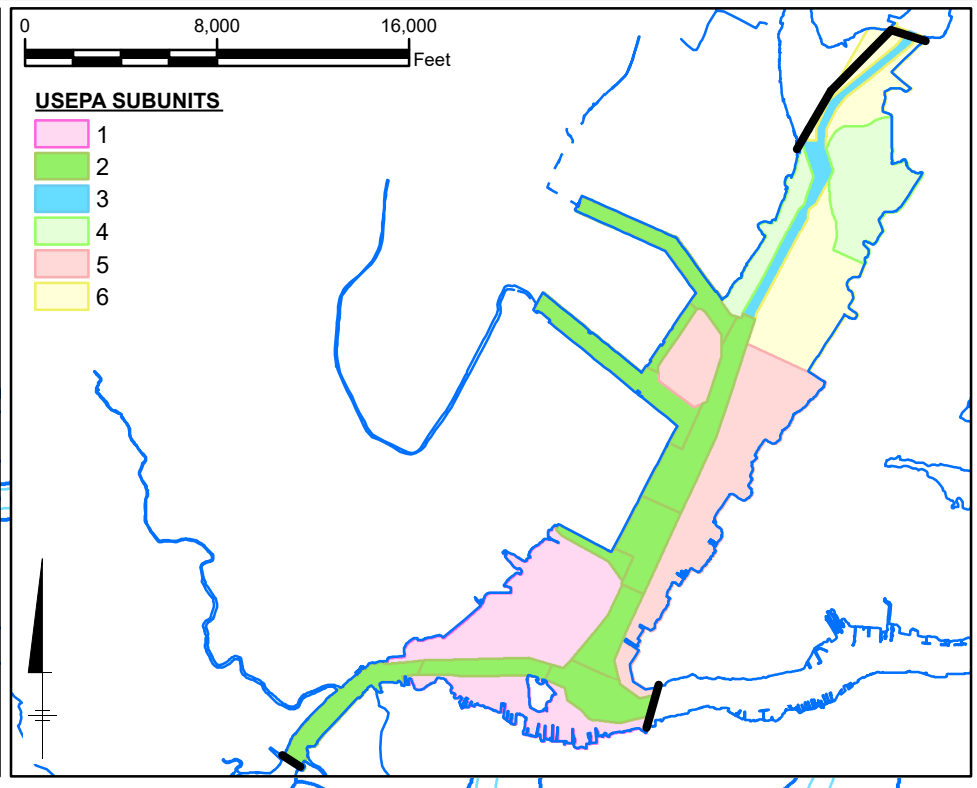
MPA Distribution of 2,3,7,8-TCDD

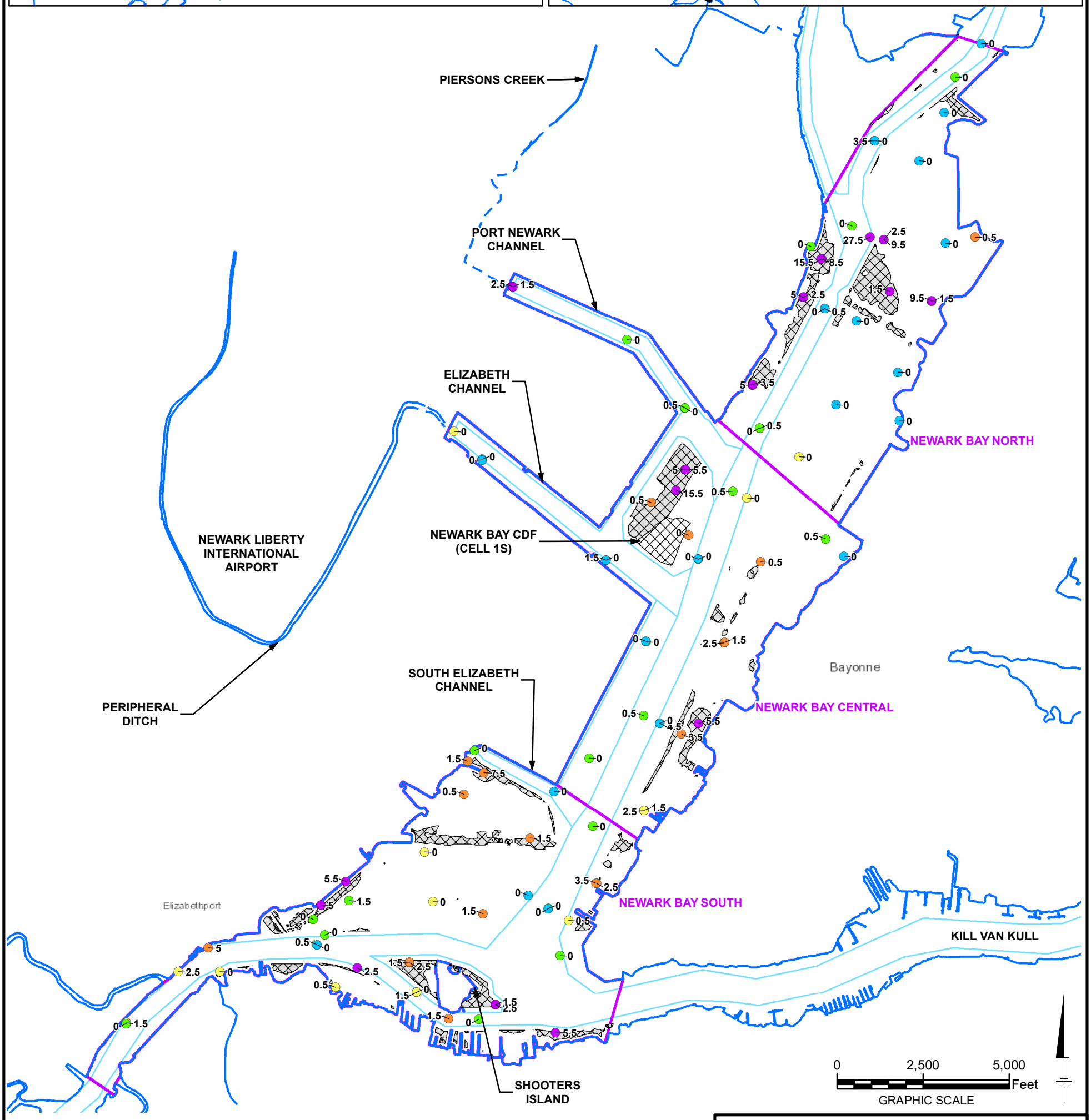
OXY Glenn Springs Holdings, Inc.
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FIGURE
5-INVEN-1a

City: SYR Div/Group: IM/DV Created By: ksinsabaugh Last Saved By: KGPeters
Newark Bay (B0009989.0045.00006) T:_ENV\GSH\GIS\Task\NBSA\2020\NB_MassPerUnitArea\NB_Mass_Per_Uni_Area_Mercury mg_sf_v2.mxd 1/20/2021 10:06:22 AM







LEGEND

- SHORELINE
- UNDERGROUND TRIBUTARY
- NAVIGATION CHANNEL
- GEOGRAPHIC ZONE BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- CDF Area

Mercury MPA mg/fs

- 9.75 - 40.4
- 40.4 - 197
- 197 - 609
- 609 - 3090
- 3090 - 77200

VALUES POSTED AT SAMPLE LOCATIONS SHOW THE DEPTH (FT) OF CORE MAXIMUM CONCENTRATION

NOTE:
1. MASS PER UNIT AREA (MPA) BIN RANGES ARE SHOWN BY QUANTILE,AND REPORTED IN MILLIGRAMS (MG) PER SQUARE FOOT (SF).
2. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
3. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
4. GEOGRAPHIC ZONE BOUNDARIES ARE USED TO DIVIDE THE STUDY AREA INTO NORTH, CENTRAL, AND SOUTH ZONES.

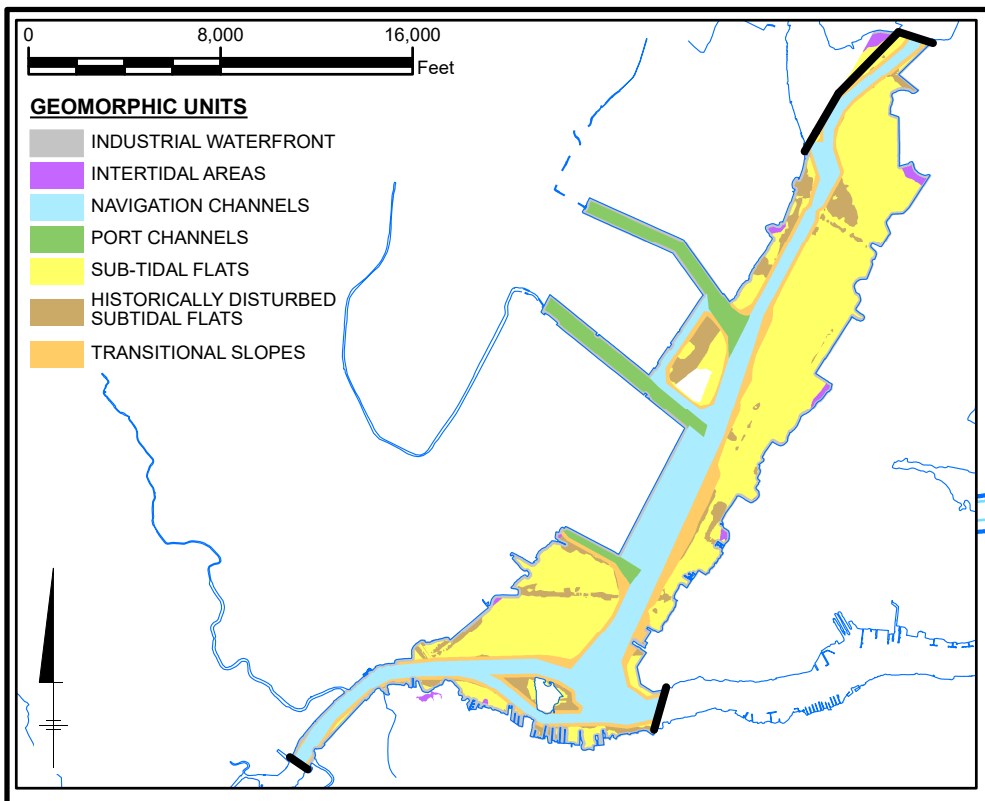
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

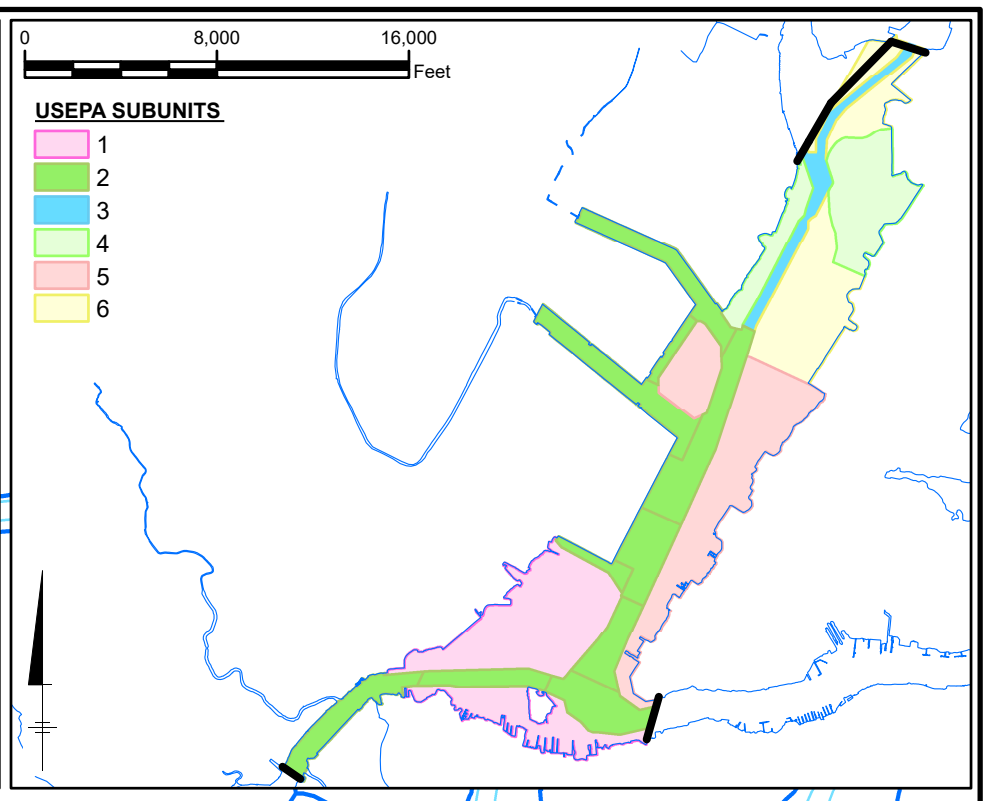
MPA Distribution of Mercury

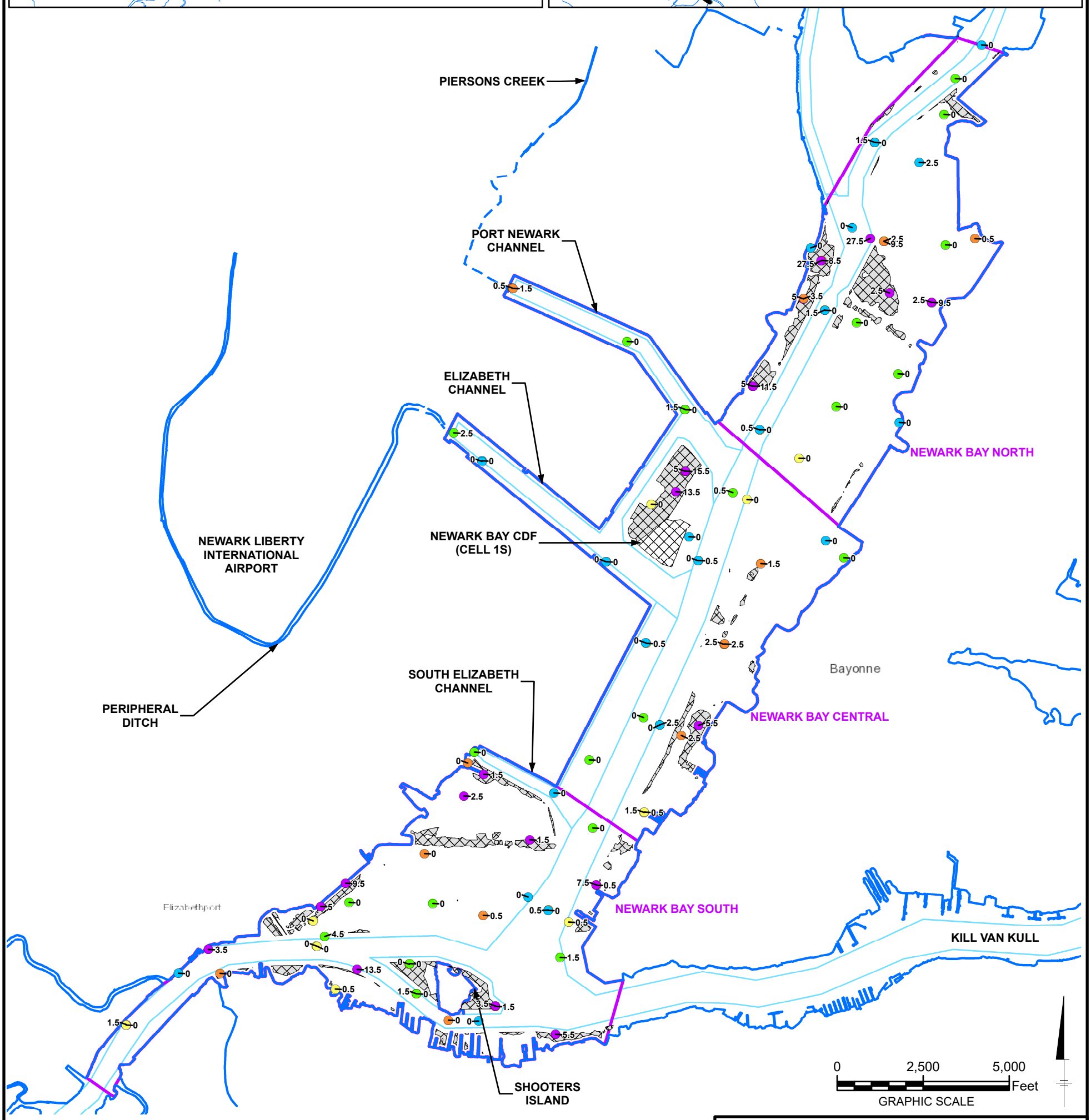
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-INVEN-1b

