

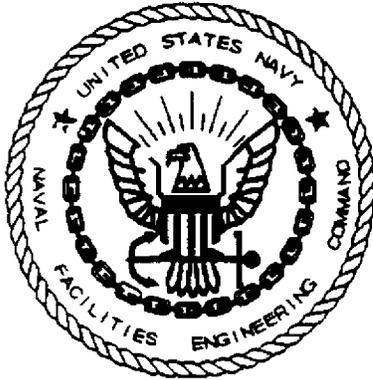
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DRAFT ZONE E RESOURCE CONSERVATION AND RECOVERY FACILITY INVESTIGATION  
REPORT VOLUME II OF XV SECTIONS 3 TO 13 CNC CHARLESTON SC  
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**DRAFT ZONE E  
RCRA FACILITY INVESTIGATION REPORT  
NAVBASE CHARLESTON**

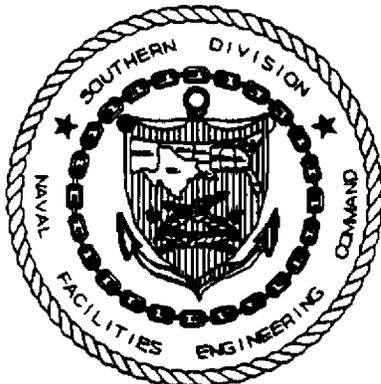
**VOLUME II OF XV  
SECTIONS 3 – 13**

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**Prepared for:**

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## ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR NAVBASE ZONE E

The following abbreviations, acronyms, and units of measurement are used in this report.

AA	Atomic Absorption
ABF	Absorption Factor
AEC	Area of Ecological Concern
AL	Action Level
AOC	Area of Concern
AQTESOLV	Aquifer Test Solver
AST	Aboveground Storage Tank
ASTM	American Society for Testing and Materials
atm	Atmospheres
AWQC	Ambient Water Quality Criteria
BAF	Bioaccumulation Factor
BAP	Benzo(a)pyrene
BDL	Below Detection Limit
BE	Barometric Efficiency
BEHP	Bis(2-ethylhexyl)phthalate
BEQ	Benzo(a)pyrene Equivalent
BEST	Building Economic Solutions Together
bgs	Below ground surface
BHC	Benzene hexachloride
BRA	Baseline Risk Assessment
BRAC	Base Realignment and Closure Act of 1988 and Defense Base Closure and Realignment Act of 1990, collectively
BTEX	Benzene, toluene, ethylbenzene, and xylene
CAMP	Corrective Action Management Plan
CAMU	Corrective Action Management Unit
CDD	Chlorinated dibenzo-p-dioxin
CDF	Chlorinated dibenzofuran
CDI	Chronic Daily Intake
CEC	Cation Exchange Capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	Calibration Factor
CFR	Code of Federal Regulations
CIA	Controlled Industrial Area
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
cm/sec	Centimeters per second
cm <sup>2</sup>	Square centimeters
CM	Corrective Measure

CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
CNS	Central Nervous System
CNSY	Charleston Naval Shipyard
COC	Chemical of Concern
COPC	Chemical of Potential Concern
cPAH	Carcinogen Polynuclear Aromatic Hydrocarbon
CPSS	Chemical Present in Site Samples
CRAVE	Carcinogen Risk Assessment Verification Endeavor
CRDL	Contract Required Detection Limit
CSAP	Comprehensive Sampling and Analysis Plan
CSI	Confirmatory Sampling Investigation
CT	Central Tendency
DAF	Dilution Attenuation Factor
DCAA	2,4-Dichlorophenylacetic acid
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyl-trichloroethane
DNAPL	Dense Non-Aqueous Phase Liquid
DQO	Data Quality Objectives
DRO	Diesel Range Organics
DWEL	Drinking Water Equivalent Level
E/A&H	EnSafe/Allen & Hoshall
ECAO	Environmental Criteria and Assessment Office
ECPC	Ecological Chemical of Potential Concern
EMPC	Estimated Maximum Possible Concentration
EOD	Explosive Ordnance Disposal
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESA	Ecological Study Area
ESDSOPQAM	Environmental Services Division Standard Operating Procedures and Quality Assurance Manual
ESOD	Erythrocyte superoxide dismutase
FC	Fraction Contracted
FFI	Focused Field Investigation
FI	Fraction Ingested
FID	Flame ionization detector
FRE	Fixed-Point Risk Evaluation
ft	feet
ft/day	feet per day

GC/MS	Gas Chromatography/Mass Spectrometry
gpm	Gallons per minute
GPS	Global Positioning System
GRO	Gasoline Range Organics
HASP	Health and Safety Plan
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMW	High Molecular Weight
HQ	Hazard Quotient
HSWA	Hazardous and Solid Waste Amendments
HTTD	High-Temperature Thermal Desorption
ICM	Interim Corrective Measure
ICAP	Inductively Coupled Argon Plasma
ID	Inside Diameter
IDL	Instrument Detection Limit
ILCR	Incremental Lifetime Excess Cancer Risk
ILO	Indeterminate Lubricating Oil
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
IS	Internal Standard
KPH	Kilometers per hour
LC <sub>50</sub>	Lethal Concentration to 50 percent of test population
LCS	Laboratory Control Sample
LD <sub>50</sub>	Lethal Dose to 50 percent of test population
LMW	Low Molecular Weight
LNAPL	Light Nonaqueous Phase Liquid
LQAC	Laboratory QA Coordinator
LTDD	Low-Temperature Thermal Desorption
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
meq/L	Milliequivalent per liter
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
mg/m <sup>3</sup>	Milligram per cubic meter
ml	Milliliter
mm	millimeter
mph	Miles per hour
msl	Mean sea level
MS/MSD	Matrix Spike/Matrix Spike Duplicate

NA	Not Applicable
NAD	North American Datum
NAVBASE	Naval Base Charleston
NBS	National Bureau of Standards
NCEA	National Center for Environmental Assessment
NCR	NEESA Contract Representative
ND	Not Detected
NEESA	Naval Energy and Environmental Support Activity
NFI	No Further Investigation
ng/kg	Nanogram per kilogram
NGVD	National Geodetic Vertical Datum
NIOSH	National Institute for Occupational Safety and Health
NL	Not Listed
NOAEL	No Observed Adverse Effect Level
NPDES	National Pollutant Discharge Elimination System
NR	Not Reported
NRC	National Research Council
NTP	National Toxicology Program
NTU	Nephelometric Turbidity Unit
OERR	Office of Emergency and Remedial Response
OIA	Other Impacted Area
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OVA	Organic Vapor Analyzer
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated biphenyl
PCT	Porphyria Cutanea Tarda
PDE	Potential Dietary Exposure
PEM	Performance Evaluation Mixture
pg/g	Picogram per gram
pg/L	Picogram per liter
POTW	Publicly Owned Treatment Works
ppb	Parts per billion
PPE	Personal Protective Equipment
ppm	Parts per million
ppt	Parts per trillion
PRC	Preliminary Risk Characterization
PRG	Preliminary Remedial Goal
PSA	Preliminary Site Assessment
psi	Pounds per square inch
PVC	Polyvinyl Chloride

QA/QC	Quality Assurance/Quality Control
RAB	Restoration Advisory Board
RAGS	Risk Assessment Guidance for Superfund
RBC	Risk-Based Concentration
RBSL	Risk-Based Screening Level
RC	Reference Concentration
RCRA	Resource Conservation and Recovery Act
RDA	Recommended Daily Allowance
RFA	RCRA Facility Assessment
RfD	Reference Dose
RFI	RCRA Facility Investigation
RGO	Remedial Goal Option
RME	Reasonable Maximum Exposure
RPD	Relative Percent Difference
RRF	Relative Response Factor
RTV	Reference Toxicity Value
SAA	Satellite Accumulation Area
SC	South Carolina
SCDHEC	South Carolina Department of Health and Environmental Control
SDG	Sample Delivery Group
SF	Slope Factor
SFF	Site Foraging Factor
SMCL	Secondary Maximum Contaminant Level
SOP	Standard Operating Procedures
SOUTHDIV	Southern Division Naval Facilities Engineering Command
SPLP	Synthetic Precipitation Leaching Procedure
SQL	Sample Quantitation Limit
SRL	Significant Risk Level
SSL	Soil Screening Levels
SSV	Sediment Screening Value
SVE	Soil Vapor Extraction
SVOA	Semivolatile Organic Analysis
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
TCDD	Tetrachlorodibenzo-p-dioxin
TCE	Trichloroethene
TD-GS/MS	Thermal Desorption-Gas Chromatography/Mass Spectrometry
TD/MS	Thermal Desorption/Mass Spectrometry
TDS	Total Dissolved Solids
TEF	Toxic Equivalency Factor
TEQ	TCDD Equivalency Quotient

TIC	Tentatively Identified Compounds
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TSCA	Toxic Substances Control Act
TTAL	Treatment Technique Action Level
TU	Temporary Unit
UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
UTL	Upper Tolerance Limit
UV	Ultraviolet
UXO	Unexploded Ordinance
USGS	United States Geological Survey
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compound
WBZ	Water-Bearing Zone
WOHL	Wisconsin Occupational Health Laboratory
WQC	Water Quality Criteria
$\mu\text{g}/\text{cm}^2$	Microgram per square centimeter
$\mu\text{g}/\text{g}$	Micrograms per gram
$\mu\text{g}/\text{kg}$	Microgram per kilogram
$\mu\text{g}/\text{L}$	Microgram per liter
%R	Percent Recovery
%RSD	Percent Relative Standard Deviation
%D	Percent Difference
2,4-D	2,4-Dichlorophenoxyacetic acid
2,4-DB	2,4-Dichlorophenoxybutyric acid
2,4,5-T	2,4,5-Trichlorophenoxyacetic acid
2,4,5-TP	Silvex

### 3.0 FIELD INVESTIGATION

The following section lists the field investigation objectives and describes the technical sampling methods, procedures, and protocols implemented during data collection within Zone E. Fieldwork was conducted in accordance with the *Final Comprehensive Sampling and Analysis Plan* (E/A&H, August 1994) (CSAP) and the U.S. Environmental Protection Agency (USEPA) Region IV Environmental Services Division, *Standard Operating Procedures and Quality Assurance Manual* (USEPA, February 1991) (ESDSOPQAM). Sampling and investigatory methods used in the Zone E RFI investigation are summarized in this section. Any deviations from the approved work plans, such as the number of samples collected, modified locations, or procedures, etc., were documented in the field and are detailed in Section 10, Site-Specific (SWMUs and AOCs) Evaluations.