City: SYR Div/Group: IM/DV Created By: ksinsabaugh Last Saved By: avi00815
Newark Bay (B0009989.0045.00006) T:_ENV\GSH\GIS\Task\NBSA\2020\NB_MassPerUnitArea\NB_Mass_Per_Uni_ Area_DDx_mg_sf_V2.mxd 3/2/2022 11:18:50 AM







LEGEND

- SHORELINE
- UNDERGROUND TRIBUTARY
- NAVIGATION CHANNEL
- GEOGRAPHIC ZONE BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- CDF Area

Total DDx (4,4) Total Fraction mg/sf

- 0.23 - 1.21
- 1.21 - 3.39
- 3.39 - 12.4
- 12.4 - 55.8
- 55.8 - 541

VALUES POSTED AT SAMPLE LOCATIONS SHOW THE DEPTH (FT) OF CORE MAXIMUM CONCENTRATION

NOTE:
1. MASS PER UNIT AREA (MPA) BIN RANGES ARE SHOWN BY QUANTILE,AND REPORTED IN MILLIGRAMS (MG) PER SQUARE FOOT (SF).
2. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
3. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
4. GEOGRAPHIC ZONE BOUNDARIES ARE USED TO DIVIDE THE STUDY AREA INTO NORTH, CENTRAL, AND SOUTH ZONES.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MPA Distribution of Total DDx (4,4') Fraction

Glenn Springs Holdings, Inc.
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FIGURE
5-INVEN-1c

City: SYR Div/Group: IM/DV Created By: ksinsabaugh Last Saved By: KGPeters
Newark Bay (B0009989.0045.00006) T:_ENV\GSH\GIS\Task\NBSA\2020\NB_MassPerUnitArea\NB_Mass_Per_Uni_Area_PCB_mg_sf_V2.mxd 1/20/2021 10:09:03 AM

0 8,000 16,000 Feet

GEOMORPHIC UNITS
- INDUSTRIAL WATERFRONT
- INTERTIDAL AREAS
- NAVIGATION CHANNELS
- PORT CHANNELS
- SUB-TIDAL FLATS
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- TRANSITIONAL SLOPES

0 8,000 16,000 Feet

USEPA SUBUNITS
- 1
- 2
- 3
- 4
- 5
- 6

PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
NEWARK BAY NORTH
NEWARK BAY CENTRAL
NEWARK BAY SOUTH
KILL VAN KULL
Bayonne
Elizabethport
SHOOTERS ISLAND

0 2,500 5,000 Feet
GRAPHIC SCALE

LEGEND
- SHORELINE
- UNDERGROUND TRIBUTARY
- NAVIGATION CHANNEL
- GEOGRAPHIC ZONE BOUNDARY
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- CDF Area

PCB MPA mg/fs
- 0.67 - 9.13
- 9.13 - 28.1
- 28.1 - 141
- 141 - 811
- 811 - 11900

VALUES POSTED AT SAMPLE LOCATIONS SHOW THE DEPTH (FT) OF CORE MAXIMUM CONCENTRATION

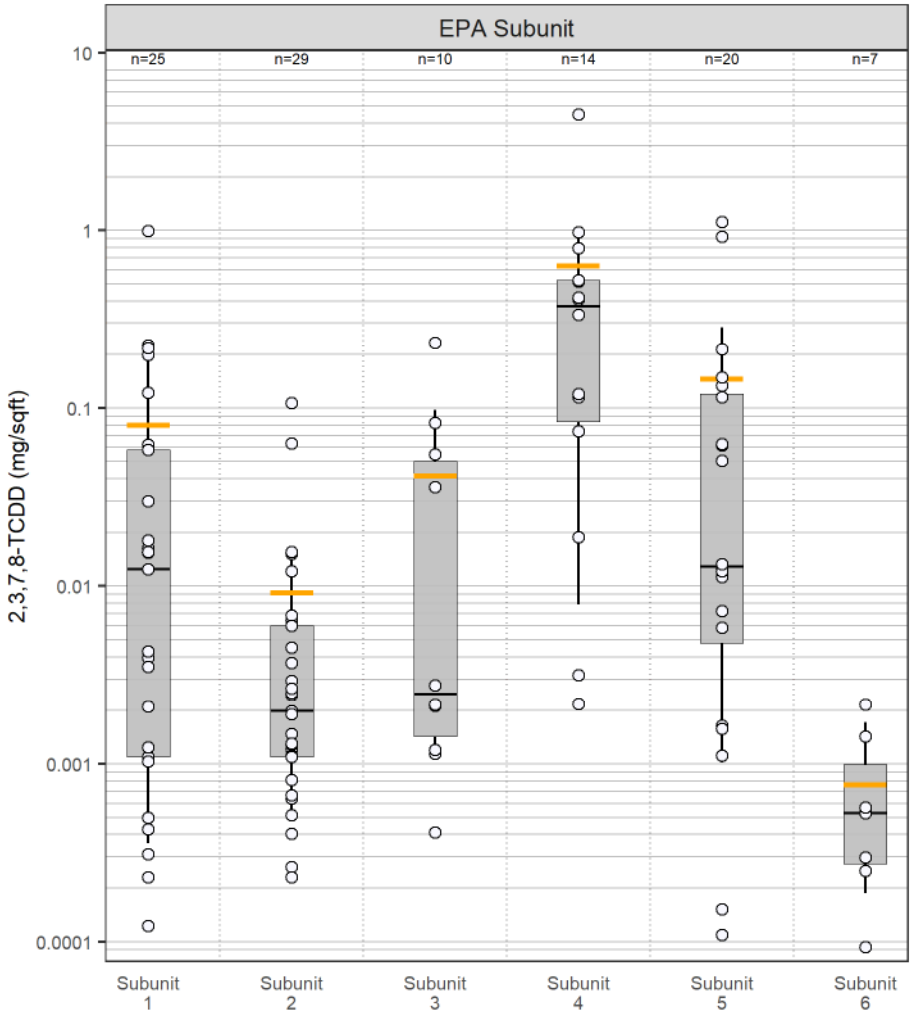
NOTE:
1. MASS PER UNIT AREA (MPA) BIN RANGES ARE SHOWN BY QUANTILE,AND REPORTED IN MILLIGRAMS (MG) PER SQUARE FOOT (SF).
2. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
3. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
4. GEOGRAPHIC ZONE BOUNDARIES ARE USED TO DIVIDE THE STUDY AREA INTO NORTH, CENTRAL, AND SOUTH ZONES.

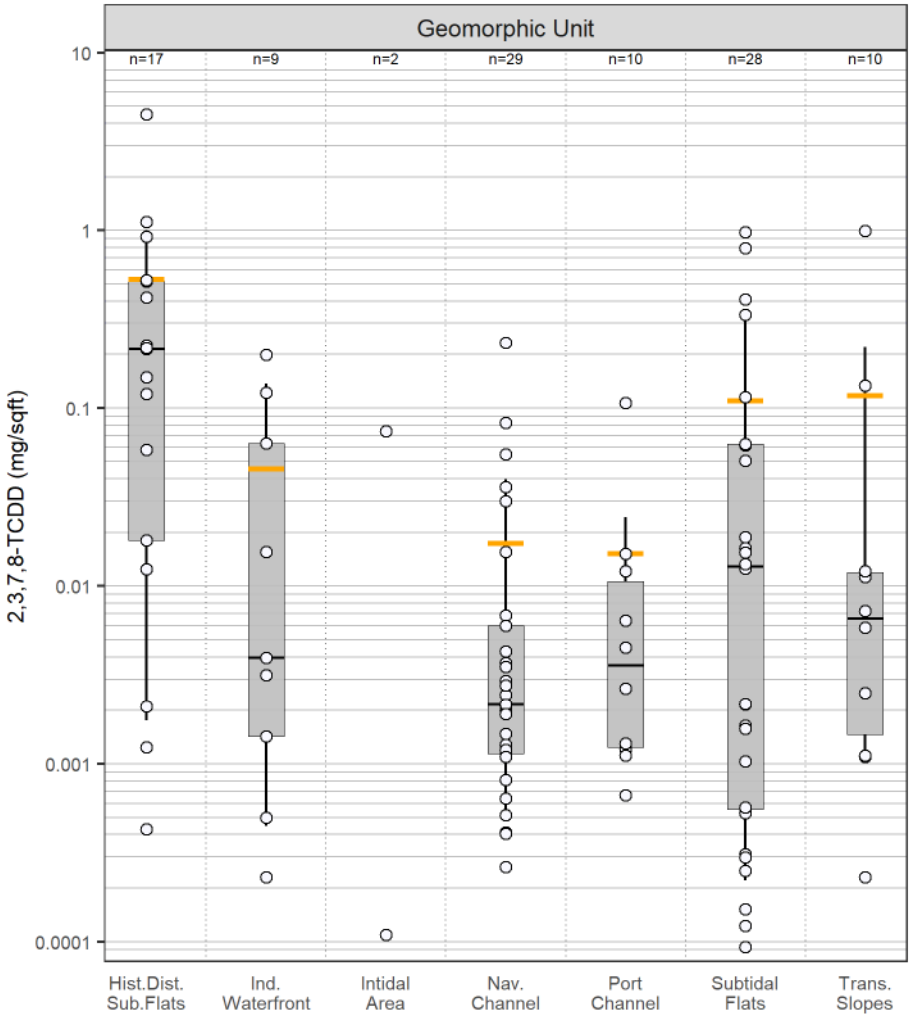
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

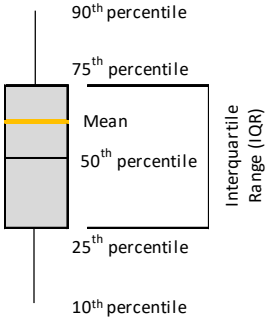
MPA Distribution of Total PCBs

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-INVEN-1d







Range of Non-detect Quantitation Limits (QL)

Detected Result

Non-detected Result (plottted at QL)

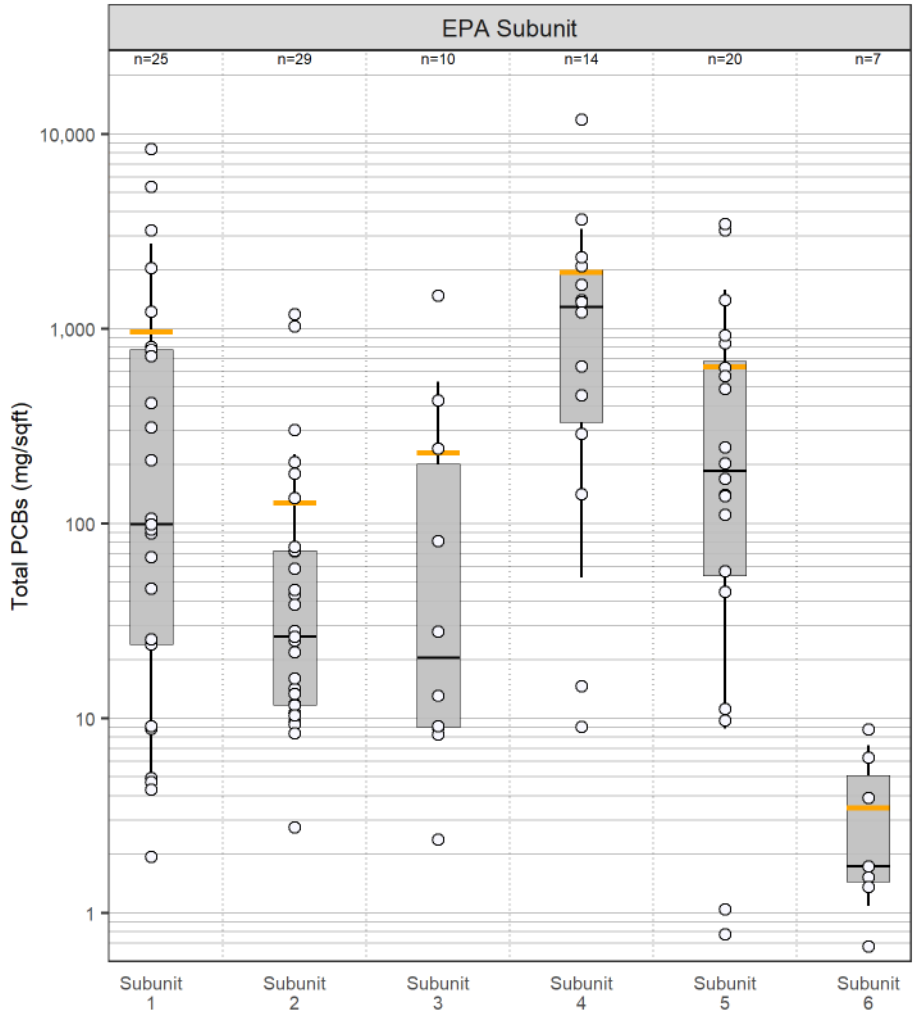
1. Results reported in milligrams per square foot (mg/sqft).
2. Summary statistics not reported for datasets with small sample size (n<3) and/or low frequency of detection (≤50%).
3. Kaplan-Meier mean and standard deviation reported for datasets with non-detect results.
4. Arithmetic mean and standard deviation reported for datasets with no non-detect results.
5. Non-detects included at the quantitation limit in percentile estimation.
6. Statistical results in brackets represent values below the maximum reporting limit.

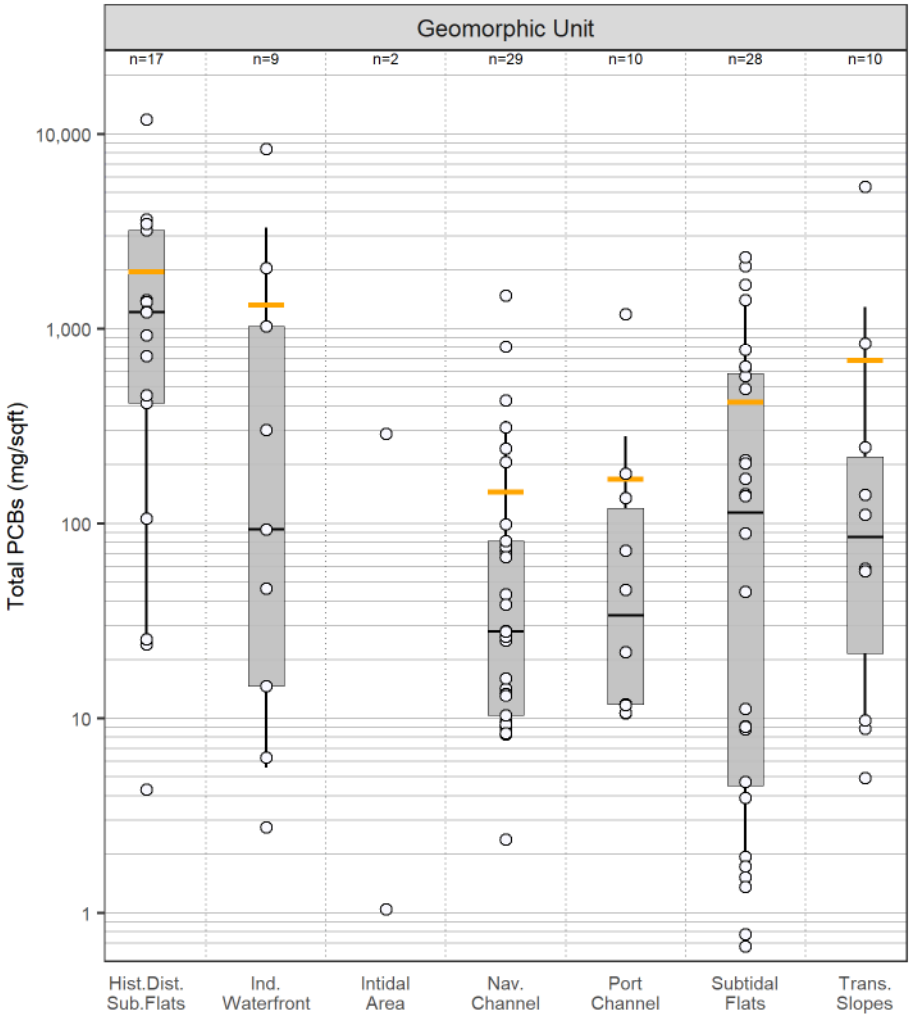
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

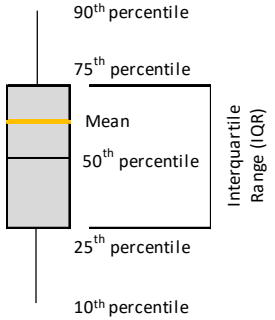
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD) MPA BOX PLOT

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-INVEN-2a







Range of Non-detect Quantitation Limits (QL)

Detected Result

Non-detected Result (plottted at QL)

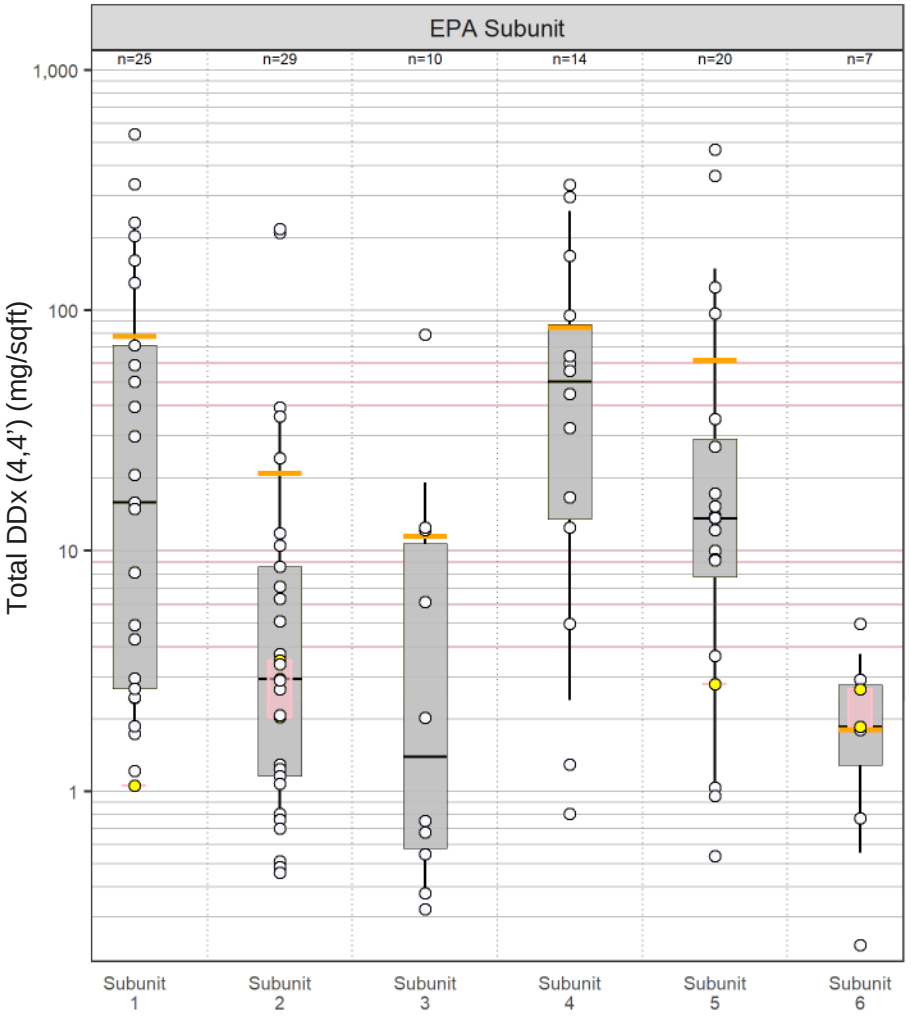
1. Results reported in milligrams per square foot (mg/sqft).
2. Summary statistics not reported for datasets with small sample size (n<3) and/or low frequency of detection (≤50%).
3. Kaplan-Meier mean and standard deviation reported for datasets with non-detect results.
4. Arithmetic mean and standard deviation reported for datasets with no non-detect results.
5. Non-detects included at the quantitation limit in percentile estimation.
6. Statistical results in brackets represent values below the maximum reporting limit.

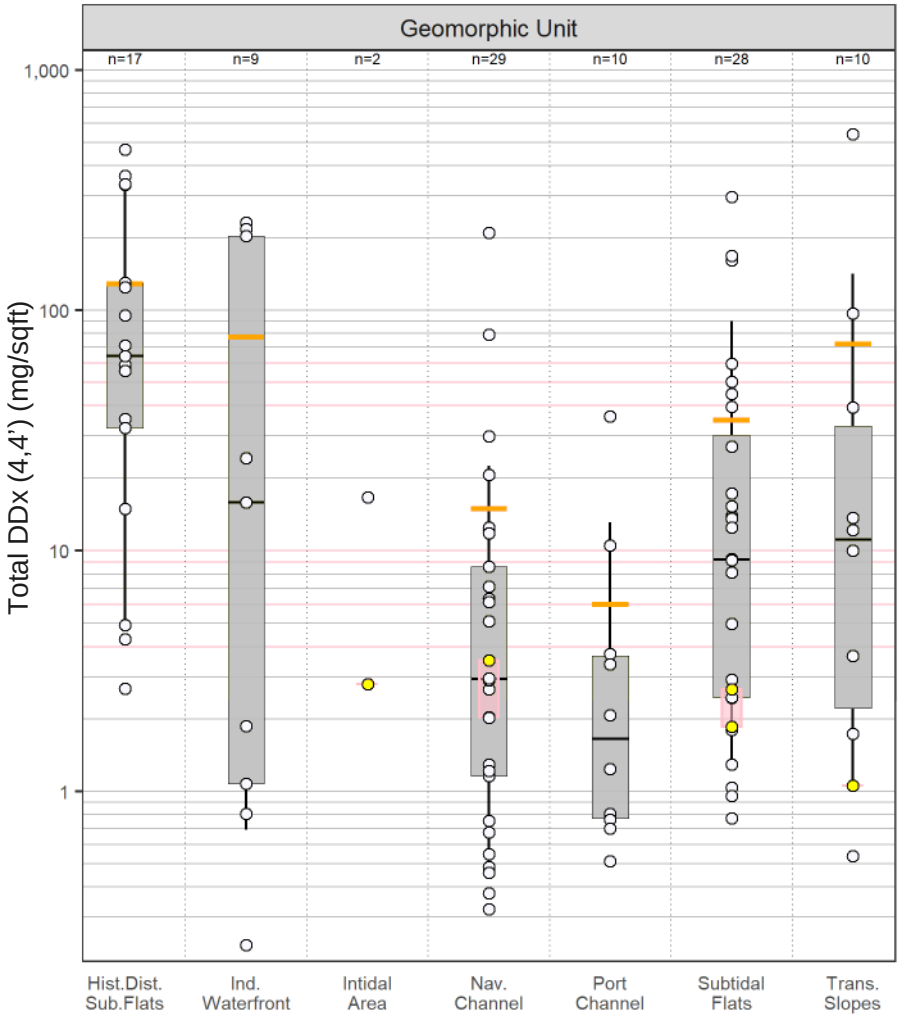
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

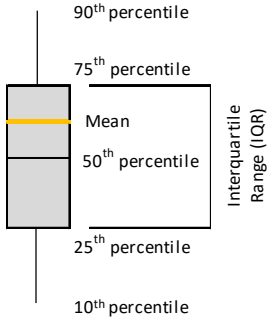
TOTAL PCBS CONGENER (209 SPECIFIED) MPA BOX PLOT

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-INVEN-2b







Range of Non-detect Quantitation Limits (QL)

Detected Result

Non-detected Result (plottted at QL)

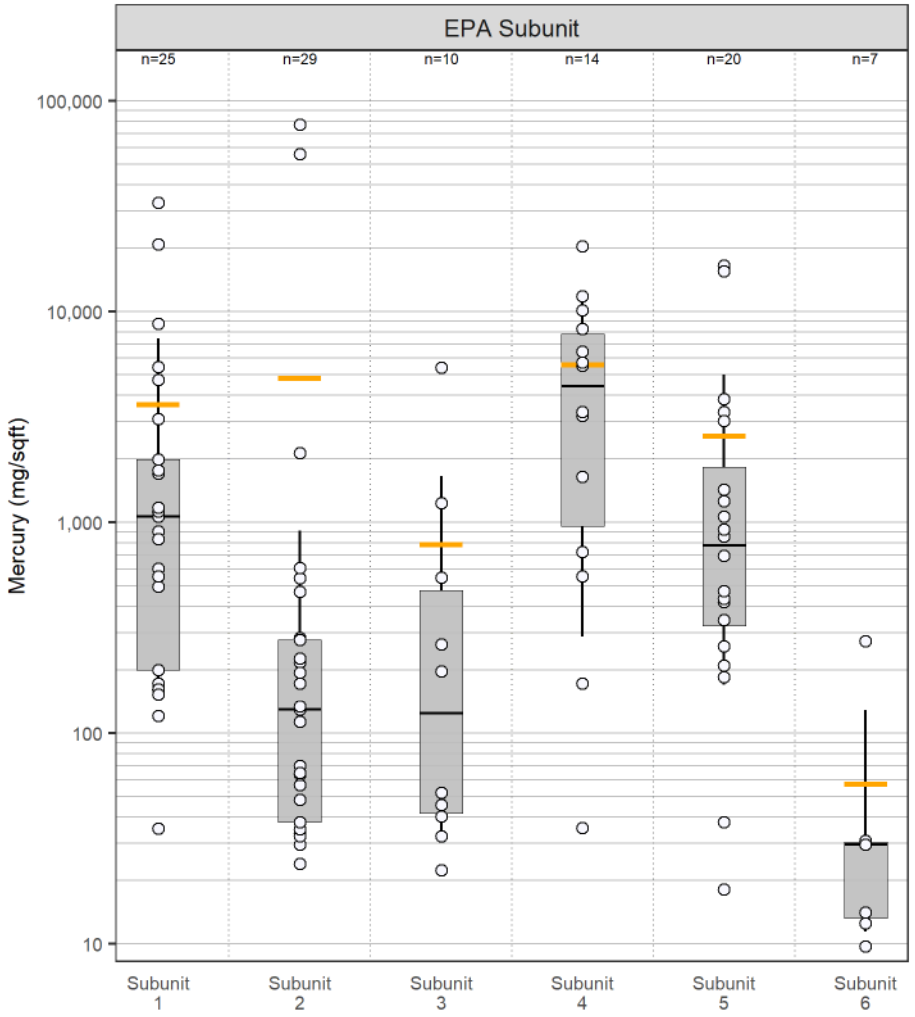
1. Results reported in milligrams per square foot (mg/sqft).
2. Summary statistics not reported for datasets with small sample size (n<3) and/or low frequency of detection (≤50%).
3. Kaplan-Meier mean and standard deviation reported for datasets with non-detect results.
4. Arithmetic mean and standard deviation reported for datasets with no non-detect results.
5. Non-detects included at the quantitation limit in percentile estimation.
6. Statistical results in brackets represent values below the maximum reporting limit.

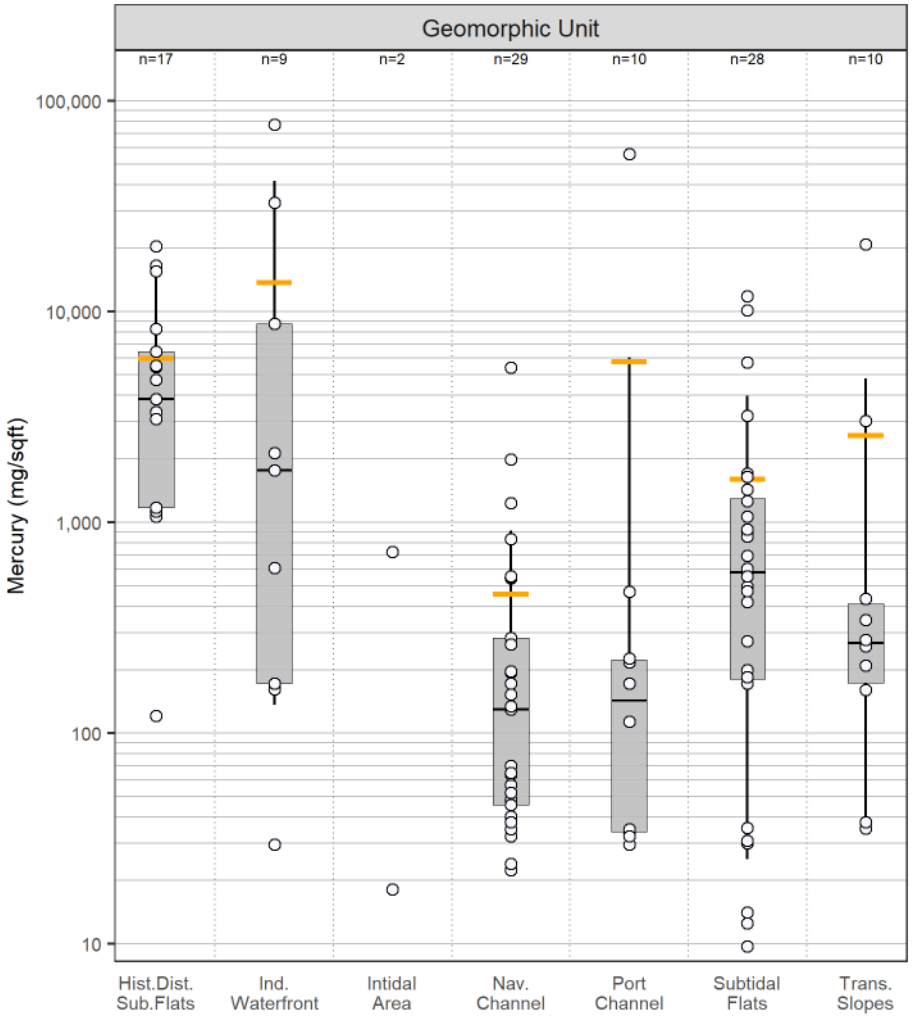
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

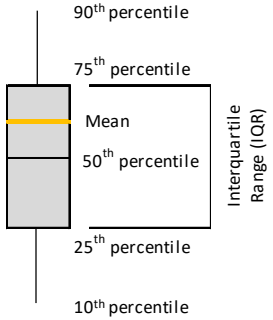
TOTAL DDX (4,4') MPA BOX PLOT

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-INVEN-2c







Range of Non-detect Quantitation Limits (QL)

Detected Result

Non-detected Result (plottted at QL)

1. Results reported in milligrams per square foot (mg/sqft).
2. Summary statistics not reported for datasets with small sample size (n<3) and/or low frequency of detection (≤50%).
3. Kaplan-Meier mean and standard deviation reported for datasets with non-detect results.
4. Arithmetic mean and standard deviation reported for datasets with no non-detect results.
5. Non-detects included at the quantitation limit in percentile estimation.
6. Statistical results in brackets represent values below the maximum reporting limit.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MERCURY MPA BOX PLOT