#### 3.1 Investigation Objectives

The sampling strategy for each Zone E AOC and SWMU, as detailed in the *Final Zone E RFI Work Plan*, was designed to collect sufficient environmental media data to accomplish the following:

- Characterize the facilities in Zone E.
- Define contaminant pathways and potential receptors (on and offsite, where applicable).
- Define the nature and extent of contamination, if any, at Zone E sites.
- Assess human health and ecological risk.
- Assess the need for corrective measures.

#### 3.2 Sampling Procedures, Protocols, and Analyses

##### 3.2.1 Sample Identification

All environmental samples collected during this investigation were identified using a 10-character alphanumeric system denoting samples by site, sample matrix, location, and other pertinent

information. This system is detailed in Section 11.4 of the CSAP. The first three characters identify the site where the sample was collected. The fourth and fifth characters represent the quality control or matrix code. Characters six through eight designate sampling location: boring or well number, sampling station, trench number, existing well identification, and others. The final two characters represent sample-specific identification such as depth to the nearest foot, depth interval, sampling event for water samples, and others. Appendix H is the complete data report for all samples collected in Zone E.

The following matrix codes were used to identify specific matrices for sample identification during the Zone E RFI.

- Soil Borings Samples — SB
- Groundwater Samples — GW
- Sediment Samples — MO
- Wipe Samples — JF, JH
- Surface Water Samples — WO
- Concrete Core Samples — CC
- Asphalt Samples — KB

### 3.2.2 Soil Sampling

Section 4 of the CSAP describes soil sampling methods. The following subsections summarize those methods as they applied to Zone E field activities.

#### 3.2.2.1 Soil Sample Locations

The first round of soil samples were collected based on the boring locations proposed in the *Final Zone E RFI Work Plan*. Additional soil samples were collected where first-round samples exceeded background concentrations, industrial soil screening levels of the Risk-Based

Concentrations (RBCs) (USEPA Region III, April 1996), or if it was identified as a site-specific constituent of concern in the *Final RFA* for NAVBASE. Typically, additional sample locations were justified due to relatively high concentrations of contaminants on the perimeter of a previous sampling pattern. Some of the original sample locations were modified due to accessibility problems, subsurface obstructions, or utility locations.

### 3.2.2.2 Soil Sample Collection

Stainless-steel hand augers, spoons, and mixing bowls were used to collect soil samples for laboratory analysis. In addition, to gain access to soil beneath most sites in Zone E, a concrete/asphalt coring machine was used. A few locations were inaccessible due to excessively thick asphalt/concrete, subsurface obstructions, or utilities. Composite soil samples were collected from the upper, 0- to 1-foot below ground surface (bgs) interval and the lower, 3- to 5-foot bgs interval. The 0- to 1-foot bgs interval is referred to in this report as the 01 or upper interval sample. The 3- to 5-foot bgs interval is referred to as the 02 or lower interval sample. At locations overlain by concrete or asphalt, the upper interval sample was collected from the base of the pavement, taking precaution not to include any asphaltic material. A clean, decontaminated hand auger was used to collect the sample from the lower interval. A relatively high water table prohibited sampling in some of the lower intervals because saturated samples were not submitted for analysis.

### 3.2.2.3 Soil Sample Preparation, Packaging, and Shipment

Section 3.2.2.3 of the Zone A RFI report details the details procedures for preparing, packaging, and shipping soil samples collected during the Zone E RFI investigation. The samples were shipped priority overnight via FedEx to Southwest Laboratory of Oklahoma in Tulsa.

### 3.2.2.4 Soil Sample Analysis

A total of 1,031 first- and second-round soil samples were analyzed per USEPA Method SW-846 at Data Quality Objective (DQO) Level III unless otherwise noted, as follows:

- Volatile organic compounds (VOCs) USEPA Method 8240
- Semivolatile organic compounds (SVOCs) USEPA Method 8270
- Pesticides/polychlorinated biphenyls (PCBs) USEPA Method 8080
- Cyanide USEPA Method 9010
- Metals Title 40 Code of Federal Regulations (CFR) Part 264 Appendix IX
- Organotins Per standard operating procedures (SOP) Triangle Laboratories, Research Triangle Park, North Carolina

Approximately 10% of the soil samples collected in Zone E were duplicated and analyzed at DQO Level IV for Appendix IX analytical parameters, which include the above parameters and methods, a more comprehensive list of VOCs and SVOCs, and the following:

- Hexavalent chromium USEPA Method 218.4
- Dioxins USEPA Method 8290
- Herbicides USEPA Method 8150
- Organophosphate pesticides USEPA Method 8140

The purpose of Appendix IX sampling was two-fold: 1) to provide a measure of reassurance that the sampling scheme was not inadvertently overlooking any compounds potentially present; 2) to provide a quality assurance/quality control (QA/QC) check on the DQO Level III data. Second-round soil samples were analyzed for site-specific parameters based on the chemicals of potential concern (COPCs) identified at each site from results of the first sampling round. To support corrective measures at NAVBASE, selected soil samples in Zone E were analyzed for the engineering parameters: leachability (Synthetic Precipitation Leaching Procedure [SPLP]), cation exchange capacity (CEC), total moisture, total organic carbon (TOC), phosphorous, ammonia, nitrate-nitrite, sulfur, and chlorides. In addition, selected thin-walled tube (Shelby) tube samples were collected and analyzed for moisture content, specific gravity, bulk density, porosity, hydraulic conductivity/permeability, and grain size per American Society for Testing and Materials (ASTM) methods. These samples are detailed in the corrective measures portions of Section 10.

### 3.2.3 Monitoring Well Installation and Development

Section 5 of the CSAP details the methods used to install and develop monitoring wells. All monitoring wells were installed in accordance with South Carolina Well Standards and Regulations (R.61-71) after acquiring well permits from South Carolina Department of Health and Environmental Control (SCDHEC). The following subsections describe the site-specific methods applied in Zone E. Appendix A includes all lithologic boring logs and monitoring well construction diagrams for Zone E.

Monitoring wells installed for the Zone E RFI investigation were identified according to the following convention. All identification numbers for monitoring wells installed during the Zone E investigation consist of 10 characters. The first three characters (NBC for all wells) identify them as Naval Base Charleston wells. The fourth character identifies the investigatory zone in which the monitoring wells were installed (E in this case). Characters 5, 6, and 7 identify the site at

which the monitoring wells were installed. For monitoring wells installed as part of the grid-based sampling network of Zone E, the well identifications contain GDE as the fifth, sixth, and seventh characters. The eighth, ninth, and tenth characters in the monitoring well identification scheme identify the individual well number. If the tenth character is D, the monitoring well is a deep well. Three complete examples of typical monitoring well identifications are as follows.

- NBCE065004 is well number 004 at SWMU 65 of Zone E at NAVBASE Charleston.
- NBCE06504D is the deep well at the well number 004 location at SWMU 65 of Zone E at NAVBASE Charleston.
- NBCEGDE025 is the number 025 grid-based monitoring well in Zone E at Naval Base Charleston.

### **3.2.3.1 Shallow Monitoring Well Installation**

Shallow monitoring wells were installed to facilitate groundwater sampling in the upper water-bearing zone of the Wando Formation. These monitoring wells were installed using the hollow-stem auger drilling and monitoring well construction methods. Every effort was made to bracket the water-table surface at each shallow monitoring well location. The water table below NAVBASE is generally 3 to 6 feet bgs, but is occasionally shallower, so bracketing was not always possible. The wells were set between 12 and 15 feet bgs by augering to the desired depth with a hollow-stem auger capped with a polyvinyl chloride (PVC) plug.

Two-foot split- spoon samples were collected for lithologic characterization at approximately 5-foot intervals from each shallow monitoring well borehole. Typical split-spoon sample intervals were from 3 to 5 feet bgs, 8 to 10 feet bgs, and 13 to 15 feet bgs. These soil samples were visually classified and screened for organic vapors and radiologic emissions by the onsite geologist. These

samples were not retained for chemical analysis. At one borehole in each AOC or SWMU, a Shelby tube was pushed to collect a sample for grain-size analysis at the terminating depth, typically 15 feet bgs.

Shallow monitoring well construction consisted of 10 feet of 2-inch inside diameter (ID), 0.010-inch slot PVC screen, flushed threaded to 2-inch ID PVC riser pipe to bring the top of casing to approximately 2 feet above ground surface. Expansion caps completed the well. The screen and riser were set inside the hollow-stem auger. Filter pack sand was poured into the annular space between the hollow-stem auger and PVC to approximately 2 feet above the top of the screen. The augers were then carefully removed to ensure uniform placement of the filter pack. To ensure that no formation material collapsed around the well, the augers were never pulled above the level of the filter pack placement. Bentonite pellets were placed to ground surface, then hydrated with potable water. After allowing sufficient time for the bentonite pellets to hydrate, the surface mount was constructed as detailed in Section 3.2.3.4 of the Zone A RFI report.

**3.2.3.2 Deep Monitoring Well Installation**

Deep monitoring wells were installed to facilitate groundwater sampling at the base of the shallow aquifer. Review of regional geology identified the Ashley Formation of the Cooper Group as the shallowest formation capable of inhibiting the downward flow of water and/or contaminants. In the Charleston area, this formation is noted for its low permeability and its effectiveness as a confining layer for the underlying Santee Limestone. Deep monitoring wells were installed at the contact between the Wando and Ashley formations to sample the Wando's basal sand.

Rotosonic drilling, which was used to install the deep monitoring wells, combines standard rotary action with sonic vibration allowing the boring barrel to displace cuttings rather than bringing them to the surface as with auger drilling. To set a well into the basal sand and to prevent

cross-contamination between the upper sand and the basal sand of the Wando Formation, a 9-inch ID PVC surface casing was set approximately 5 feet into the *marsh clay*. The casing was installed similarly to the shallow monitoring well except 9.5-inch ID augers were used instead of 4.25-inch ID augers. The casing was set with a mixture of grout and approximately 5% to 10% bentonite powder. Once the grout mixture cured, a Rotosonic drill rig completed the boring for monitoring well installation. A continuous core up to 20 feet long is produced, allowing very accurate lithologic characterizations. Cores were screened for organic vapors and radiological emissions by the onsite geologist, along with visual lithologic characterization and logging.

As with shallow monitoring wells, deep monitoring well construction consisted of 10 feet of 2-inch ID, 0.010-inch slot PVC screen attached to 2-inch ID PVC riser pipe to approximately 3 feet above ground surface. Expansion caps completed the well. The screen and riser were set inside the Rotosonic casing. Filter pack materials were set similarly to the shallow monitoring wells. Filter pack sand was poured into the annular space between the core barrel and PVC to approximately 2 feet above the top of the screen. The core barrels were then carefully removed to ensure uniform placement of the filter pack. To ensure that no formation material collapsed around the well, the core barrels were never pulled above the level of the sand. Bentonite pellets were placed to approximately 2 feet above the sand, then hydrated with potable water to form a seal. A mixture of grout and approximately 5% to 10% bentonite powder was poured down the annulus between the core barrel and PVC riser pipe to ground surface. After the grout mixture cured sufficiently, a surface mount was constructed as described in Section 3.2.3.4 of the Zone A RFI report.

### 3.2.3.3 Surface Casing Construction

Section 3.2.3.4 of the Zone A RFI report details the surface casing construction process.

### 3.2.3.4 Monitoring Well Development

Section 3.2.3.5 of the Zone A RFI report details Zone E monitoring well development.

### **3.2.4 Groundwater Sampling**

Section 3.2.4 of the Zone A RFI report details the groundwater sampling process. The following subsections summarize the site-specific methods applied in Zone E.

#### **3.2.4.1 Groundwater Sampling Locations**

Groundwater samples were collected from monitoring wells based on approved locations identified in the *Final Zone E RFI Work Plan*. Some proposed locations were adjusted due to inaccessibility or obstructing utilities.

Additional wells were required at some sites to determine the extent of groundwater contamination. Following analysis and interpretation of groundwater analytical data for samples collected from the initial wells, additional monitoring wells were proposed due to relatively high concentrations of contaminants on the perimeter of a previous sample pattern. Upon approval, the monitoring wells were installed, developed, and sampled as described above.

#### **3.2.4.2 Groundwater Sample Collection**

Section 3.2.4.2 of the Zone A RFI report details the groundwater sample collection process.

#### **3.2.4.3 Groundwater Sample Preparation, Packaging, and Shipment**

Section 3.2.4.3 of the Zone A RFI report details preparation, packaging, and shipment of groundwater samples collected during the Zone E RFI. All samples were shipped priority overnight via Fed Ex to the Southwest Laboratory of Oklahoma.

#### **3.2.4.4 Groundwater Sample Analysis**

One-hundred eighty-eight monitoring wells (130 shallow, 58 deep) were installed during two rounds of drilling. Groundwater samples were analyzed per USEPA Method SW-846 at DQO Level III unless otherwise noted, as follows:

•	VOCs	USEPA Method 8240	1
•	SVOCs	USEPA Method 8270	2
•	Pesticides/PCBs	USEPA Method 8080	3
•	Cyanide	USEPA Method 9010	4
•	Metals	Title 40 CFR Part 264 Appendix IX	5
•	Organotins	Per SOP of Triangle Laboratories	6

Eighteen of the 188 groundwater samples collected were duplicated and analyzed at DQO Level IV for Appendix IX analytical parameters, which include the above parameters and methods, and a more comprehensive list of VOCs and SVOCs, as well as the following:

•	Hexavalent chromium	USEPA Method 218.4	10
•	Dioxins	USEPA Method 8290	11
•	Herbicides	USEPA Method 8150	12
•	Organophosphate pesticides	USEPA Method 8140	13

At the time of this report, no samples for analysis of engineering parameters had been collected relevant to the CMS.

**3.2.5 Sediment and Surface Water Sampling** 16

Section 7 of the CSAP describes sediment and surface water sampling methods in detail. The following subsections summarize those methods as applied in the Zone E RFI. 18

**3.2.5.1 Sediment and Surface Water Sample Locations** 19

Sediment and surface water samples were collected from the locations proposed in the *Final Zone E RFI Work Plan*. All sediment and surface water sample locations were accessible. 21

At locations where both surface water and sediment were sampled, surface water samples were collected first to prevent disturbance of the substrate.

### **3.2.5.2 Sediment and Surface Water Sample Collection**

Composite sediment samples were collected from 0 to 6 inches bgs for laboratory analysis. Underwater sediment samples were collected using a Ponar grab sampler as outlined in Section 7.2.1 of the CSAP. Samples collected from sediment buildup in storm drains or other catch basins were collected with a stainless-steel spoon and bowl as outlined in Section 7.2.3 of the CSAP. Surface water samples were collected using a Kemmerer sampling device in accordance with Section 7.3.2 of the CSAP.

Underwater dredge samples were collected by lowering a steel, clam-shell type Ponar sampler into the sediment and releasing tension on the rope, closing the sampler jaws. The sampler was then retrieved and the jaws opened to collect the sediment sample. VOC samples were collected immediately from the sampler.

Surface water samples were collected by submerging the Kemmerer sampler with both ends open until the cylinder reached the designated sampling interval, at which the device was closed. Surface water samples were collected at nine locations with one to three samples collected at each location, depending on the depth of water as outlined in the ESDSOPQAM. Care was taken not to disturb bottom sediments during the sample procedure. VOC samples were collected immediately upon sampler retrieval.

Stainless-steel spoons and bowls were used to collect sediment samples from storm drains and catch basins. Upon identification of the sample location, the sediment surface was removed with a decontaminated stainless-steel spoon or spatula to expose a fresh surface. Using a clean decontaminated stainless-steel spoon, the sediment was scooped into a decontaminated stainless-

steel bowl. VOC samples were filled directly from the sampling device, taking care to avoid twigs, large rocks, and grass. The rest of the sample was homogenized in the bowl and placed into appropriate sample containers.

### **3.2.5.3 Sediment and Surface Water Sample Preparation, Packaging, and Shipment**

Guidelines in Section 11 of the CSAP were followed for the preparation, packaging, and shipment of sediment and surface water samples collected during the Zone E RFI. The following summarizes those activities.

Sediment and surface water samples were identified upon collection in accordance with Section 11.4 of the CSAP and as stated in Section 3.2.1. Samples were stored on ice in a cooler until prepared for shipment. Date and time of sample collection, weather, sampling team, sketch map of sample location, tidal phase, and analytical parameters were recorded in the Zone E sampling logbook for individual or groups of samples.

At the close of each day of sampling, sediment and surface water samples were grouped by sample identification, individually custody-sealed and encased in bubble wrap, double-bagged in waterproof plastic bags, and placed in a sample cooler. Ice, double-bagged in waterproof, resealable plastic bags, was placed on top of the samples to preserve them at approximately 4°C. Before sealing the sample cooler for shipment, all sample data were entered onto an official chain-of-custody form which was then affixed to the top, inside surface of the sample cooler. The coolers were then secured and two custody seals were affixed before shipment.

Records of sampling were entered into a dedicated field logbook and a master logbook placed in a fireproof safe in the site trailer. Sample coolers were shipped by air for next-day delivery to Southwest Laboratory of Oklahoma.



### 3.2.6 Wipe Sampling 1

Wipe sampling for metals and PCBs was conducted in accordance with Section 9.1 of the CSAP 2  
and Section 4.12.6 of the ESDSOPQAM. The following subsections summarize those methods 3  
as applied in Zone E. 4

#### 3.2.6.1 Wipe Sample Locations 5

Sample locations were not predetermined, but were selected in the field based on visual 6  
observations of horizontal structural building components, such as supports and window sills, 7  
unlikely to have undergone significant dusting or maintenance. Each sample location was marked, 8  
numbered, and documented in a field logbook. 9

#### 3.2.6.2 Wipe Sample Collection 10

Wipe samples were collected by swabbing or wiping the material or surface with No. 42 Whatman 11  
Filters dampened with deionized water. The wipes were supplied by the Wisconsin Occupational 12  
Health Laboratory (WOHL) of Madison, Wisconsin, in 8-ounce, precleaned glass jars. A clean 13  
set of gloves was used with each sample to prevent cross-contamination. The optimal wipe area 14  
was 100 square centimeters (cm<sup>2</sup>). However, due to the nature of the matrices to be sampled, the 15  
optimal area was not always available. The area wiped was approximated and noted in a field 16  
logbook. The filter was folded with the exposed sides against each other, then folded again. The 17  
filter was then returned to the sample jar and a corresponding number was placed in the logbook. 18  
One filter blank was dampened with deionized water, folded, and returned to the sample jar to 19  
serve as a media blank. 20

Asbestos wipe samples were collected by swabbing or wiping the material or surface with prepared 21  
37-millimeter (mm) mixed cellulose ester filters that were dampened with deionized water. The 22  
wipes were supplied by WOHL in an 8-ounce, precleaned glass jars. A clean set of gloves was 23  
used with each individual sample to prevent cross-contamination. The optimal wipe area was 24

100 cm<sup>2</sup>. However, the optimal area was not always available. The area wiped was approximated and noted in a field logbook. The filter was folded with the exposed sides against each other, then folded again. The filter was then returned to the sample jar and a corresponding number was placed in the logbook. One filter blank was dampened with deionized water, folded, and returned to the sample jar to serve as a media blank.

### 3.2.6.3 Wipe Sample Preparation, Packaging, and Shipment

The sample jar was labeled immediately in accordance with Section 11.4 of the CSAP. The jars were individually custody-sealed, encased in bubble wrap, and boxed for shipment. A chain-of-custody form was prepared and placed in the box. The samples were shipped overnight to WOHL. Air-bill information and sample labels were recorded in a master sample log.

### 3.2.6.4 Wipe Sampling Analysis

The metals and PCB wipe samples were submitted to WOHL for elemental analysis. The samples were analyzed by inductively coupled argon plasma, atomic emission spectroscopy using the National Institute for Occupational Safety and Health (NIOSH) Method 7300.

## 3.2.7 Concrete/Asphalt Sampling

Concrete and asphalt were sampled in accordance with Section 4.12.5 of the USEPA-ESDSOPQAM. The following subsections summarize those methods as applied in Zone E.

### 3.2.7.1 Concrete/Asphalt Sample Locations

Sample locations were collected based on the concrete/asphalt core locations proposed in the *Final Zone E RFI Work Plan*. Each sample location was marked, numbered, and documented in a field logbook. Some of the original sample locations were modified due to accessibility problems, surface/subsurface obstructions, or utility locations.

**3.2.7.2 Concrete/Asphalt Sample Collection**

Concrete/asphalt samples were collected with an air-driven chipping hammer using a decontaminated stainless-steel chipping bit, stainless-steel spoons, and stainless-steel mixing bowls. A clean set of gloves was used with each individual sample to prevent cross-contamination. Composite samples were collected from a circular area approximately 4 inches in diameter. A clean, decontaminated chipping bit was used to crush representative portions of the concrete or asphalt. Once crushed, the sample material was thoroughly mixed and containerized.

**3.2.7.3 Concrete/Asphalt Sample Preparation, Packaging, and Shipment**

Section 11.4 of the CSAP details procedures for the preparation, packaging, and shipment of samples collected during the Zone E RFI investigation. Below is an overview of the procedures used during concrete and asphalt sampling.