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
5-INVEN-2d

City: Frame Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: ksinsabaugh
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\Fig6-1_Accessible Surface Sediment Sampling Locations.mxd 1/17/2021 9:55:53 AM

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. SQT REPRESENTS THREE ANALYSES: SEDIMENT CHEMISTRY, BENTHIC INVERTEBRATE COMMUNITY, AND TOXICITY TESTING WITH L. PLUMULOSUS (10-DAY AND 28-DAY).
4. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
5. REFERENCE:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

ACRONYMS:
BHHRA - BASELINE HUMAN HEALTH RISK ASSESSMENT
BIO - BIOLOGICAL
LP - LEPTOCHEIRUS PLUMULOSUS
PW - POREWATER
SQT = SEDIMENT QUALITY TRIAD

PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
SHOOTERS ISLAND
NEWARK BAY NORTH
NEWARK BAY CENTRAL
NEWARK BAY SOUTH
KILL VAN KULL

122A 122B 122C 164 140 166 123A 123B 136 133 161 160 132A 167 168 169 142 125 170 143 171 127A 145 127B 172 173 174 178 175 131B 155 131A 130 135 177 134 129 149 176

LEGEND:

- SEDIMENT SAMPLING LOCATION

ANALYSES
- BHHRA
- SQT/PW+LP+BHHRA (INTERTIDAL AREA)
- SQT/PW+LP+BHHRA (SUB-TIDAL FLATS)
- SQT/PW+LP+Bio+BHHRA (INTERTIDAL AREA)
- SQT/PW+LP+Bio+BHHRA (SUB-TIDAL FLATS)

- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- GEOGRAPHIC ZONE BOUNDARY

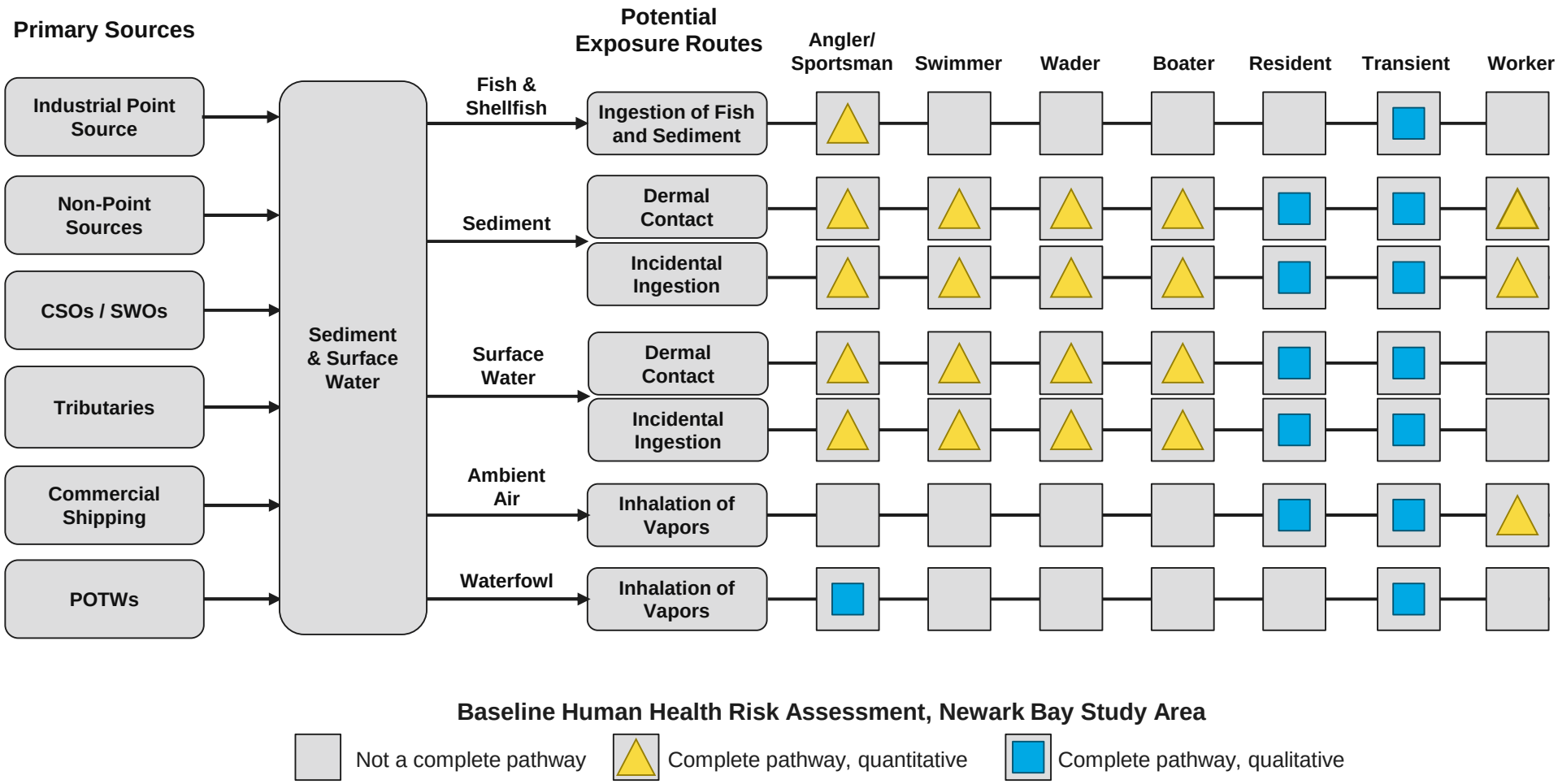
0 2,500 5,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

ACCESSIBLE SURFACE SEDIMENT SAMPLING LOCATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
6-1



Baseline Human Health Risk Assessment, Newark Bay Study Area

Not a complete pathway | Complete pathway, quantitative | Complete pathway, qualitative

Note:
Original figure from Baseline Human Health Risk Assessment (GSH. 2019. Newark Bay Study Area Final Baseline Human Health Risk Assessment. December).
Sources listed have been updated to reflect those discussed herein.
Atmospheric deposition is not considered a significant source to NBSA

Acronyms:

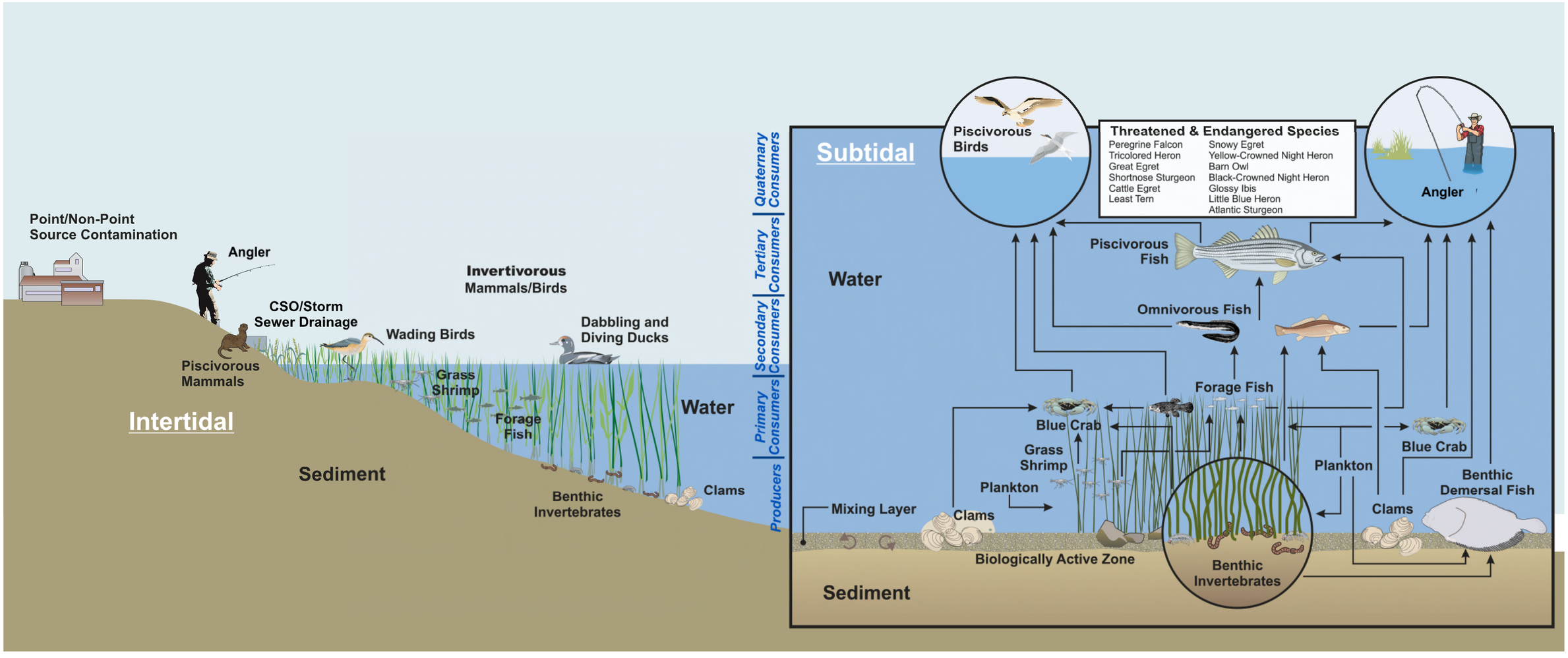
CSOs	Combined Sewer Overflows
POTWs	Publicly Owned Treatment Works
SWOs	Stormwater Outfalls

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

HUMAN HEALTH CONCEPTUAL SITE MODEL

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
6-2



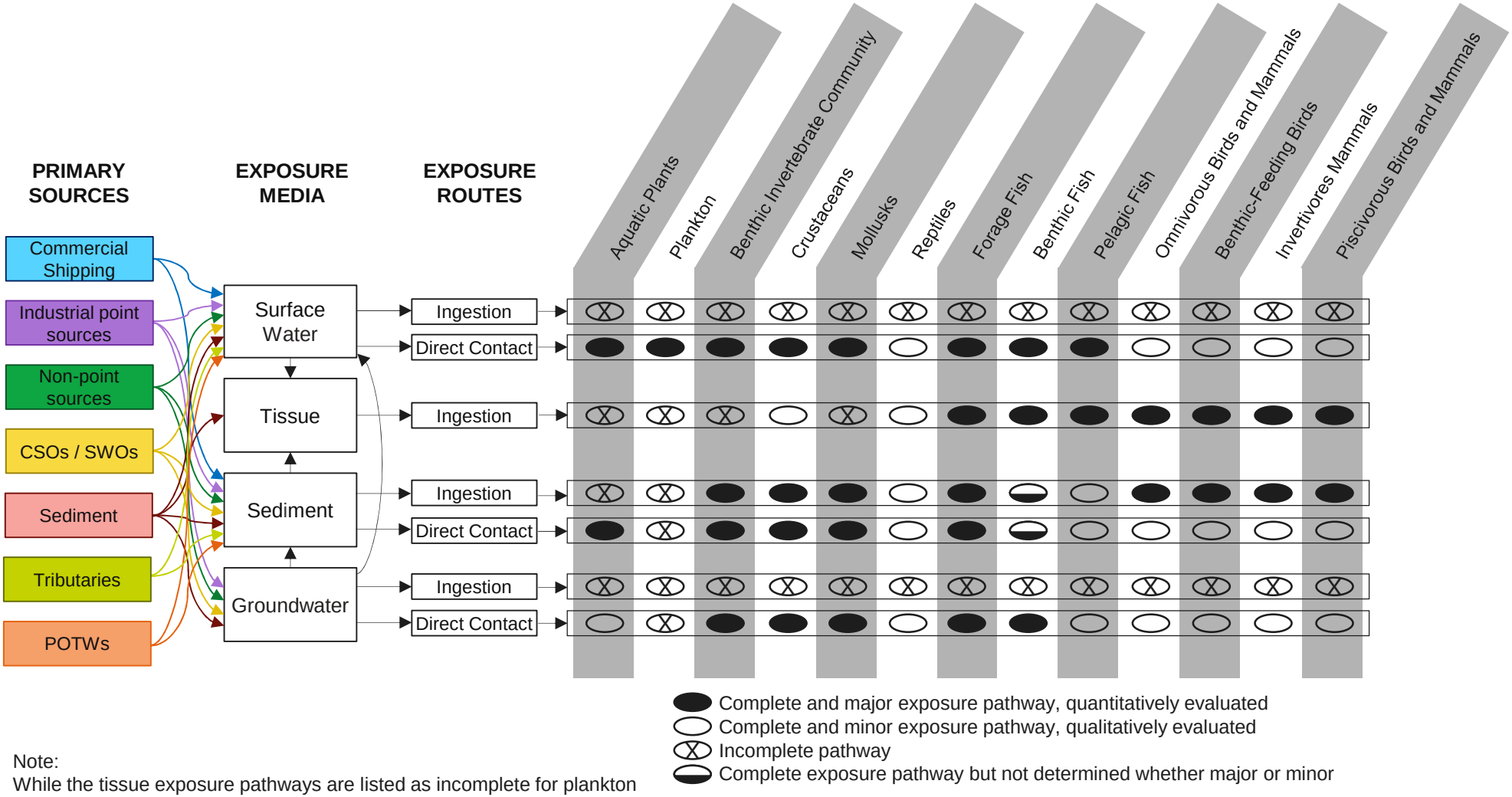
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CONCEPTUAL FOOD WEB DIAGRAM

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
6-3

04/22/2020 \\ARCADIS-US.COM\OFFICE\DATA\SYRACUSE-NY\ENV\COM\PROJECT
MATERIALS\30009165.00028\B. BUTTERLY\W. COFFEY



Note:
While the tissue exposure pathways are listed as incomplete for plankton and the benthic invertebrate community, there are animals in each of these receptor groups that are both carnivorous and herbivorous/filter-feeders.

Reference:
Original figure from Baseline Ecological Risk Assessment (GSH. 2020. Newark Bay Study Area Final Baseline Ecological Risk Assessment. August). Sources listed have been updated to reflect those discussed herein.
Atmospheric deposition is not considered a significant source to NBSA

Acronyms:

CSOs	Combined Sewer Overflows
POTWs	Publicly Owned Treatment Works
SWOs	Stormwater Outfalls

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

ECOLOGICAL CONCEPTUAL SITE MODEL

Glenn Springs Holdings, Inc.
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FIGURE
6-4

City: Frame Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: MEstifanos
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\Fig6-5_AmphipodSurvival_10day.mxd 4/6/2021 7:29:55 PM

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. BASE MAP INFORMATION AND NEWARK BAY NAVIGATION CHANNEL IS FROM NOAA CHARTS 12331, 12333, AND 12337, DATED MAY 4, 1995. PASSAIC NAVIGATION CHANNEL WAS PROVIDED BY THE USACE. ALL NAVIGATION CHANNEL BOUNDARIES SHOWN ARE APPROXIMATE. CHANNEL DREDGING AND DEEPENING AS PART OF THE HARBOR DEEPENING PROJECT (50-FOOT) IS COMPLETE; CONTACT USACE OPERATIONS DIVISION TO REFERENCE THE MOST CURRENT CHANNEL BOUNDARIES.
4. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
5. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.
6. REFERENCE:
   A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

PASSAIC RIVER
CONRAIL BRIDGE REMNANTS
PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
PERIPHERAL DITCH
NEWARK BAY CDF (CELL 1S)
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
KILL VAN KULL
BAYONNE BRIDGE
SHOOTERS ISLAND
GOETHALS BRIDGE
ARTHUR KILL
PRALLS ISLAND

383 384 331 190 154 191 199 194 206 201 207 213 208 220 151 235 134 129 237 239 232

LEGEND:
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- NAVIGATION CHANNEL
- HISTORICALLY DISTURBED SUBTIDAL FLATS

MODEL PREDICTED 10 DAY AMPHIPOD SURVIVAL
- > 80% OF CONTROL
- 60 - 80% OF CONTROL
- < 60% OF CONTROL

0 3,000 6,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MODEL PREDICTED 10 DAY AMPHIPOD SURVIVAL

Glenn Springs Holdings, Inc.
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FIGURE
6-5

City: Frame Div/Group: IM/DV Created By: K. Sinsabaugh Last Saved By: MEstifanos
T:_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Revised\Fig6-6_AmphipodSurvival_28day.mxd 4/6/2021 7:36:15 PM

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.