Sample material was transferred from the stainless-steel bowl to a glass sample jar using a stainless-steel spoon. Samples collected for VOC analysis were not homogenized, but were containerized immediately with as little headspace as possible to minimize the possibility of volatilization. Material for all other analyses was homogenized with a stainless-steel spoon and packed into the appropriate containers.

Samples were identified as described in Section 3.2.1 of this document. From the moment of collection, labels were affixed to each sample container. Other information, such as weather conditions, date and time of collection, sampling team, and a sketch of the location was included in a Zone E sample logbook.

Sample jars were individually custody-sealed, encased in bubble wrap and a resealable plastic bag, and placed in a cooler for shipment. The samples were packed with ice double-bagged in

waterproof, resealable plastic bags to ensure proper preservation at 4°C. A chain-of-custody form 1  
was prepared and placed in the cooler. 2

The samples were shipped overnight via FedEx to Southwest Laboratory of Oklahoma. Air-bill 3  
information and sample numbers were recorded in a master sample log. 4

**3.2.7.4 Concrete/Asphalt Sampling Analysis** 5

A total of 11 concrete samples and 32 asphalt samples were analyzed per USEPA Method SW-846 6  
and DQO Level III unless otherwise noted, as follows: 7

- VOCs USEPA Method 8240 8
- SVOCs USEPA Method 8270 9
- Pesticides/PCBs USEPA Method 8080 10
- Cyanide USEPA Method 9010 11
- Metals Title 40 CFR Part 264 Appendix IX 12
- Organotins Per SOP Triangle Laboratories 13

**3.2.8 Vertical and Horizontal Surveying** 14

Section 3.2.7 of the Zone A RFI report discusses the procedures for vertical and horizontal 15  
surveying in Zone E. 16

**3.2.9 Decontamination Procedures** 17

Section 3.2.9 of the Zone A RFI report discusses the decontamination procedures used during the 18  
Zone E RFI. 19

## **4.0 DATA VALIDATION**

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### **4.1 Introduction**

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Section 4.1 of the *Zone A RFI Report* details the DQOs and the appropriate guidance for the RFI at NAVBASE.

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### **4.2 Validation Summary**

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Section 4.2 of the Zone A RFI report details QA/QC criteria of the data produced from the environmental samples collected at NAVBASE. RFI environmental samples were collected at Zone E from August 1995 to February 1997. All samples were analyzed by Southwest Laboratory of Oklahoma. Third-party independent data validation of all analytical work was conducted by Heartland Environmental Services Inc., St. Charles, Missouri, based on the QC criteria developed for the Contract Laboratory Program (CLP). The third-party validator's function was to assess and summarize the quality and reliability of the data to determine their usability and to document any factors affecting data usability, such as compliance with methods, possible matrix interferences, and laboratory blank contamination.

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#### **4.2.1 Organic Evaluation Criteria**

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Section 4.2.1 of the Zone A RFI report details organic evaluation criteria for samples collected at NAVBASE. Appendix H includes the complete analytical dataset for Zone E. Appendix I contains the complete analytical validation report for Zone E.

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##### **4.2.1.1 Holding Times**

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Section 4.2.1.1 of the Zone A RFI report details the acceptable holding times for samples collected at NAVBASE.

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<b>4.2.1.2 GC/MS Instrument Performance Checks</b>	1
Section 4.2.1.2 of the Zone A RFI report details gas chromatograph/mass spectrometer (GC/MS) instrument performance checks for NAVBASE.	2 3
<b>4.2.1.3 Surrogate Spike Recoveries</b>	4
Section 4.2.1.3 of the Zone A RFI report details surrogate spike recoveries for NAVBASE.	5
<b>4.2.1.4 Instrument Calibration</b>	6
Section 4.2.1.4 of the Zone A RFI report details instrument calibration for NAVBASE.	7
<b>4.2.1.5 Matrix Spike/Matrix Spike Duplicate</b>	8
Section 4.2.1.5 of the Zone A RFI report details matrix spike/matrix spike duplicates for NAVBASE.	9 10
<b>4.2.1.6 Laboratory Control Samples and Laboratory Duplicates</b>	11
Section 4.2.1.6 of the Zone A RFI report details laboratory control samples and laboratory duplicates for NAVBASE.	12 13
<b>4.2.1.7 Blank Analysis</b>	14
Section 4.2.1.7 of the Zone A RFI report details blank analysis for samples collected at NAVBASE.	15 16
<b>4.2.1.8 Field-Derived Blanks</b>	17
Section 4.2.1.8 of the Zone A RFI report details field-derived blanks for samples collected at NAVBASE.	18 19

**4.2.1.9 Internal Standard Performance**

Section 4.2.1.9 of the Zone A RFI report details internal standard performance criteria for NAVBASE.

**4.2.1.10 Diluted Samples**

A special evaluation was performed for diluted samples to determine if method detection limits were sufficiently low to be compared with reference concentrations (e.g., Maximum Contaminant Levels [MCLs], RBCs, etc.). Table 4.1 lists the diluted samples for Zone E.

**Table 4.1**  
**Diluted Samples**  
 (micrograms per kilogram)

Method	Parameter	Sample ID	Result	VQUAL
APX9 PEST	4,4'-DDD	087CB00101	156.00	DJ
APX9 PEST	4,4'-DDE	574CB00801	250.00	D
APX9 PEST	4,4'-DDE	087CB00101	664.00	DJ
APX9 PEST	4,4'-DDT	574CB00801	290.00	DJ
APX9 PEST	Heptachlor epoxide	574CB00801	29.00	D
APX9 PEST	alpha-Chlordane	543CB00402	34.00	D
APX9 PEST	alpha-Chlordane	097CB00301	97.00	DJ
APX9 PEST	gamma-Chlordane	102CB03601	36.00	DJ
APX9 PEST	gamma-Chlordane	543CB00402	45.00	D
APX9 PEST	gamma-Chlordane	574CB00801	49.00	D
APX9 PEST	gamma-Chlordane	559CB02701	62.00	D
APX9 PEST	gamma-Chlordane	097CB00301	260.00	DJ
APX9 VOA	Acetone	065CB00101	160.00	D
SW846-PEST	4,4'-DDD	087SB00101	73.00	DJ
SW846-PEST	4,4'-DDD	102SB03401	87.00	DJ
SW846-PEST	4,4'-DDD	559SB02702	110.00	D
SW846-PEST	4,4'-DDD	598SB00101	132.00	DJ

**Table 4.1**  
**Diluted Samples**  
 (micrograms per kilogram)

Method	Parameter	Sample ID	Result	VQUAL
SW846-PEST	4,4'-DDD	559SB01901	400.00	D
SW846-PEST	4,4'-DDE	563SB00501	30.00	DJ
SW846-PEST	4,4'-DDE	559SB02702	33.00	D
SW846-PEST	4,4'-DDE	559SB00701	45.00	D
SW846-PEST	4,4'-DDE	549SB00101	49.00	D
SW846-PEST	4,4'-DDE	542SB00501	96.00	D
SW846-PEST	4,4'-DDE	559SB02001	100.00	D
SW846-PEST	4,4'-DDE	GDESB01401	110.00	D
SW846-PEST	4,4'-DDE	526SB00801	140.00	D
SW846-PEST	4,4'-DDE	102SB03401	190.00	DJ
SW846-PEST	4,4'-DDE	574SB00801	200.00	D
SW846-PEST	4,4'-DDE	GDESB00502	380.00	D
SW846-PEST	4,4'-DDE	559SB01901	740.00	D
SW846-PEST	4,4'-DDT	542SB00601	13.00	D
SW846-PEST	4,4'-DDT	563SB00501	52.00	DJ
SW846-PEST	4,4'-DDT	526SB00801	58.00	D
SW846-PEST	4,4'-DDT	542SB00501	66.00	D
SW846-PEST	4,4'-DDT	025M000101	110.00	DJ
SW846-PEST	4,4'-DDT	102SB03801	130.00	DJ
SW846-PEST	4,4'-DDT	GDESB00502	140.00	D
SW846-PEST	4,4'-DDT	102SB03601	150.00	DJ
SW846-PEST	4,4'-DDT	574SB00801	180.00	DJ
SW846-PEST	4,4'-DDT	102SB03401	220.00	DJ
SW846-PEST	4,4'-DDT	102SB03701	230.00	DJ
SW846-PEST	Aldrin	544SB00101	349.00	DJ
SW846-PEST	Dieldrin	544SB00201	260.00	D
SW846-PEST	Dieldrin	087SB00101	290.00	DJ
SW846-PEST	Dieldrin	539M000101	370.00	D

**Table 4.1**  
**Diluted Samples**  
 (micrograms per kilogram)

Method	Parameter	Sample ID	Result	VQUAL
SW846-PEST	Dieldrin	544SB00101	586.00	DJ
SW846-PEST	Endosulfan sulfate	025M000101	51.00	DJ
SW846-PEST	Endrin aldehyde	025M000101	51.00	DJ
SW846-PEST	Endrin aldehyde	539M000101	490.00	D
SW846-PEST	Heptachlor	540SB00101	130.00	D
SW846-PEST	Heptachlor epoxide	574SB00801	33.00	D
SW846-PEST	Methoxychlor	053SB00202	32.00	D
SW846-PEST	Technical chlordane	525SB00201	230.00	D
SW846-PEST	Technical chlordane	525SB00402	610.00	D
SW846-PEST	Technical chlordane	525SB00102	3400.00	D
SW846-PEST	Technical chlordane	544SB00101	11000.00	D
SW846-PEST	alpha-Chlordane	559SB02701	11.00	D
SW846-PEST	alpha-Chlordane	559SB00101	27.00	D
SW846-PEST	alpha-Chlordane	559SB02302	30.00	DJ
SW846-PEST	alpha-Chlordane	063SB00202	32.00	DJ
SW846-PEST	alpha-Chlordane	087SB00101	33.00	DJ
SW846-PEST	alpha-Chlordane	GDESB00502	33.00	D
SW846-PEST	alpha-Chlordane	543SB00402	38.00	DJ
SW846-PEST	alpha-Chlordane	542SB00701	52.00	DJ
SW846-PEST	alpha-Chlordane	063SB00201	67.00	DJ
SW846-PEST	alpha-Chlordane	540SB00101	82.00	DJ
SW846-PEST	alpha-Chlordane	543SB00401	130.00	D
SW846-PEST	gamma-Chlordane	559SB00101	26.00	D
SW846-PEST	gamma-Chlordane	559SB02302	28.00	D
SW846-PEST	gamma-Chlordane	087SB00101	29.00	DJ
SW846-PEST	gamma-Chlordane	GDESB00502	34.00	D
SW846-PEST	gamma-Chlordane	063SB00202	35.00	D
SW846-PEST	gamma-Chlordane	102SB03601	43.00	DJ

**Table 4.1**  
**Diluted Samples**  
(micrograms per kilogram)

Method	Parameter	Sample ID	Result	VQUAL
SW846-PEST	gamma-Chlordane	097SB00301	46.30	DJ
SW846-PEST	gamma-Chlordane	543SB00402	48.00	D
SW846-PEST	gamma-Chlordane	102SB03401	53.00	DJ
SW846-PEST	gamma-Chlordane	559SB02701	55.00	D
SW846-PEST	gamma-Chlordane	542SB00701	74.00	D
SW846-PEST	gamma-Chlordane	063SB00201	77.00	D
SW846-PEST	gamma-Chlordane	540SB00101	140.00	D
SW846-PEST	gamma-Chlordane	543SB00401	240.00	D
SW846-SVOA	2-Methylnaphthalene	530SB00601	10000.00	D
SW846-SVOA	2-Methylnaphthalene	054SB03102	12000.00	D
SW846-SVOA	2-Methylnaphthalene	559SB01901	25000.00	DJ
SW846-SVOA	Acenaphthene	574SB00501	1000.00	D
SW846-SVOA	Acenaphthene	530SB00601	5700.00	D
SW846-SVOA	Acenaphthene	065SB00702	15000.00	D
SW846-SVOA	Acenaphthene	054SB03102	83000.00	D
SW846-SVOA	Acenaphthene	559SB01901	98000.00	DJ
SW846-SVOA	Acenaphthylene	530SB00601	2000.00	D
SW846-SVOA	Anthracene	084SB00401	5000.00	D
SW846-SVOA	Anthracene	065SB00702	5200.00	D
SW846-SVOA	Anthracene	574SB00801	6200.00	DJ
SW846-SVOA	Anthracene	559SB01901	240000.00	DJ
SW846-SVOA	Anthracene	054SB03102	250000.00	D
SW846-SVOA	Benzo(a)anthracene	574SB00801	9300.00	DJ
SW846-SVOA	Benzo(a)anthracene	084SB00401	11000.00	D
SW846-SVOA	Benzo(a)anthracene	599SB00701	19000.00	D
SW846-SVOA	Benzo(a)anthracene	530SB00601	20000.00	D
SW846-SVOA	Benzo(a)anthracene	559SB01901	260000.00	DJ
SW846-SVOA	Benzo(a)anthracene	054SB03102	460000.00	D

**Table 4.1**  
**Diluted Samples**  
 (micrograms per kilogram)

Method	Parameter	Sample ID	Result	VQUAL
SW846-SVOA	Benzo(a)pyrene	574SB00801	7600.00	DJ
SW846-SVOA	Benzo(a)pyrene	102SB03701	8200.00	DJ
SW846-SVOA	Benzo(a)pyrene	084SB00401	9300.00	D
SW846-SVOA	Benzo(a)pyrene	530SB00601	15000.00	D
SW846-SVOA	Benzo(a)pyrene	599SB00701	17000.00	D
SW846-SVOA	Benzo(a)pyrene	559SB01901	210000.00	DJ
SW846-SVOA	Benzo(a)pyrene	054SB03102	290000.00	D
SW846-SVOA	Benzo(b)fluoranthene	559SB02501	6000.00	DJ
SW846-SVOA	Benzo(b)fluoranthene	574SB00801	6000.00	DJ
SW846-SVOA	Benzo(b)fluoranthene	084SB00401	8500.00	D
SW846-SVOA	Benzo(b)fluoranthene	102SB03701	11000.00	DJ
SW846-SVOA	Benzo(b)fluoranthene	599SB00701	17000.00	D
SW846-SVOA	Benzo(b)fluoranthene	054SB03102	290000.00	D
SW846-SVOA	Benzo(b)fluoranthene	559SB01901	320000.00	DJ
SW846-SVOA	Benzo(g,h,i)perylene	084SB00401	8400.00	D
SW846-SVOA	Benzo(g,h,i)perylene	102SB03701	9400.00	DJ
SW846-SVOA	Benzo(g,h,i)perylene	530SB00601	10000.00	D
SW846-SVOA	Benzo(g,h,i)perylene	559SB01901	89000.00	DJ
SW846-SVOA	Benzo(k)fluoranthene	574SB00801	4900.00	DJ
SW846-SVOA	Benzo(k)fluoranthene	559SB02501	5700.00	DJ
SW846-SVOA	Benzo(k)fluoranthene	084SB00401	8700.00	D
SW846-SVOA	Benzo(k)fluoranthene	102SB03701	9300.00	DJ
SW846-SVOA	Benzo(k)fluoranthene	530SB00601	16000.00	D
SW846-SVOA	Benzo(k)fluoranthene	054SB03102	220000.00	D
SW846-SVOA	Butylbenzylphthalate	563SB00601	7200.00	D
SW846-SVOA	Chrysene	559SB02501	7400.00	DJ
SW846-SVOA	Chrysene	102SB03701	8400.00	DJ
SW846-SVOA	Chrysene	574SB00801	9400.00	DJ

**Table 4.1**  
**Diluted Samples**  
**(micrograms per kilogram)**

Method	Parameter	Sample ID	Result	VQUAL
SW846-SVOA	Chrysene	084SB00401	12000.00	D
SW846-SVOA	Chrysene	530SB00601	20000.00	D
SW846-SVOA	Chrysene	599SB00701	20000.00	D
SW846-SVOA	Chrysene	559SB01901	260000.00	DJ
SW846-SVOA	Chrysene	054SB03102	360000.00	D
SW846-SVOA	Dibenz(a,h)anthracene	084SB00401	3600.00	D
SW846-SVOA	Dibenz(a,h)anthracene	530SB00601	4400.00	D
SW846-SVOA	Dibenz(a,h)anthracene	559SB01901	60000.00	DJ
SW846-SVOA	Dibenzofuran	530SB00601	4000.00	D
SW846-SVOA	Dibenzofuran	559SB01901	49000.00	DJ
SW846-SVOA	Dibenzofuran	054SB03102	72000.00	D
SW846-SVOA	Fluoranthene	531SB00501	7000.00	D
SW846-SVOA	Fluoranthene	574SB00501	10000.00	D
SW846-SVOA	Fluoranthene	065SB00702	15000.00	D
SW846-SVOA	Fluoranthene	574SB00801	22000.00	DJ
SW846-SVOA	Fluoranthene	084SB00401	24000.00	D
SW846-SVOA	Fluoranthene	599SB00701	44000.00	D
SW846-SVOA	Fluoranthene	530SB00601	45000.00	D
SW846-SVOA	Fluoranthene	530SB00801	90000.00	D
SW846-SVOA	Fluoranthene	559SB01901	550000.00	DJ
SW846-SVOA	Fluoranthene	054SB03102	700000.00	D
SW846-SVOA	Fluorene	084SB00401	200.00	D
SW846-SVOA	Fluorene	599SB00701	9000.00	D
SW846-SVOA	Fluorene	054SB03102	11000.00	D
SW846-SVOA	Fluorene	065SB00702	12000.00	D
SW846-SVOA	Fluorene	559SB01901	92000.00	DJ
SW846-SVOA	Indeno(1,2,3-cd)pyrene	574SB00801	5500.00	DJ
SW846-SVOA	Indeno(1,2,3-cd)pyrene	084SB00401	6800.00	D

**Table 4.1**  
**Diluted Samples**  
**(micrograms per kilogram)**

Method	Parameter	Sample ID	Result	VQUAL
SW846-SVOA	Indeno(1,2,3-cd)pyrene	599SB00701	7000.00	D
SW846-SVOA	Indeno(1,2,3-cd)pyrene	530SB00601	7900.00	D
SW846-SVOA	Indeno(1,2,3-cd)pyrene	102SB03701	8000.00	DJ
SW846-SVOA	Indeno(1,2,3-cd)pyrene	559SB01901	84000.00	DJ
SW846-SVOA	Naphthalene	084SB00401	3000.00	D
SW846-SVOA	Naphthalene	530SB00601	6100.00	D
SW846-SVOA	Naphthalene	054SB03102	10000.00	D
SW846-SVOA	Naphthalene	559SB01901	76000.00	DJ
SW846-SVOA	Phenanthrene	574SB00501	10000.00	D
SW846-SVOA	Phenanthrene	065SB00702	20000.00	D
SW846-SVOA	Phenanthrene	084SB00401	26000.00	D
SW846-SVOA	Phenanthrene	574SB00801	26000.00	DJ
SW846-SVOA	Phenanthrene	599SB00701	48000.00	D
SW846-SVOA	Phenanthrene	530SB00601	55000.00	D
SW846-SVOA	Phenanthrene	530SB00801	100000.00	D
SW846-SVOA	Phenanthrene	559SB01901	600000.00	DJ
SW846-SVOA	Phenanthrene	054SB03102	700000.00	D
SW846-SVOA	Pyrene	531SB00501	6600.00	D
SW846-SVOA	Pyrene	559SB02501	7000.00	DJ
SW846-SVOA	Pyrene	574SB00501	14000.00	D
SW846-SVOA	Pyrene	065SB00702	17000.00	D
SW846-SVOA	Pyrene	102SB03701	17000.00	DJ
SW846-SVOA	Pyrene	574SB00801	18000.00	DJ
SW846-SVOA	Pyrene	084SB00401	24000.00	D
SW846-SVOA	Pyrene	599SB00701	29000.00	D
SW846-SVOA	Pyrene	530SB00601	45000.00	D
SW846-SVOA	Pyrene	530SB00801	74000.00	D
SW846-SVOA	Pyrene	559SB01901	430000.00	DJ

**Table 4.1**  
**Diluted Samples**  
 (micrograms per kilogram)

Method	Parameter	Sample ID	Result	VQUAL
SW846-SVOA	Pyrene	054SB03102	590000.00	D
SW846-SVOA	bis(2-Ethylhexyl)phthalate (BEHP)	563SB00701	5400.00	D
SW846-SVOA	BEHP	054SB03101	7600.00	D
SW846-SVOA	BEHP	563SB00601	13000.00	D
SW846-SVOA	BEHP	528M000101	17000.00	D
SW846-VOA	Acetone	170SB01401	210.00	D
SW846-VOA	Acetone	172SB00601	250.00	D
SW846-VOA	Acetone	172SB00101	300.00	D
SW846-VOA	Acetone	578SB00301	300.00	DJ
SW846-VOA	Acetone	170SB01501	310.00	DJ
SW846-VOA	Benzene	569SB00502	10000.00	D
SW846-VOA	Ethylbenzene	569SB00502	170000.00	D
SW846-VOA	Methylene chloride	578SB00301	57.00	DJ
SW846-VOA	Toluene	569SB00502	220000.00	D
SW846-VOA	Xylene (Total)	569SB00502	800000.00	D

**Notes:**

- PEST = pesticide
- SVOA = semivolatle organic analysis
- VOA = volatile organic analysis
- VQUAL = qualifier
- D = diluted
- DJ = diluted; quantitation limit estimated

**4.2.2 Inorganic Evaluation Criteria**

Section 4.2.2 of the Zone A RFI report details inorganic evaluation criteria for NAVBASE.