2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).

3. BASE MAP INFORMATION AND NEWARK BAY NAVIGATION CHANNEL IS FROM NOAA CHARTS 12331, 12333, AND 12337, DATED MAY 4, 1995. PASSAIC NAVIGATION CHANNEL WAS PROVIDED BY THE USACE. ALL NAVIGATION CHANNEL BOUNDARIES SHOWN ARE APPROXIMATE. CHANNEL DREDGING AND DEEPENING AS PART OF THE HARBOR DEEPENING PROJECT (50-FOOT) IS COMPLETE; CONTACT USACE OPERATIONS DIVISION TO REFERENCE THE MOST CURRENT CHANNEL BOUNDARIES.

4. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS. IN APRIL 2020, USEPA REVISED THE BOUNDARY BETWEEN OU2 AND OU3 SUCH THAT KEARNY POINT IS ENTIRELY INCLUDED IN OU2 (USEPA 2020), AS SHOWN. THE BOUNDARY MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.

5. THE CONRAIL BRIDGE REMNANTS, BAYONNE BRIDGE, AND GOETHALS BRIDGE ARE CONVENIENT LANDMARKS, BUT THEY DO NOT CONSTITUTE ADMINISTRATIVE BOUNDARIES.

6. REFERENCE:
A. USEPA. 2020. DIAMOND ALKALI SUPERFUND SITE - BOUNDARY BETWEEN OPERABLE UNIT 2 AND OPERABLE UNIT 3. MEMORANDUM FROM MICHAEL SIVAK, BRANCH CHIEF OF PASSAIC, HACKENSACK, AND NEWARK BAY REMEDIATION BRANCH TO FILE. APRIL 6.

PASSAIC RIVER
PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
PERIPHERAL DITCH
NEWARK BAY CDF (CELL 1S)
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
CONRAIL BRIDGE REMNANTS
BAYONNE BRIDGE
GOETHALS BRIDGE
ARTHUR KILL
PRALLS ISLAND
SHOOTERS ISLAND
KILL VAN KULL

371, 293, 312, 321, 161, 138, 327, 160, 333, 383, 331, 384, 338, 408, 353, 143, 127B, 172, 173, 179, 184, 183, 180, 190, 185, 154, 191, 199, 206, 207, 212, 213, 222, 220, 151, 224, 245, 235, 225, 129, 237, 176, 239, 149, 250, 231, 232

LEGEND:

- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- FORMER OU2/OU3 BOUNDARY
- NAVIGATION CHANNEL
- HISTORICALLY DISTURBED SUBTIDAL FLATS

MODEL PREDICTED 29 DAY AMPHIPOD SURVIVAL

- > 80% OF CONTROL
- 60 - 80% OF CONTROL
- < 60% OF CONTROL

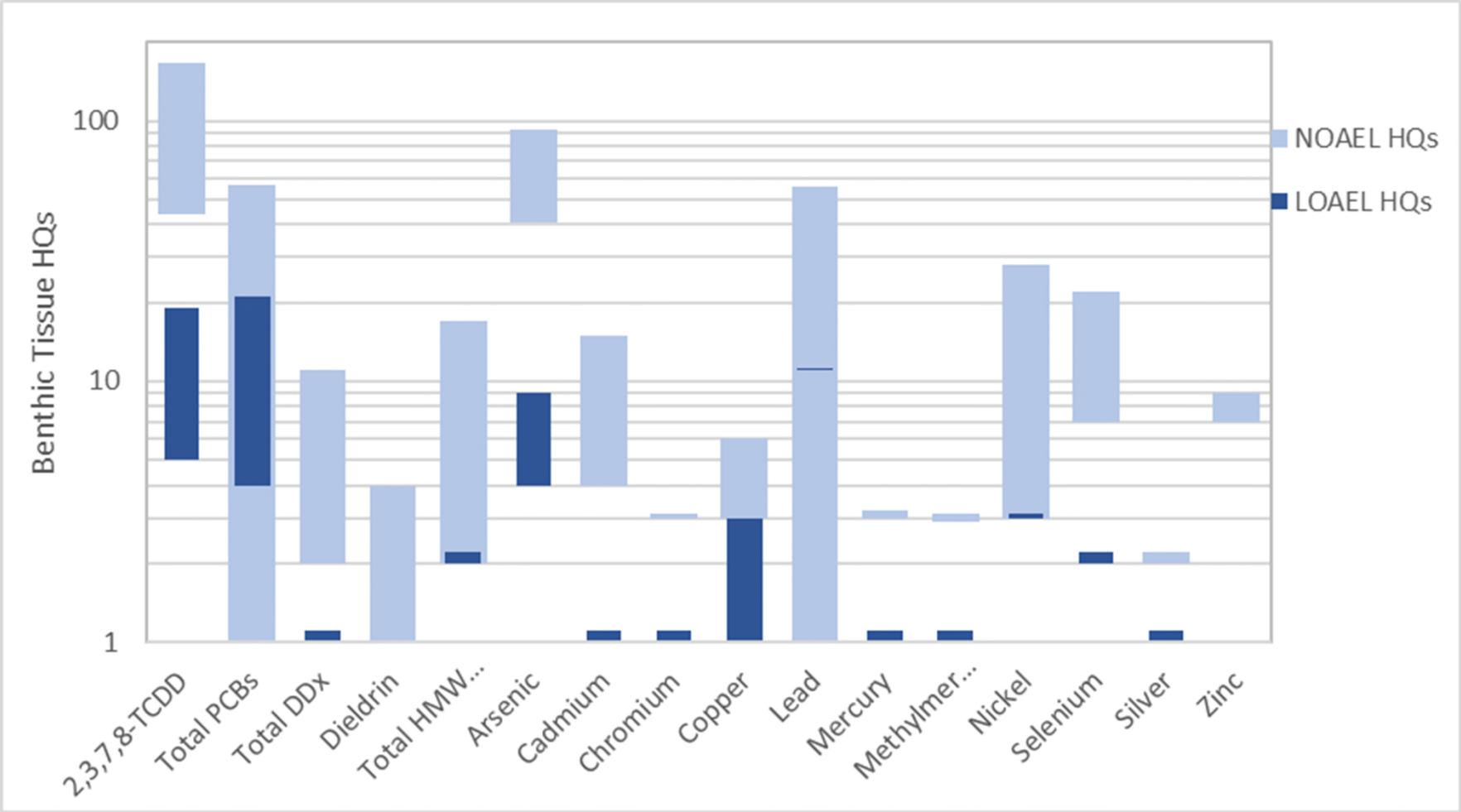
0 3,000 6,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION REMEDIAL INVESTIGATION REPORT

MODEL PREDICTED 28 DAY AMPHIPOD SURVIVAL

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
6-6



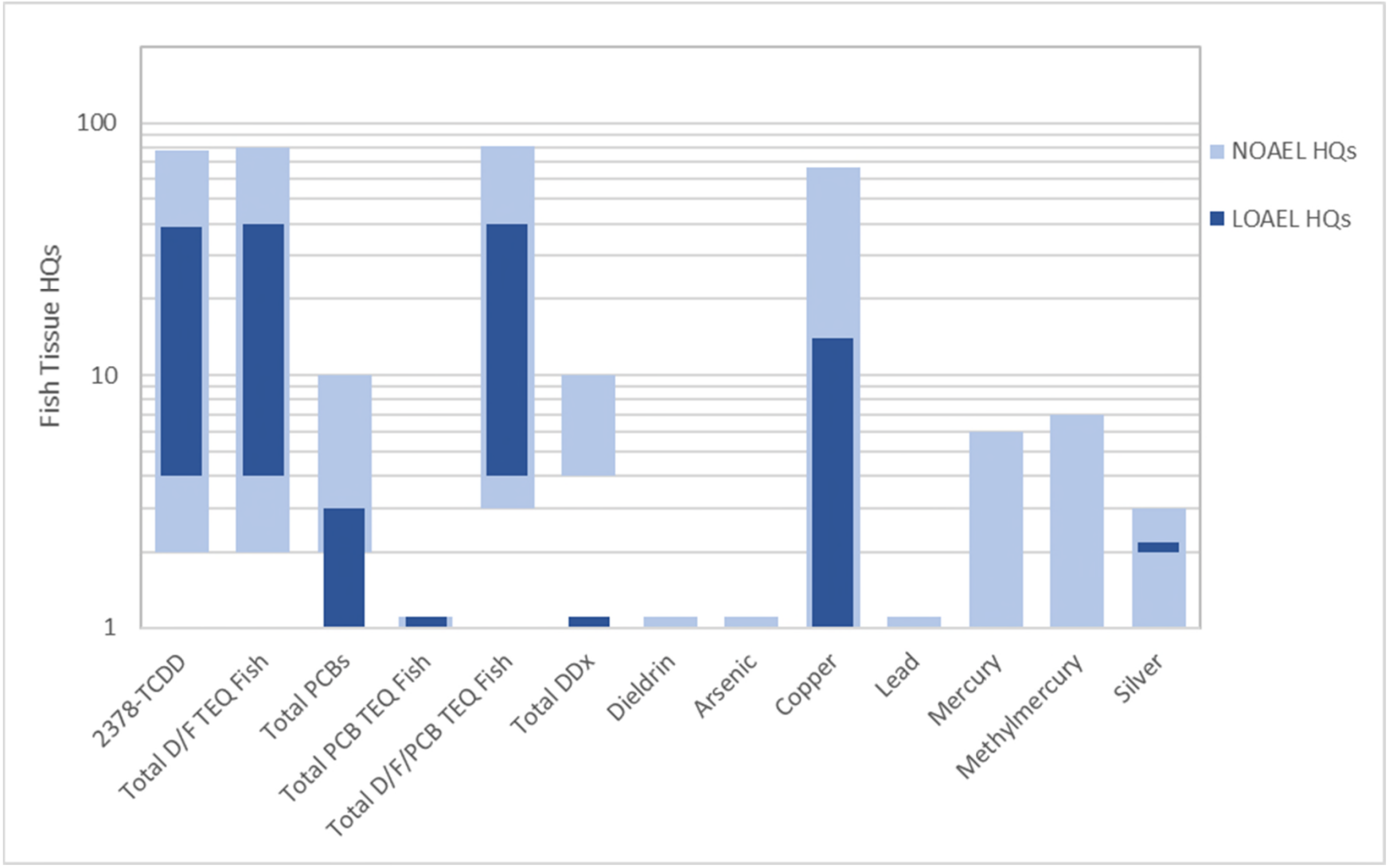
Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
HQ = hazard quotient
PCBs = polychlorinated biphenyls
NOAEL = no-observed-adverse-effect level
LOAEL = lowest-observed-adverse-effect level
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MAGNITUDE OF NBSA-WIDE NOAEL AND LOAEL HQS ≥ 1 FOR INVERTEBRATE TISSUE ASSESSMENT

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
6-7



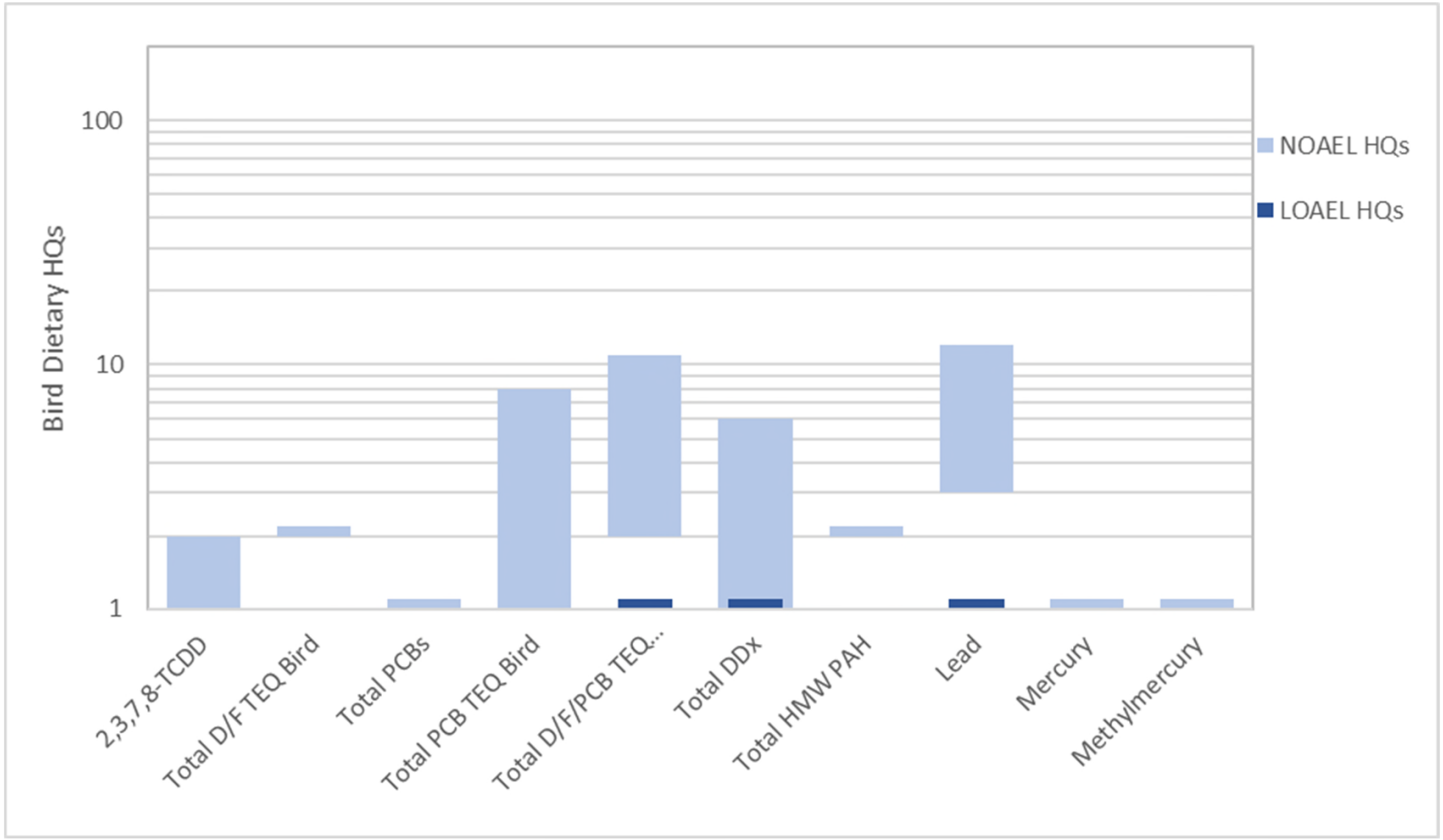
Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
HQ = hazard quotient
PCBs = polychlorinated biphenyls
NOAEL = no-observed-adverse-effect level
LOAEL = lowest-observed-adverse-effect level
TEQ = toxic equivalents
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
Total D/F = total dioxin furan

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MAGNITUDE OF NBSA-WIDE NOAEL AND LOAEL HQS ≥ 1 FOR FISH TISSUE ASSESSMENT

OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
6-8



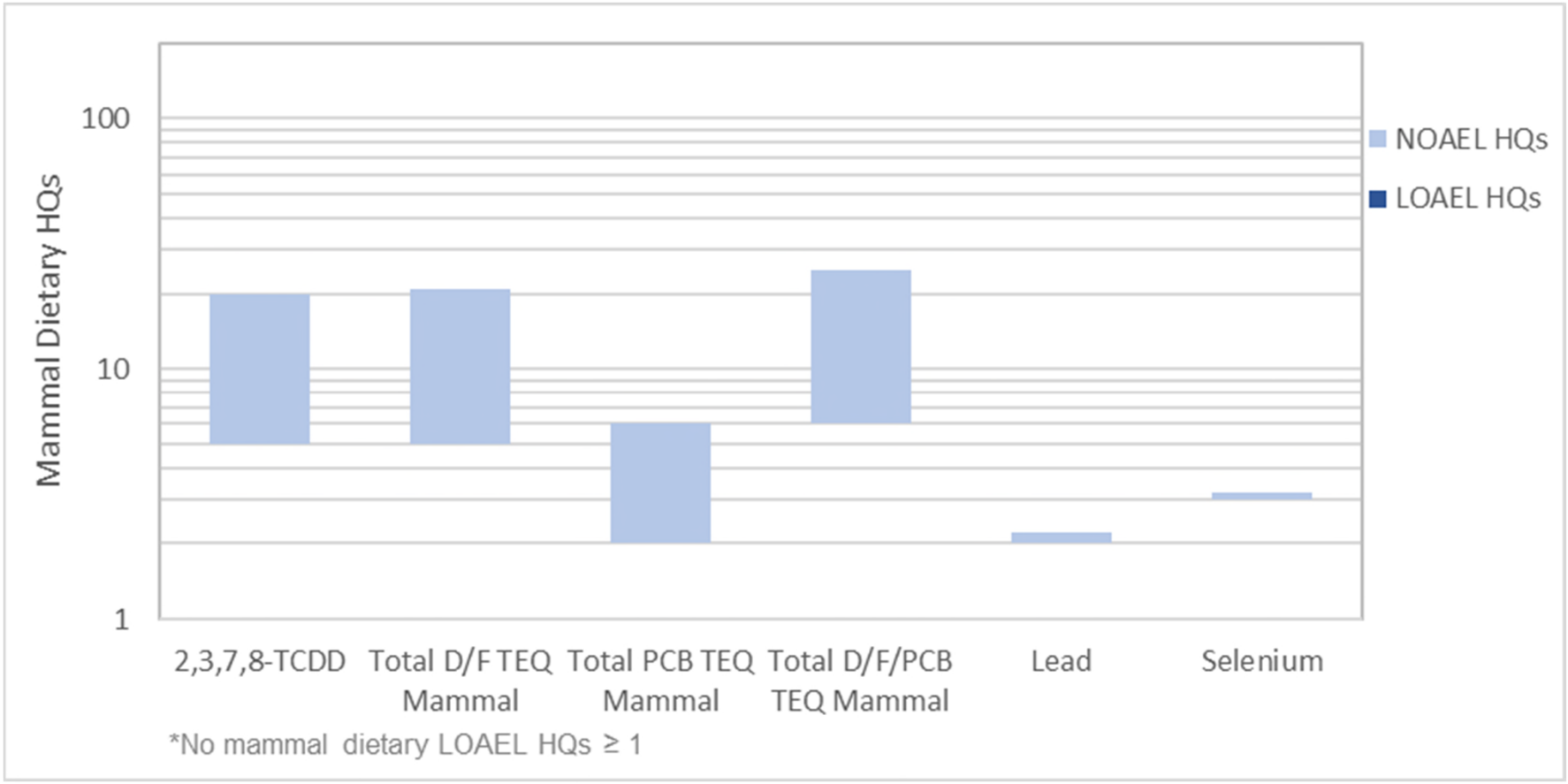
Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
HQ = hazard quotient
PCBs = polychlorinated biphenyls
NOAEL = no-observed-adverse-effect level
LOAEL = lowest-observed-adverse-effect level
TEQ = toxic equivalents
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
Total D/F = total dioxin furan

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MAGNITUDE OF NBSA-WIDE NOAEL AND LOAEL HQS ≥ 1 FOR BIRD DIETARY ASSESSMENT

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
6-9



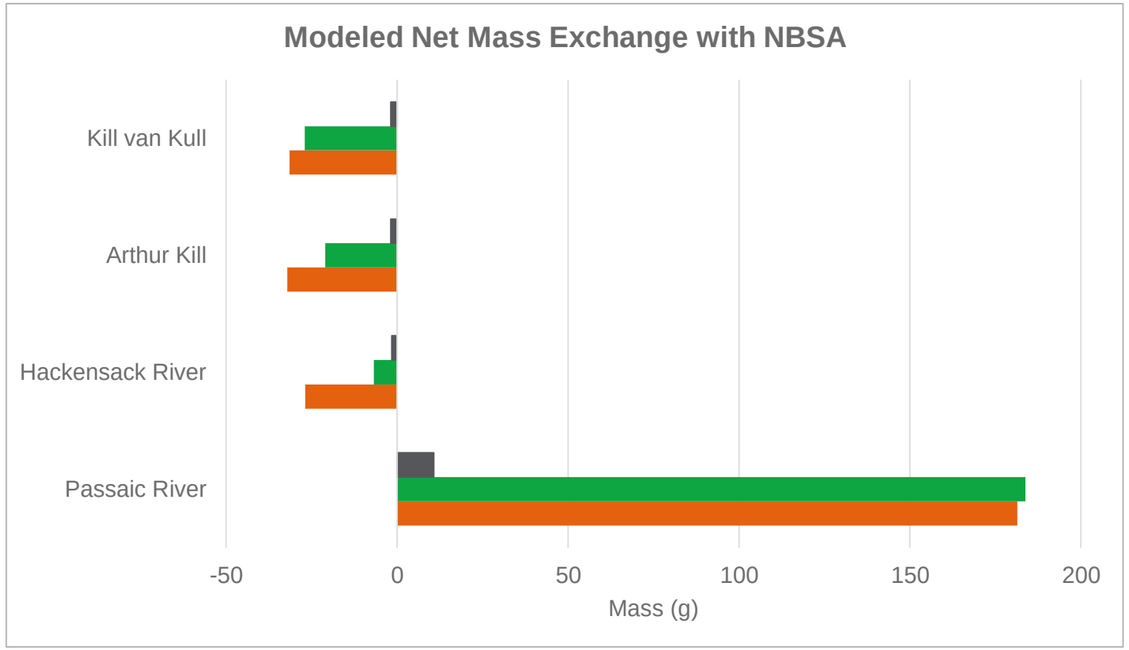
Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
HQ = hazard quotient
PCBs = polychlorinated biphenyls
NOAEL = no-observed-adverse-effect level
LOAEL = lowest-observed-adverse-effect level
TEQ = toxic equivalents
Total DDx = sum of dichlorodiphenyldichloroethylene, dichlorodiphenyldichloroethane, and dichlorodiphenyltrichloroethane
Total D/F = total dioxin furan

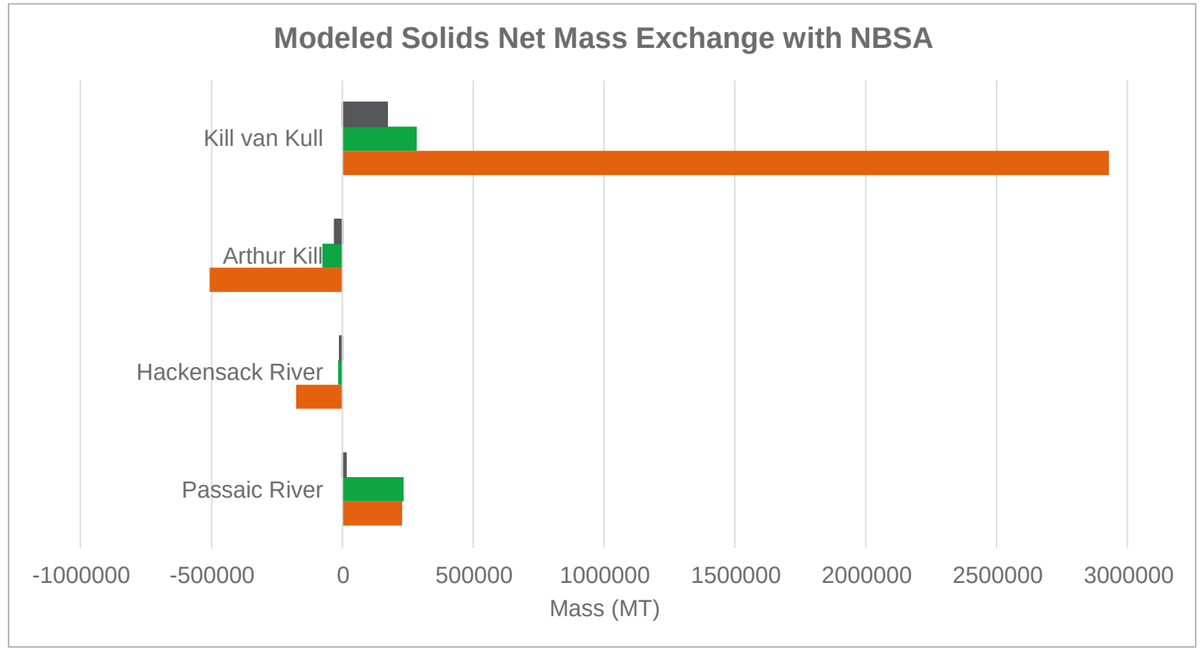
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

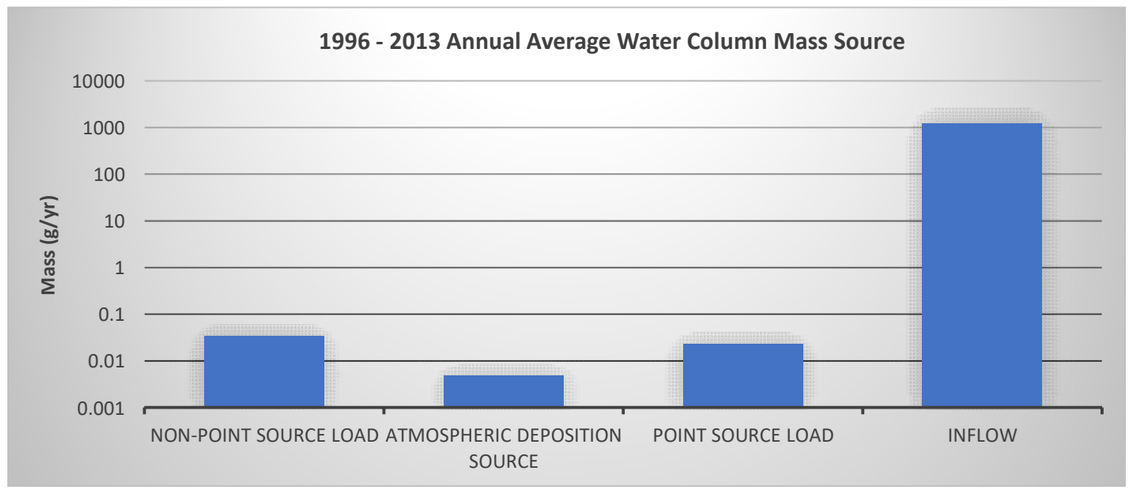
MAGNITUDE OF NBSA-WIDE NOAEL AND LOAEL HQS ≥ 1 FOR MAMMAL DIETARY ASSESSMENT

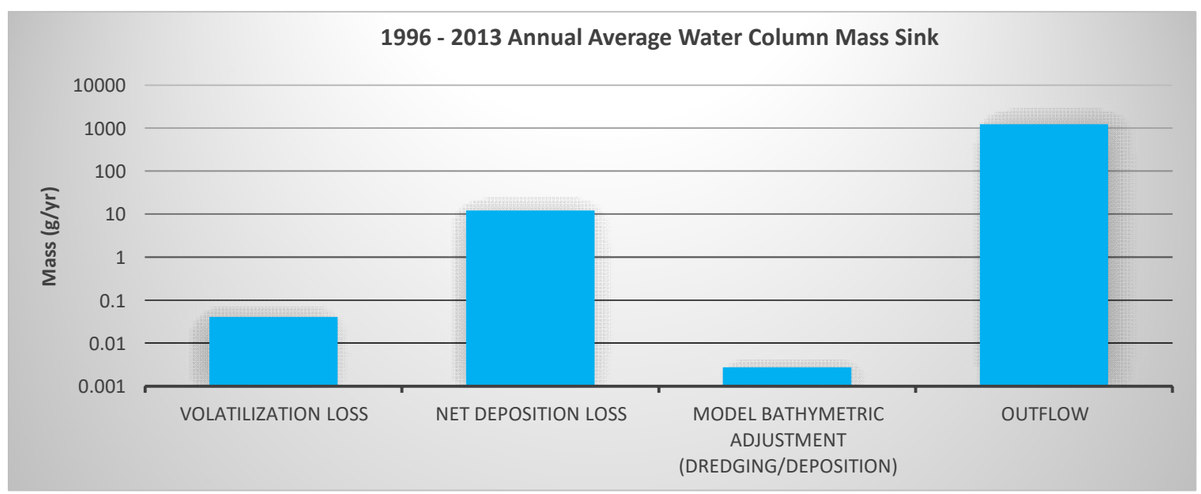
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
6-10









Notes:

- Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR in September 2021.
- Total net mass calculated for the model period 1996-2013.
- USEPA's CFT model setup includes various point sources such as POTWs, CSOs, storm sewers, and landfills. For the purposes of the mass balance reported herein around Newark Bay, point sources include publicly owned treatment works discharging directly to Newark Bay, as well as point and non-point loads discharged to the Elizabeth River. Nonpoint sources include combined sewer overflows and storm drains discharging directly to Newark Bay Point; point and nonpoint sources discharging to the Hackensack, Passaic, Arthur Kill or Kill Van Kull are included in the flux terms associated with those model regions (HDR 2021a).
- The magnitude of the overall flux (net inflow – outflow) is shown on Figure 5-MOD-5.
- Net deposition loss represents: Deposition – (Resuspension+ Diffusion + Navigation Scour)

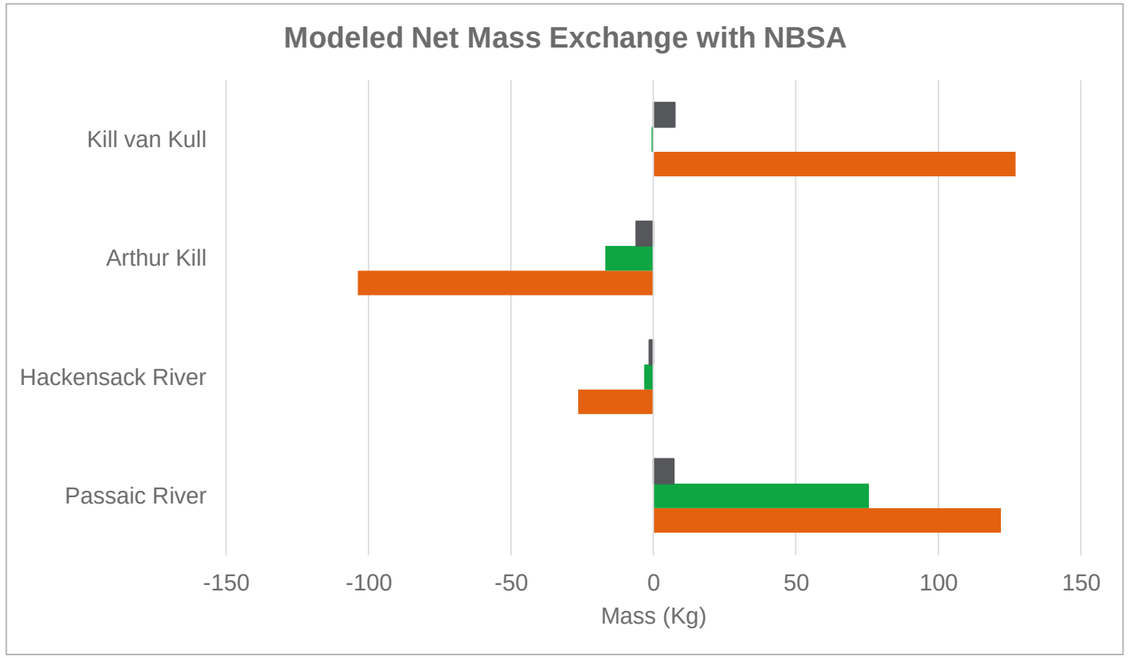
Average Annual for Non-Hurricane Years (1996 – 2010, 2012, 2013)
Net Mass Exchanged with the Bay for Hurricane Irene Year (2011)
Combined Total Net Mass Exchange with the Bay for Non-Hurricane Years (1996 – 2010, 2012, 2013)