**4.2.2.1 Holding Times**

Section 4.2.2.1 of the Zone A RFI report details acceptable holding times for NAVBASE samples.

<b>4.2.2.2 Instrument Calibration</b>	1
Section 4.2.2.2 of the Zone A RFI report details instrument calibration criteria for NAVBASE.	2
<b>4.2.2.3 Blank Analysis</b>	3
Section 4.2.2.3 of the Zone A RFI report details blank analysis criteria for NAVBASE.	4
<b>4.2.2.4 Inductively Coupled Argon Plasma Interference Check Samples</b>	5
Section 4.2.2.4 of the Zone A RFI report details Inductively Coupled Argon Plasma (ICAP) interference check samples for NAVBASE.	6 7
<b>4.2.2.5 Laboratory Control Samples</b>	8
Section 4.2.2.5 of the Zone A RFI report details laboratory control samples for NAVBASE.	9
<b>4.2.2.6 Spike Sample Analysis</b>	10
Section 4.2.2.6 of the Zone A RFI report discusses spike sample analysis for NAVBASE.	11
<b>4.2.2.7 Laboratory Duplicates</b>	12
Section 4.2.2.7 of the Zone A RFI report discusses laboratory duplicates for NAVBASE.	13
<b>4.2.2.8 ICAP Serial Dilutions</b>	14
Section 4.2.2.8 of the Zone A RFI report discusses ICAP serial dilutions for NAVBASE.	15
<b>4.2.2.9 AA Duplicate Injections and Postdigestion Spike Recoveries</b>	16
Section 4.2.2.9 of the Zone A RFI report discusses atomic absorption duplicate injections and postdigestion spike recoveries for NAVBASE.	17 18

### 4.3 Zone E Data Validation Reports

A complete copy of the Zone E Data Validation Reports are included as Appendix I for review. These reports are the outcome of the evaluations described above and are specific to the analytical data collected during the Zone E RFI. During data validation review of Zone E soil and groundwater analytical sample results, the following deficiencies and/or problems were noted in the volatile, semivolatile, and metals method.

In the volatile method, acetone and methylene chloride were common laboratory contaminants in the soil and groundwater samples. In the semivolatile method, bis(2-Ethylhexyl)phthalate (BEHP) was a common contaminant in soil and groundwater samples. In the metals method, antimony, barium, beryllium, chromium, cobalt, magnesium, nickel, potassium, and silver were common contaminants in soil and groundwater samples.

#### 4.3.1 Site-Specific Soil/Sediment Blank Contaminants

Site 005 had acetone and methylene chloride in the method blanks for the volatile method and chloroform in the trip blank. The metals method detected sodium in the method blank.

Site 018 had acetone and methylene chloride in the equipment, method, and trip blanks in the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected sodium in the method blank.

Site 022 had acetone and methylene chloride in the method blank. Chloroform was in the distilled water and method blanks for the volatile method. BEHP was detected in the semivolatile method blank for the semivolatile method.

Site 023 had methylene chloride in the method blank and acetone in the distilled water and equipment blanks for the volatile method. The semivolatile method detected BEHP in the

equipment and method blanks. The metals method detected beryllium, nickel, potassium, and tin 1  
in the method blank and calcium, cobalt, magnesium, manganese, sodium, and thallium in the 2  
equipment blanks. Barium, iron, and silver were detected in the equipment and method blanks. 3

**Site 025** had acetone in the trip blank and methylene chloride in the method blank for the volatile 4  
method. The semivolatile method detected BEHP in the method blank. The metals method 5  
detected tin in the method blank and potassium and sodium were detected in the distilled water and 6  
equipment blanks. 7

**Site 053** had acetone and methylene chloride in the method blank and trichloroethene was detected 8  
in the trip blank for the volatile method. The semivolatile method detected BEHP in the method 9  
blank. The metals method detected antimony, nickel, and tin in the method blank and arsenic in 10  
the equipment blank. Barium and vanadium were detected in the distilled water and equipment 11  
blanks and beryllium, potassium, and sodium were detected in the distilled water, equipment, and 12  
method blanks. 13

**Site 054** had methylene chloride in the distilled water, equipment, and method blanks for the 14  
volatile method. The semivolatile method detected BEHP in the distilled water, equipment, and 15  
method blanks and benzoic acid was detected in the distilled water and equipment blanks. The 16  
metals method detected tin in the method blank and potassium and sodium were detected in the 17  
distilled water, equipment, and method blanks. 18

**Site 063** had potassium and sodium in the equipment blank for the metals method. 19

**Site 065** had 2-butanone and methylene chloride in the equipment and acetone detected in the 20  
distilled water and equipment blanks for the volatile method. The semivolatile method detected 21  
BEHP in the equipment and method blanks. The metals method detected antimony, arsenic, 22

barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, 1  
manganese, nickel, potassium, sodium, and zinc in the equipment blank. Aluminum and vanadium 2  
were detected in the equipment and method blanks. 3

Site 070 had acetone in the distilled water blank and methylene chloride was detected in the 4  
distilled water, equipment, and method blanks. Acenaphthlene was detected in the distilled water 5  
blank for the semivolatile method. 6

Site 081 had methylene chloride in the trip blank and acetone was detected in the method and trip 7  
blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The 8  
metals method detected tin in the method blank. 9

Site 083 had methylene chloride in the distilled water, equipment, and trip blanks for the volatile 10  
method. For the metals method, tin was detected in the method blank, barium and calcium were 11  
detected in the equipment blank, and potassium and sodium were detected in the distilled water 12  
and equipment blanks. 13

Site 084 had methylene chloride in the distilled water, equipment, and trip blanks and acetone was 14  
detected in the distilled water, equipment, trip, and method blanks for the volatile method. The 15  
metals method detected lead and magnesium in the distilled water blank. Barium, calcium, 16  
potassium, sodium, and zinc were detected in the distilled water and equipment blanks. 17

Site 087 had chloroform in the distilled water and equipment blanks for the volatile method and 18  
BEHP was detected in the method blank for the semivolatile method. 19

**Site 097** had methylene chloride in the method blank and chloroform was detected in the equipment and method blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected sodium in the method blank.

**Site 100** had acetone and methylene chloride in the method blank for the volatile method. The metals method detected potassium in the method blank.

**Site 102** had acetone and methylene chloride in the distilled water, equipment, and trip blanks for the volatile method. The semivolatile method detected BEHP in the distilled water, equipment, and method blanks. The metals method detected antimony in the equipment blank and tin was detected in the distilled water blank. Calcium, lead, magnesium, manganese, potassium, and zinc were detected in the distilled water and equipment blanks. Barium and sodium were detected in the distilled water, equipment, and method blanks.

**Site 106** had acetone and chloroform in the method and trip blanks and methylene chloride was detected in the distilled water, equipment, and method blanks for the volatile method. The semivolatile method detected acenaphthlene in the method blank.

**Site 170** had chloroform and methylene chloride in the trip blank for the volatile method.

**Site 172** had acetone and methylene chloride in the method blank and chloroform was detected in the method and trip blanks for the volatile method. The semivolatile method detected BEHP in the distilled water and method blanks.

**Site 173** had methylene chloride in the method blank and acetone was detected in the method and trip blanks for the volatile method.

**Site 525** had diethylphthalate and BEHP in the method blank for the semivolatile method and tin was detected in the method blank for the metals method. 1  
2

**Site 526** had methylene chloride in the distilled water blank and acetone detected in the distilled water and equipment blanks for the volatile method. The semivolatile method detected diethylphthalate and dimethyl phthalate in the method blank and BEHP was detected in the equipment and method blanks. The metals method detected potassium in the equipment blank, tin was detected in the method blank, and sodium was detected in the distilled water and equipment blanks. 3  
4  
5  
6  
7  
8

**Site 528** had acetone in the method and trip blanks and methylene chloride was detected in the equipment and method blanks for the volatile method. 9  
10

**Site 530** had acetone in the trip blank and methylene chloride was detected in the method and trip blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected tin in the method blank and beryllium, calcium, cobalt, copper, magnesium, manganese, mercury, and nickel were detected in the equipment blank. Barium, iron, and sodium were detected in the equipment and method blanks. 11  
12  
13  
14  
15

**Site 531** had acetone and chloroform in the distilled water, equipment, and trip blanks for the volatile method. Methylene chloride was detected in the distilled water, equipment, method, and trip blanks. The metals method detected cobalt, copper and tin in the method blank, and lead, magnesium, and manganese were detected in the equipment blank. Calcium, nickel, and sodium were detected in the distilled water and equipment blanks, and vanadium and zinc were detected in the equipment and method blanks. Aluminum was detected in the distilled water, equipment, and method blanks. 16  
17  
18  
19  
20  
21  
22

Site 538 had methylene chloride in the method blank for the volatile method. The semivolatile method detected BEHP in the method blank. Sodium was detected in the method blank for the metals method.

Site 539 had acetone and methylene chloride in the method blank for the volatile method. The metals method detected potassium and sodium detected in the method blank.

Site 540 had acetone in the distilled water blank and methylene chloride was detected in the distilled water, equipment, and method blanks for the volatile method. The semivolatile method detected acenaphthalene detected in the distilled water blank and potassium and sodium in the method blank.

Site 541 had potassium and sodium in the method blank for the metals method.

Site 542 had acetone and methylene chloride in the method blank for the volatile method and potassium and sodium were detected in the metals method blank.

Site 543 had acetone, carbon tetrachloride, and methylene chloride in the equipment, method, and trip blanks for the volatile method. The semivolatile method detected acenaphtalene in the distilled water blank. The metals blank had chromium, potassium, and sodium in the method blank.

Site 544 had acetone and methylene chloride in the method and trip blanks for the volatile method. The semivolatile method detected BEHP in the equipment and method blanks. Potassium and sodium were detected in the method blank for the metals method.

Site 548 had acetone in the distilled water blank and chloroform and methylene chloride in the distilled water, equipment, and method blanks for the volatile method. The semivolatile method

detected BEHP in the distilled water and method blanks. The metal method detected potassium  
in the method blank. 1  
2

Site 549 had acetone in the distilled water blank and methylene chloride was detected in the  
distilled water, equipment, and method blanks for the volatile method. The semivolatile method  
detected BEHP in the equipment and method blanks. The metals method detected tin in the  
method blank and beryllium, calcium, magnesium, manganese, silver, sodium, and thallium in the  
equipment blank. Barium and iron were detected in the equipment and method blanks. 3  
4  
5  
6  
7

Site 550 had acetone and methylene chloride in the trip blank for the volatile method. The  
semivolatile method detected BEHP in the method blanks. The metals method detected antimony,  
beryllium, potassium, sodium, and tin in the method blanks. 8  
9  
10

Site 551 had acetone and methylene chloride in the equipment, method, and trip blanks for the  
volatile method. The semivolatile method detected BEHP in the method blank. The metals  
method detected sodium and tin in the method blanks. 11  
12  
13

Site 552 had methylene chloride in the method blank for the volatile method and BEHP was  
detected in the method blank for the semivolatile method. 14  
15

Site 554 had acetone and methylene chloride in the method blank for the volatile method. BEHP  
was detected in the distilled water blank for the semivolatile method. 16  
17

Site 559 had acetone in the method and trip blanks and methylene chloride was detected in the  
distilled water, equipment, method, and trip blanks for the volatile method. The semivolatile  
method detected BEHP in the method blank. The metals method detected lead and magnesium in  
the distilled water blank, manganese in the equipment blank, and tin in the method blank. Barium 18  
19  
20  
21

and zinc were detected in the distilled water and equipment blanks and potassium and sodium were detected in the distilled water, equipment, and method blanks. 1  
2

**Site 560** had acetone in the method blank and methylene chloride in the method and trip blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected potassium, sodium, and tin in the method blank. 3  
4  
5

**Site 561** had acetone and methylene chloride in the method and trip blanks for the volatile method. The metals method detected potassium, sodium, and tin in the method blank. 6  
7

**Site 563** had acetone and methylene chloride in the trip blank for the volatile method. The metals method detected potassium, sodium, and tin in the method blank. 8  
9

**Site 564** had acetone and methylene chloride in the trip blank for the volatile method. The semivolatile method detected BEHP in the distilled water blank. 10  
11

**Site 566** had acetone in the trip blank and chloroform and methylene chloride were detected in the method and trip blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected copper, nickel, and potassium detected in the method blank. 12  
13  
14  
15  
16

**Site 567** had potassium in the method blank for the metals method. 17

**Site 569** had methylene chloride in the method blank and acetone was detected in the method and trip blanks for the volatile method. 18  
19

**Site 570** had acetone and methylene chloride in the equipment and method blanks for the volatile method. The semivolatile method detected BEHP in the equipment and method blanks. The metals method detected beryllium, calcium, cobalt, copper, magnesium, manganese, mercury, nickel, potassium, and thallium in the equipment blank. Antimony, barium, and iron were detected in the equipment and method blanks and sodium was detected in the distilled water, equipment, and method blanks. Tin was detected in the method blank.

**Site 572** had chloroform and methylene chloride in the distilled water, equipment, and method blank for the volatile method. The semivolatile method detected BEHP in the equipment and distilled water blanks. The metals method detected antimony, beryllium, and sodium in the distilled water and method blanks, and potassium was detected in the equipment and method blanks.

**Site 573** had acetone in the trip blank, methylene chloride was detected in the method blank, and chloroform was detected in the distilled water, equipment, and trip blanks for the volatile method. The semivolatile method detected BEHP in the equipment, distilled water, and method blanks. The metals method detected tin in the method blank, potassium in the equipment and method blanks, and sodium in the distilled water and method blanks.

**Site 574** had methylene chloride in the method blank for the volatile method. The semivolatile method detected BEHP in the equipment and method blanks. The metals method detected potassium, silver, sodium, and tin in the method blank.

**Site 576** had chloroform in the method blank for the volatile method. The semivolatile method detected BEHP in the equipment blank. The metals method detected nickel and potassium in the method blank.

**Site 578** had acetone in the equipment blank and methylene chloride was detected in the method blank for the volatile method. Butylbenzylphthalate was detected in the method blank for the semivolatile method. 1  
2  
3

**Site 579** had BEHP in the method blank for the semivolatile method and potassium and tin were detected in the method blank for the metals method. 4  
5

**Site 580** had methylene chloride in the method blank and chloroform was detected in the equipment and method blanks for the volatile method. BEHP was detected in the method blank for the semivolatile method. The metals method detected tin and zinc in the method blank and copper was detected in the distilled water and equipment blanks. 6  
7  
8  
9

**Site 583** had chloroform in the equipment and method blanks and methylene chloride was detected in the method and trip blanks for the volatile method. BEHP was detected in the distilled water, equipment, and method blanks for the semivolatile method. The metals method detected sodium and tin in the method blank. 10  
11  
12  
13

**Site 586** had methylene chloride in the distilled water, equipment, and the trip blanks and acetone was detected in the distilled water, equipment, trip blank, and the method blanks for the volatile method. 14  
15  
16

**Site 590** had methylene chloride in the distilled water and the trip blanks for the volatile method. Tin was detected in the equipment blank for the metals method. 17  
18

**Site 596** had acetone in the distilled water, method, and trip blanks and methylene chloride was detected in the distilled water, equipment, and trip blanks for the volatile method. BEHP was 19  
20

detected in the distilled water, equipment, and method blanks for the semivolatile method. The metals method detected sodium and tin in the method blank.

**Site 597** had potassium, sodium, and thallium in the method blank for the metals method.

**Site 598** had acetone and methylene chloride in the method blank for the volatile method. BEHP was detected in the method blank for the semivolatile method. The metals method detected tin in the method blank.

**Site 599** had acetone and methylene chloride in the method blank and chloroform detected in the trip blank for the volatile method. BEHP was detected in the method blank for the semivolatile method. The metals method detected tin in the method blank.

**Site 602** had chloroform in the distilled water, equipment, and method blanks for the volatile method.

**Site 603** had chloroform in the method and trip blanks and methylene chloride was detected in the trip blank for the volatile method.

**Site 604** had chloroform in the distilled water and equipment blanks for the volatile method.

**Site 605** had methylene chloride in the trip blank and chloroform was detected in the method and trip blanks for the volatile method. The semivolatile method detected acenaphthene in the method blank and BEHP was detected in the distilled water, equipment, and method blanks. The metals method detected sodium and tin in the method blank.

**Grid samples** had acetone, chloroform, and methylene chloride in the equipment, method, and trip blanks for the volatile method. The semivolatile method detected benzo(a)anthracene, phenanthrene, and chrysene in the method blank and BEHP in the equipment and method blanks. The metals method detected antimony, arsenic, barium, beryllium, cadmium, calcium, copper, lead, magnesium, manganese, and silver in the equipment blanks. Aluminum, cobalt, iron, nickel, potassium, sodium, thallium, vanadium, and zinc were detected in the equipment and method blanks.

#### **4.3.2 Site-Specific Groundwater/Surface Water Blank Contaminants**

**Site 005** had acetone and methylene chloride in the method blank and chloroform in the trip blank for the volatile method. The metals method detected sodium in the method blank.

**Site 018** had acetone and methylene chloride in the equipment, method, and trip blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected sodium in the method blank.

**Site 022** had acetone and methylene chloride in the method blank for the volatile method and chloroform was detected in the distilled water and method blanks. The semivolatile method detected BEHP in the method blank.

**Site 023** had methylene chloride in the method blank and acetone was detected in the distilled water and equipment blanks for the volatile method. The semivolatile method detected BEHP in the equipment and method blanks. The metals method detected calcium, cobalt, magnesium, manganese, sodium, and thallium in the equipment blank. Beryllium, nickel, and potassium were detected in the method blank and barium and iron were detected in the equipment and method blanks.

Site 025 had acetone in the trip blank and methylene chloride in the distilled water and trip blanks for the volatile method. The semivolatile method detected BEHP in the method blank. For the metals method, tin was detected in the method blank and potassium and sodium were detected in the distilled water and equipment blanks.

Site 053 had acetone and methylene chloride in the method blank and trichloroethene was detected in the trip blank for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected antimony and tin in the method blank and arsenic was detected in the equipment blank. Barium and vanadium were detected in the distilled water and equipment blanks and beryllium, potassium, and sodium were detected in the distilled water, equipment, and method blanks. Cyanide was detected in the distilled water blank.

Site 054 had methylene chloride in the distilled water, equipment, and trip blanks for the volatile method. The semivolatile method detected benzoic acid in the distilled water and equipment blanks and BEHP in the distilled water, equipment, and method blanks. The metals method detected tin in the method blank and nickel in the equipment and method blanks. Potassium and sodium were detected in the distilled water, equipment, and method blanks.

Site 063 had potassium and sodium in the equipment blank for the metals method.

Site 065 had 2-butanone and methylene chloride in the equipment blank and acetone was detected in the distilled water and equipment blanks for the volatile method. The semivolatile method detected BEHP in the equipment and method blanks. The metals method detected tin in the method blank and antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, sodium, and zinc in the equipment blank. Aluminum and vanadium were detected in the equipment and method blanks.

**Site 070** had acetone in the distilled water blank and methylene chloride was detected in the distilled water, equipment, and method blanks for the volatile method. 1  
2

**Site 081** had methylene chloride in the trip blank and acetone in the method and trip blanks for the volatile method. The semivolatile method detected BEHP in the equipment and method blanks. 3  
4  
The metals method detected tin in the method blank. 5

**Site 083** had methylene chloride in the distilled water, equipment, and trip blanks for the volatile method. BEHP was detected in the method blank for the semivolatile method. The metals method detected tin in the method blank and barium and calcium in the equipment blank. Potassium and sodium were detected in the distilled water and equipment blanks. 6  
7  
8  
9

**Site 084** had methylene chloride in the distilled water, equipment, and trip blanks and acetone in the distilled water, equipment, method, and trip blanks for the volatile method. The metals method detected lead and magnesium in the distilled water blank and barium, calcium, potassium, sodium, and zinc in the distilled water and equipment blanks. 10  
11  
12  
13

**Site 087** had chloroform in the distilled water and equipment blanks for the volatile method. BEHP was detected in the distilled water blank for the semivolatile method. 14  
15

**Site 097** had methylene chloride in the method blank and chloroform in the equipment and method blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected sodium in the method blank. 16  
17  
18

**Site 100** had acetone and methylene chloride in the method blank for the volatile method. Potassium was detected in the method blank for the metals method. 19  
20

**Site 102** had acetone and methylene chloride in the distilled water, equipment, and trip blanks for the volatile method. The semivolatile method detected diethylphthalate and BEHP in the distilled water, equipment, and method blanks. The metals method detected antimony in the equipment blank and tin was detected in the distilled water blank. Calcium, lead, magnesium, manganese, potassium, and zinc were detected in the distilled water and equipment blanks. Barium and sodium were detected in the distilled water, equipment, and method blanks.