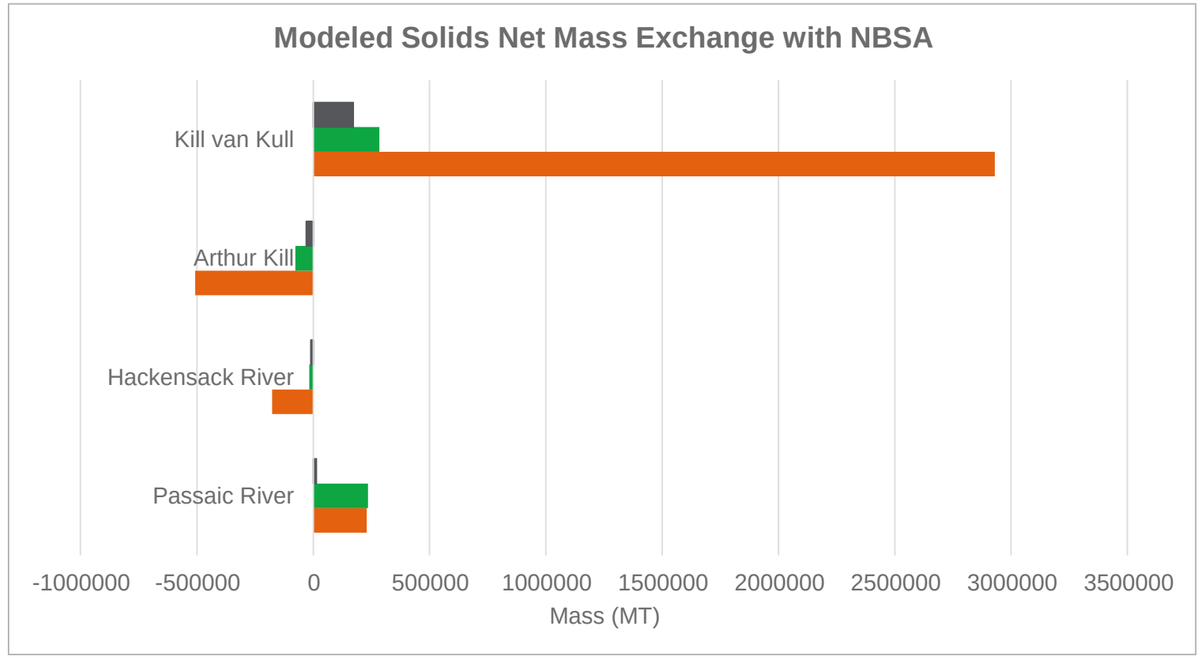
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

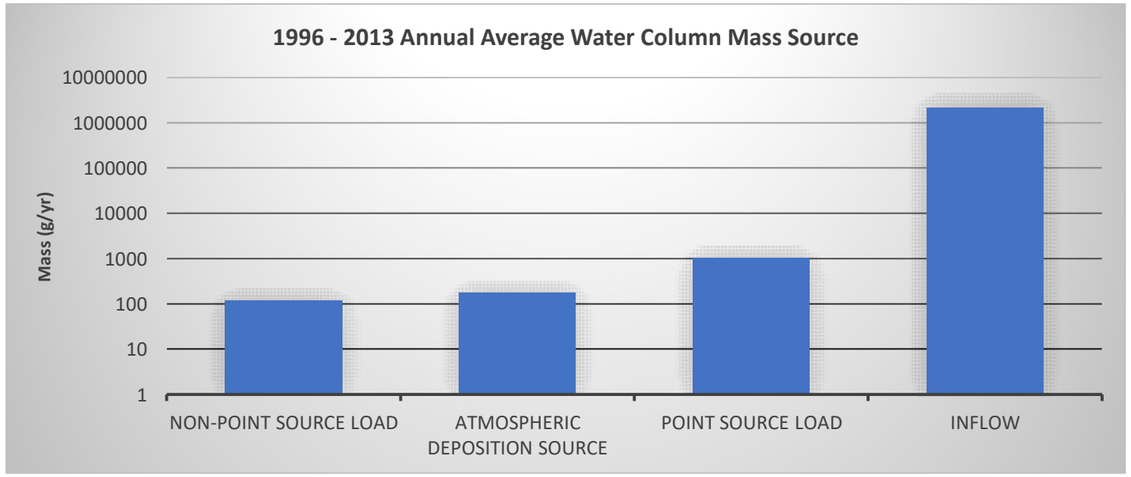
2,3,7,8 TCDD FATE AND TRANSPORT SUMMARY

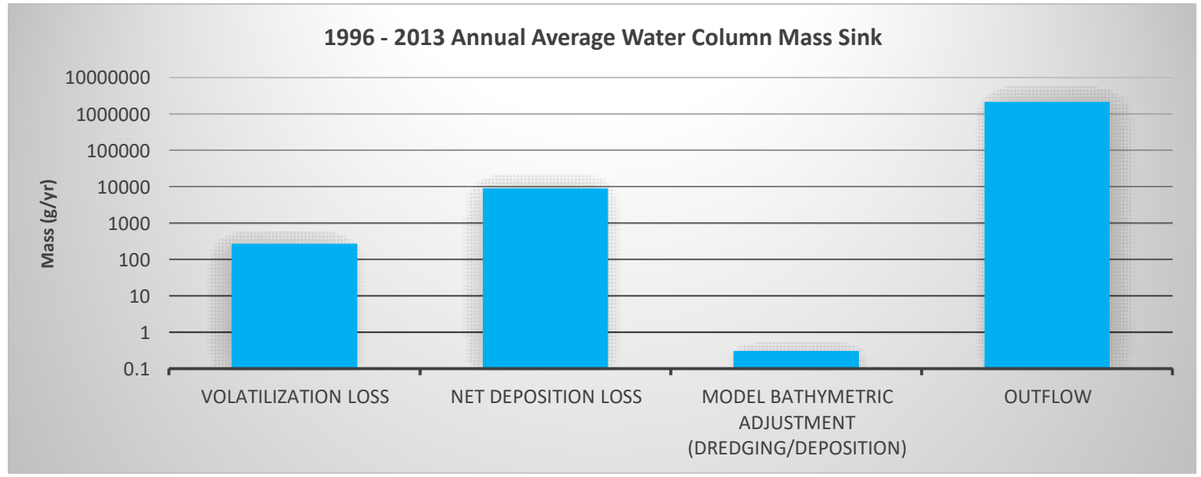
Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
7-1









Notes:

- Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR in September 2021.
- Total net mass calculated for the model period 1996-2013.
- USEPA's CFT model setup includes various point sources such as POTWs, CSOs, storm sewers, and landfills. For the purposes of the mass balance reported herein around Newark Bay, point sources include publicly owned treatment works discharging directly to Newark Bay, as well as point and non-point loads discharged to the Elizabeth River. Nonpoint sources include combined sewer overflows and storm drains discharging directly to Newark Bay Point; point and nonpoint sources discharging to the Hackensack, Passaic, Arthur Kill or Kill Van Kull are included in the flux terms associated with those model regions (HDR 2021a).
- The magnitude of the overall flux (net inflow – outflow) is shown on Figure 5-MOD-5.
- Net deposition loss represents: Deposition – (Resuspension+ Diffusion + Navigation Scour)

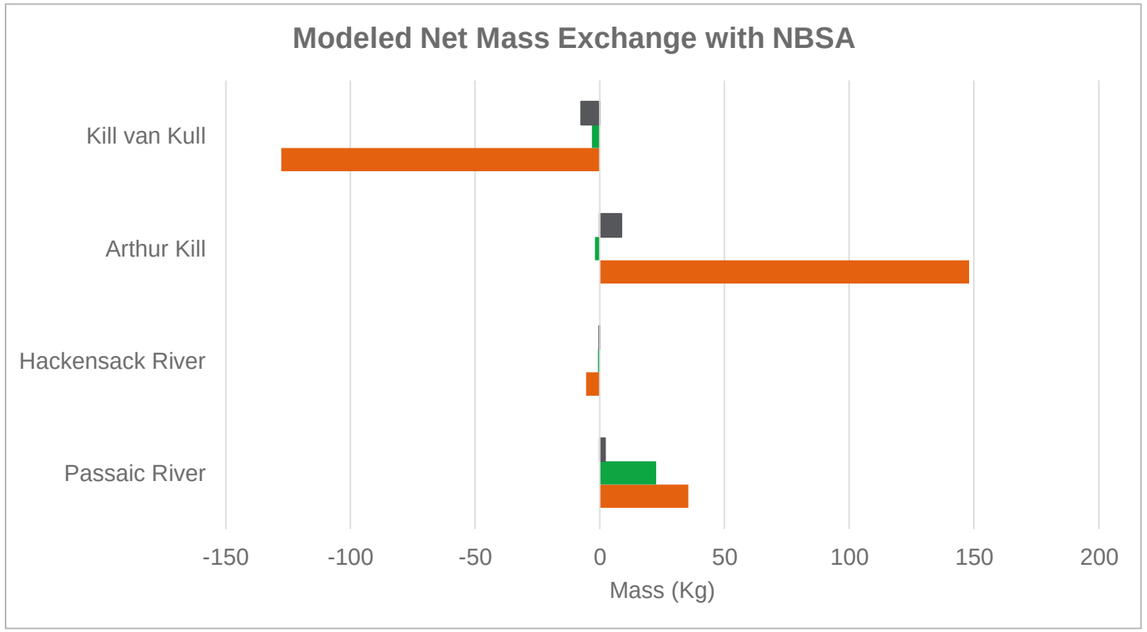
Average Annual for Non-Hurricane Years (1996 – 2010, 2012, 2013)
Net Mass Exchanged with the Bay for Hurricane Irene Year (2011)
Combined Total Net Mass Exchange with the Bay for Non-Hurricane Years (1996 – 2010, 2012, 2013)

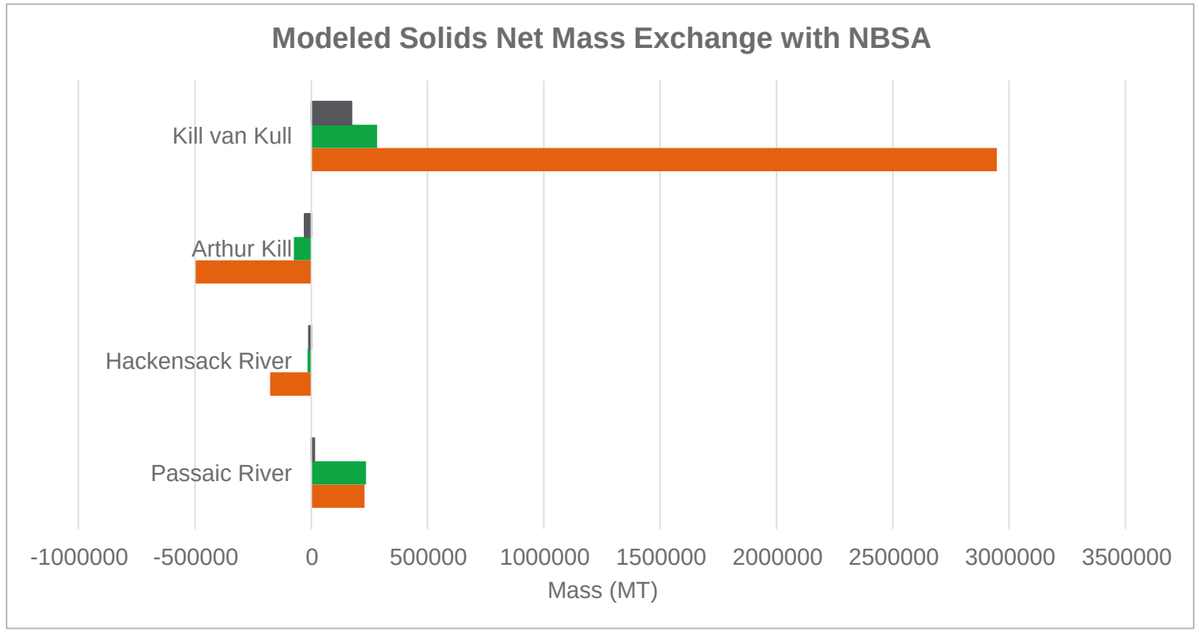
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

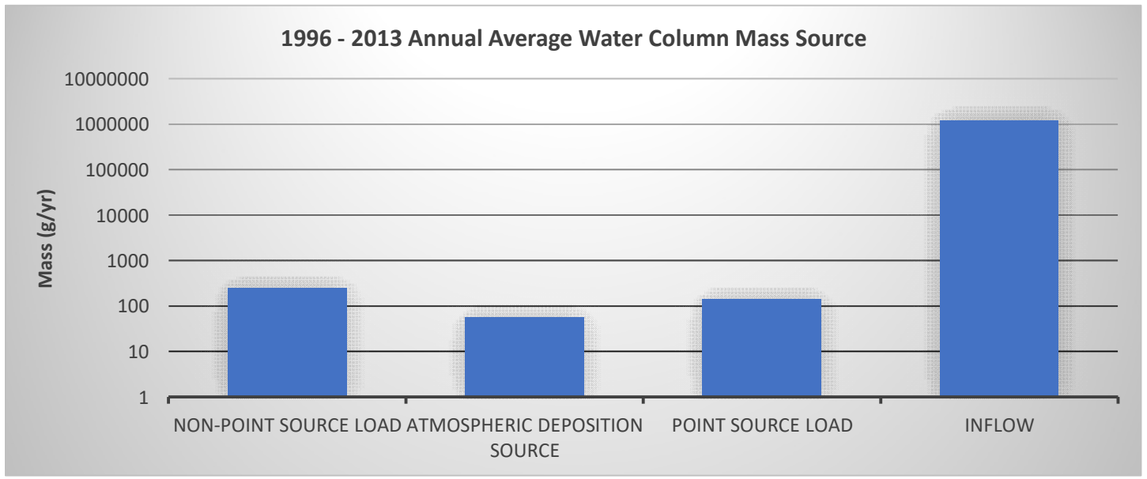
TETRA-PCBs FATE AND TRANSPORT SUMMARY

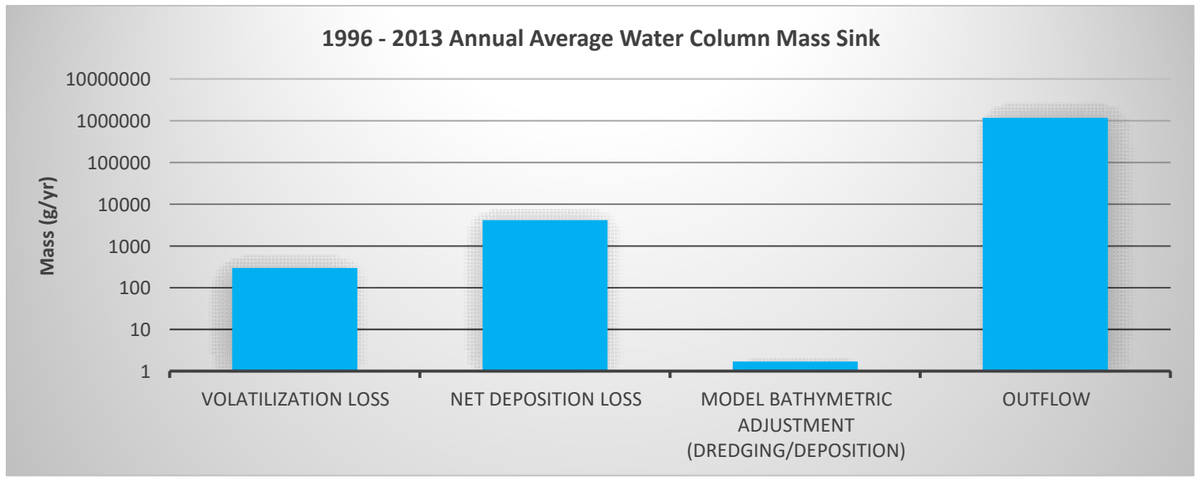
OXY Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum Corporation

FIGURE
7-2









Notes:

- Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR in September 2021.
- Total net mass calculated for the model period 1996-2013.
- USEPA's CFT model setup includes various point sources such as POTWs, CSOs, storm sewers, and landfills. For the purposes of the mass balance reported herein around Newark Bay, point sources include publicly owned treatment works discharging directly to Newark Bay, as well as point and non-point loads discharged to the Elizabeth River. Nonpoint sources include combined sewer overflows and storm drains discharging directly to Newark Bay Point; point and nonpoint sources discharging to the Hackensack, Passaic, Arthur Kill or Kill Van Kull are included in the flux terms associated with those model regions (HDR 2021a).
- The magnitude of the overall flux (net inflow – outflow) is shown on Figure 5-MOD-5.
- Net deposition loss represents: Deposition – (Resuspension+ Diffusion + Navigation Scour)

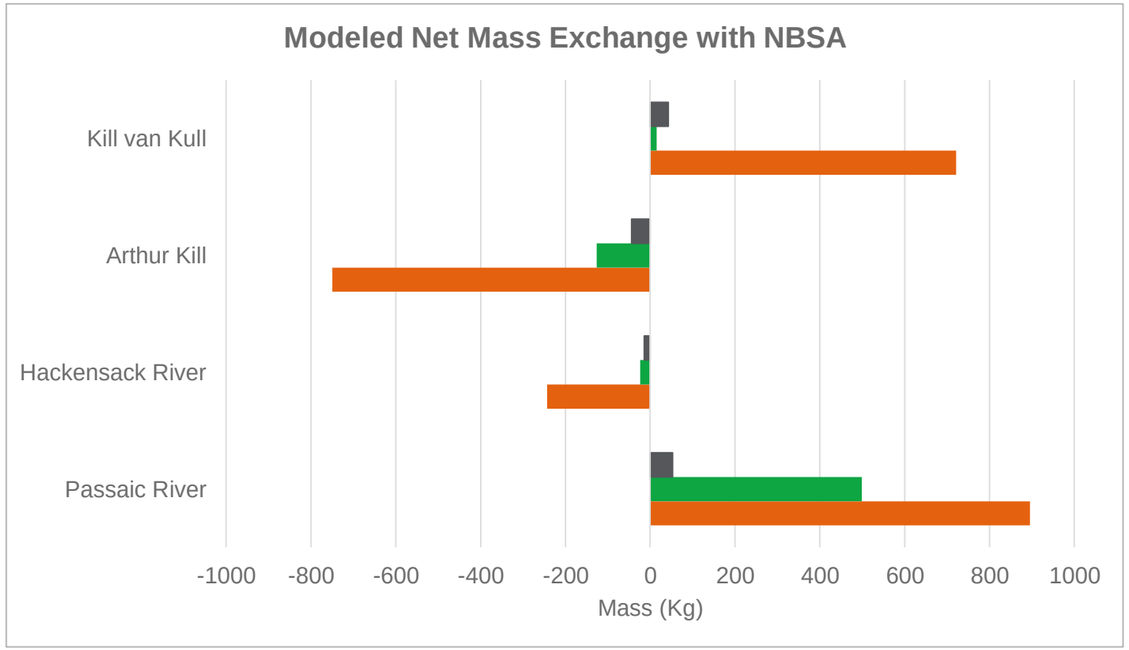
Average Annual for Non-Hurricane Years (1996 – 2010, 2012, 2013)
Net Mass Exchanged with the Bay for Hurricane Irene Year (2011)
Combined Total Net Mass Exchange with the Bay for Non-Hurricane Years (1996 – 2010, 2012, 2013)

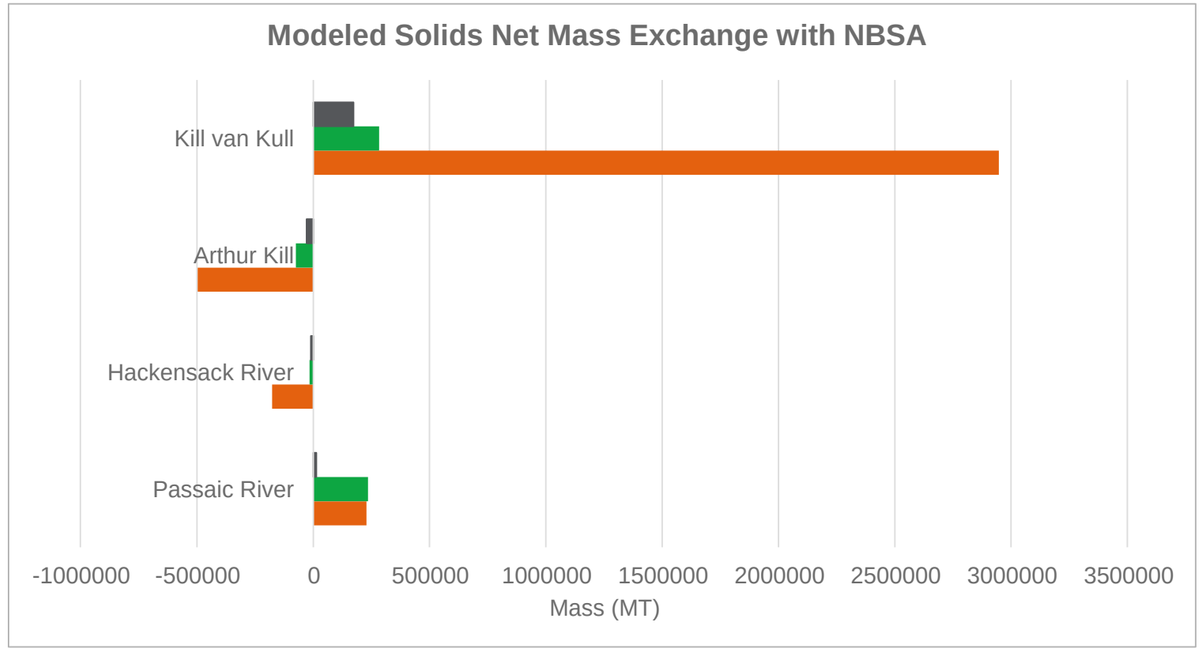
DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

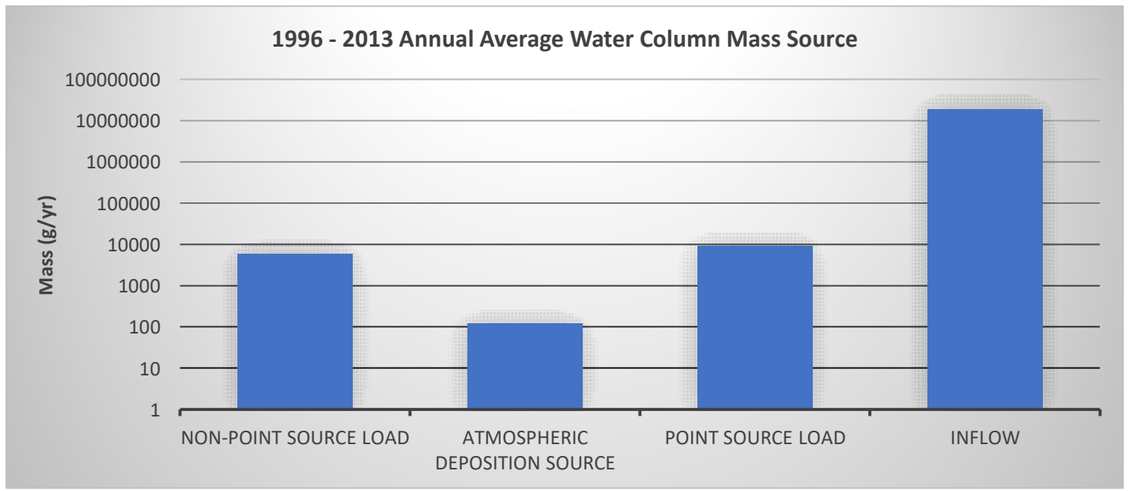
TOTAL DDx (4,4') FATE AND TRANSPORT SUMMARY

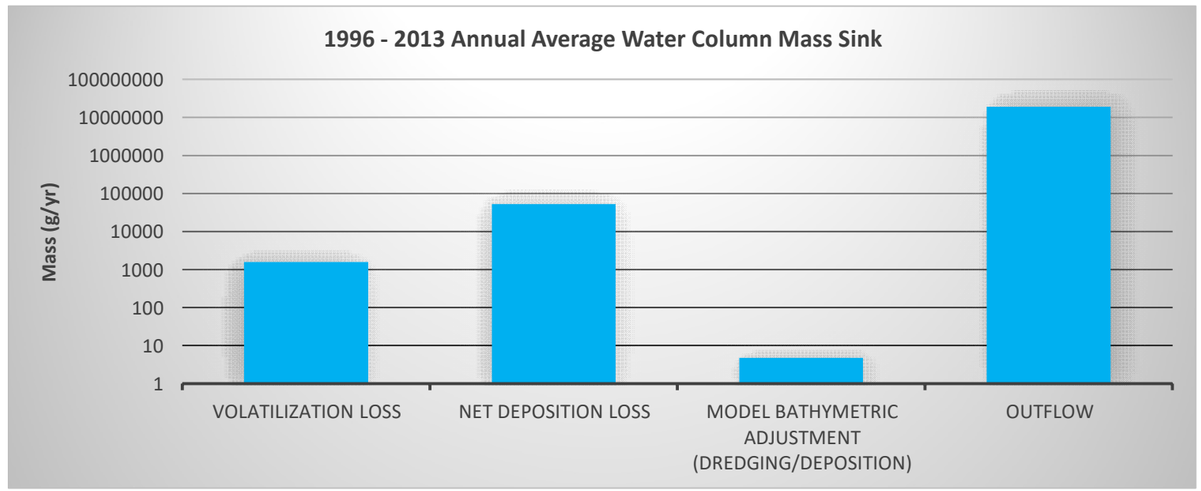
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FIGURE
7-3









Notes:

- Results are computed from model output summaries from the fate and transport model jointly developed by USEPA and the Cooperating Parties Group that were provided by HDR in September 2021.
- Total net mass calculated for the model period 1996-2013.
- USEPA's CFT model setup includes various point sources such as POTWs, CSOs, storm sewers, and landfills. For the purposes of the mass balance reported herein around Newark Bay, point sources include publicly owned treatment works discharging directly to Newark Bay, as well as point and non-point loads discharged to the Elizabeth River. Nonpoint sources include combined sewer overflows and storm drains discharging directly to Newark Bay Point; point and nonpoint sources discharging to the Hackensack, Passaic, Arthur Kill or Kill Van Kull are included in the flux terms associated with those model regions (HDR 2021a).
- The magnitude of the overall flux (net inflow – outflow) is shown on Figure 5-MOD-5.
- Net deposition loss represents: Deposition – (Resuspension+ Diffusion + Navigation Scour)

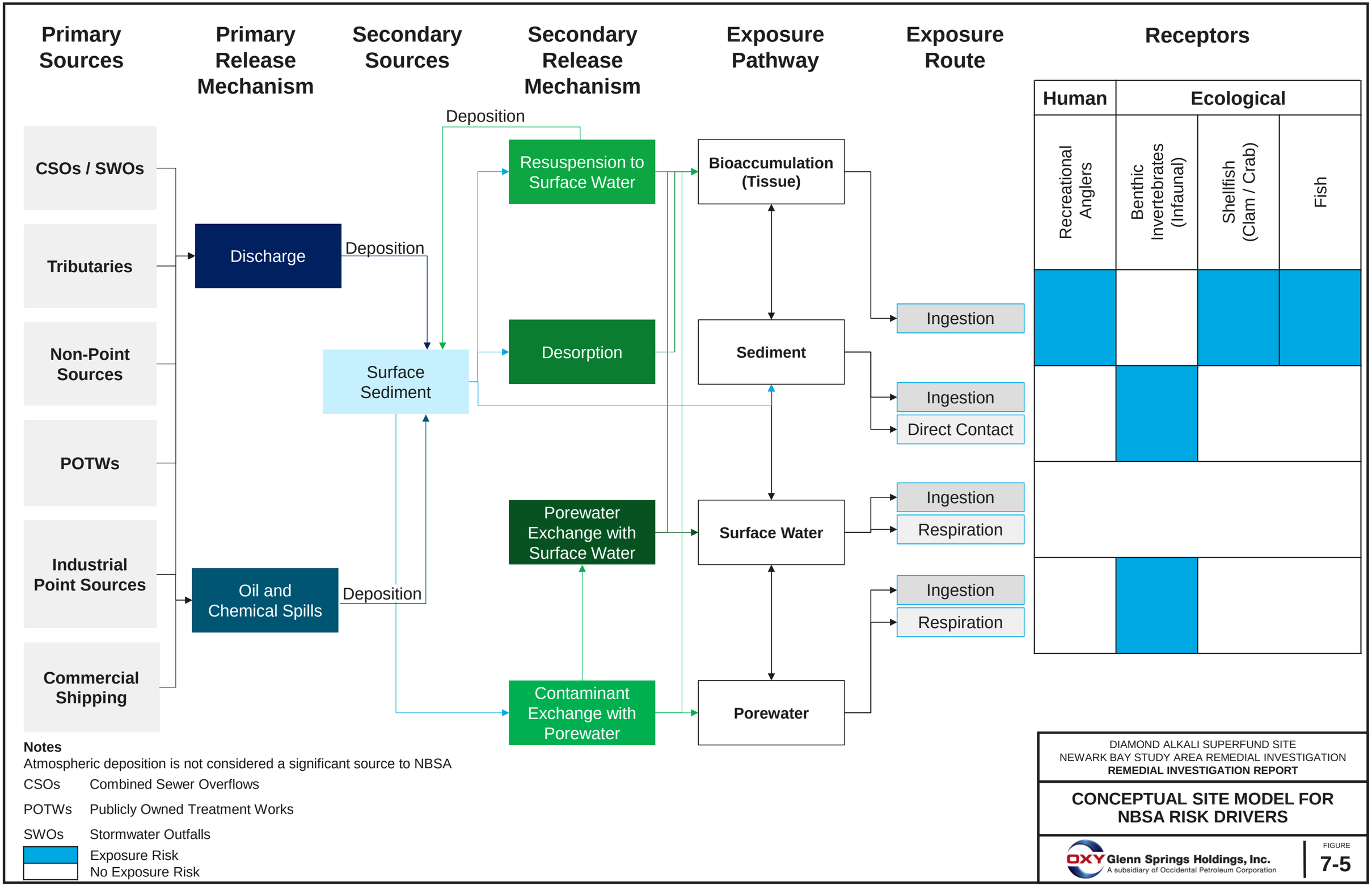
Average Annual for Non-Hurricane Years (1996 – 2010, 2012, 2013)
Net Mass Exchanged with the Bay for Hurricane Irene Year (2011)
Combined Total Net Mass Exchange with the Bay for Non-Hurricane Years (1996 – 2010, 2012, 2013)

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

MERCURY FATE AND TRANSPORT SUMMARY

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FIGURE
7-4



Notes

Atmospheric deposition is not considered a significant source to NBSA

CSOs Combined Sewer Overflows

POTWs Publicly Owned Treatment Works

SWOs Stormwater Outfalls

Exposure Risk

No Exposure Risk

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CONCEPTUAL SITE MODEL FOR NBSA RISK DRIVERS

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FIGURE
7-5