**Site 106** had acetone and chloroform in the method and trip blanks and methylene chloride was detected in the equipment, method, and trip blanks for the volatile method.

**Site 170** had chloroform and methylene chloride in the trip blank for the volatile method.

**Site 172** had acetone and methylene chloride in the method blank and chloroform was detected in the method blank and trip blanks for the volatile method. The semivolatile method detected BEHP in the distilled water and method blanks.

**Site 173** had methylene chloride in the method and trip blanks and acetone was detected in the equipment, method, and trip blanks for the volatile method. The semivolatile method detected diethylphthalate and BEHP in the distilled water and method blanks. The metals method detected tin in the method blank.

**Site 525** had diethylphthalate and BEHP in the method blank for the semivolatile method. The metals method detected tin in the method blank.

**Site 526** had acetone and methylene chloride in the distilled water and equipment blanks for the volatile method. The semivolatile method detected diethylphthalate and dimethyl phthalate in the

method blank and BEHP in the equipment and method blanks. The metals method detected tin in the method blank and sodium was detected in the distilled water and equipment blanks.

Site 528 had carbon tetrachloride in the equipment blank, acetone was detected in the method blank and trip blanks, and methylene chloride was detected in equipment and method blanks for the volatile method.

Site 530 had acetone in the trip blank and methylene chloride was detected in the method and trip blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected beryllium, calcium, cobalt, copper, magnesium, manganese, mercury, and nickel in the equipment blank. Antimony, barium, iron, and sodium were detected in the equipment and method blanks.

Site 531 had acetone and chloroform in the distilled water, equipment, and trip blanks and methylene chloride was detected in the distilled water, equipment, method, and trip blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected arsenic, barium, beryllium, cadmium, lead, magnesium and manganese in the equipment blank. Calcium, nickel, potassium, and sodium were detected in the distilled water and equipment blanks and cobalt, copper, tin, vanadium, and zinc were detected in the equipment and method blanks. Aluminum and iron were detected in the distilled water, equipment, and method blanks.

Site 538 had methylene chloride in the method blank for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected sodium in the method blank.

**Site 539** had acetone in the trip blank and methylene chloride in the method blank for the volatile method. The metals method detected potassium and sodium in the method blank. 1  
2

**Site 540** had acetone in the distilled water blank and methylene chloride in the distilled water, equipment, and method blanks for the volatile method. The semivolatile method detected acenaphthene in the distilled water blank. The metals method detected potassium and sodium in the method blank. 3  
4  
5  
6

**Site 542** had acetone and methylene chloride in the method blank for the volatile method. The metals method detected potassium and sodium in the method blank. 7  
8

**Site 543** had acetone and methylene chloride in the distilled water, equipment, method and trip blanks for the volatile method. The semivolatile method detected acenaphthene in the distilled water blank and BEHP in the distilled water and method blanks. The metals method detected chromium, potassium, and sodium in the method blank. 9  
10  
11  
12

**Site 544** had acetone and methylene chloride in the method and trip blanks for the volatile method. The semivolatile method detected BEHP in the equipment and method blanks. The metals method detected potassium and sodium in the method blank. 13  
14  
15

**Site 548** had acetone in the distilled water blank and chloroform and methylene chloride were in the distilled water, equipment, and method blanks for the volatile method. The semivolatile method detected BEHP in the distilled water and method blanks. The metals method detected potassium in the method blank. 16  
17  
18  
19

**Site 549** had acetone in the distilled water blank and methylene chloride in the distilled water, equipment, and method blanks for the volatile method. The semivolatile method detected BEHP 20  
21

in the equipment and method blanks. The metals method detected beryllium, calcium, magnesium, 1  
manganese, potassium, silver, sodium, and thallium in the equipment blank. Antimony, barium, 2  
and iron were detected in the equipment and method blank for the metals method. 3

Site 550 had acetone and methylene chloride in the trip blank for the volatile method. The 4  
semivolatile method detected BEHP in the method blank. The metals method detected antimony, 5  
beryllium, potassium, sodium, and tin in the method blank. 6

Site 551 had acetone and methylene chloride in the equipment, method, and trip blanks for the 7  
volatile method. The semivolatile method detected BEHP in the method blank. The metals 8  
method detected sodium and tin in the method blank. 9

Site 552 had methylene chloride in the method blank for the volatile method. The semivolatile 10  
method detected BEHP in the equipment and method blanks. 11

Site 554 had acetone and methylene chloride in the method blank for the volatile method. The 12  
semivolatile method detected BEHP in the distilled water blank. 13

Site 559 had acetone in the equipment, method, and trip blanks and methylene chloride was 14  
detected in the distilled water, equipment, method, and trip blanks for the volatile method. The 15  
semivolatile method detected BEHP in the method blank. The metals method detected tin in the 16  
method blank and lead and magnesium in the distilled water blank. Barium, manganese, and zinc 17  
were detected in the distilled water and equipment blanks and potassium and sodium were detected 18  
in the distilled water, equipment, and method blanks for the metals method. 19

**Site 560** had acetone in the method blank and methylene chloride in the method and trip blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected potassium, sodium, and tin in the method blank.

**Site 561** had acetone and methylene chloride in the method and trip blanks for the volatile method. The metals method detected potassium, sodium, and tin in the method blank.

**Site 562** had methylene chloride in the equipment, method, and trip blanks for the volatile method.

**Site 563** had acetone and methylene chloride in the trip blank for the volatile method. The metals method detected potassium, sodium, and tin in the method blank.

**Site 564** had BEHP in the distilled water blank for the semivolatile method.

**Site 566** had acetone and chloroform in the trip blank and methylene chloride was detected in the method and trip blanks for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected copper, nickel, and potassium in the method blank.

**Site 567** had potassium in the method blank for the metals method.

**Site 569** had methylene chloride in the method blank and acetone in the trip and method blanks for the volatile method. The metals method detected antimony, beryllium, and nickel in the method blank.

**Site 570** had acetone in the equipment and method blanks and methylene chloride in the equipment, method, and trip blanks for the volatile method. The semivolatile method detected BEHP in the equipment and method blanks. The metals method detected tin in the method blank.

and beryllium, calcium, cobalt, copper, magnesium, manganese, mercury, nickel, and thallium 1  
in the equipment blank. Antimony, barium, iron, and potassium were detected in the equipment 2  
and method blanks and sodium was detected in the distilled water, equipment, and method blanks. 3

**Site 572** had chloroform and methylene chloride in the distilled water, equipment, and method 4  
blanks for the volatile method. The semivolatile method detected BEHP in the equipment and 5  
distilled water blanks. The metals method detected potassium in the equipment and method blanks 6  
and sodium in the distilled water and method blanks. 7

**Site 573** had acetone and chloroform in the distilled water, equipment, and trip blanks and 8  
methylene chloride in the distilled water, equipment, and method blanks for the volatile method. 9  
The semivolatile method detected BEHP in the equipment, distilled water, and method blanks. 10  
The metals method detected tin in the method blank, sodium in the distilled water and method 11  
blanks, and potassium in the distilled water, equipment, and method blanks. 12

**Site 574** had methylene chloride in the method and trip blanks for the volatile method. BEHP was 13  
detected in the equipment and method blanks for the semivolatile method. The metals method 14  
detected potassium, silver, sodium, and tin in the method blank. 15

**Site 576** had chloroform in the method blank for the volatile method. BEHP was detected in the 16  
equipment blank for the semivolatile method. Potassium was detected in the equipment blank for 17  
the metals method. 18

**Site 578** had acetone in the equipment blank and methylene chloride in the method blank for the 19  
volatile method. The semivolatile method detected butylbenzylphthalate in the method blank. 20

**Site 579** had BEHP in the method blank for the semivolatile method. Potassium and tin were detected in the method blank for the metals method. 1  
2

**Site 580** had methylene chloride in the method blank and chloroform in the equipment and method blanks for the volatile method. The semivolatile method detected BEHP in the distilled water, equipment, and method blanks. The metals method had tin and zinc in the method blank and copper in the distilled water and equipment blanks. 3  
4  
5  
6

**Site 583** had chloroform in the equipment and method blanks for the volatile method. The metals method detected sodium and tin in the method blank. 7  
8

**Site 586** had methylene chloride in the distilled water, equipment, and trip blanks and acetone in the distilled water, equipment, method, and trip blanks for the volatile method. 9  
10

**Site 590** had methylene chloride in the distilled water and trip blanks and chloroform in the distilled water, equipment, and trip blanks for the volatile method. The metals method detected tin in the equipment blank. 11  
12  
13

**Site 596** had methylene chloride in the distilled water, equipment, and trip blanks and acetone in the distilled water, equipment, trip, and method blanks for the volatile method. The semivolatile method detected BEHP in the distilled water, equipment, and method blanks. The metals method detected potassium, sodium, thallium, and tin in the method blank. 14  
15  
16  
17

**Site 597** had potassium, sodium, thallium, and tin in the method blank for the metals method. 18

**Site 598** had acetone and methylene chloride in the method blank for the volatile method. The semivolatile method detected BEHP in the distilled water, equipment, and method blanks. The metals method detected tin in the method blank.

**Site 599** had acetone and methylene chloride in the method blank and chloroform in the trip blank for the volatile method. The semivolatile method detected BEHP in the method blank. The metals method detected tin in the method blank.

**Site 602** had chloroform in the distilled water, equipment, and method blanks for the volatile method.

**Site 603** had methylene chloride in the trip blank and chloroform in the method and trip blanks for the volatile method.

**Site 604** had chloroform in the method and trip blanks for the volatile method.

**Site 605** had methylene chloride in the trip blank and chloroform was detected in the method and trip blanks for the volatile method. The semivolatile method detected acenaphthene in the method blank and BEHP in the distilled water, equipment, and method blanks. The metals method detected sodium and tin in the method blank.

**Grid samples** had acetone, chloroform, and methylene chloride in the equipment, method, and trip blanks for the volatile method. The semivolatile method detected benzo(a)anthracene and phenanthrene in the method blank and BEHP in the equipment and method blanks. The metals method detected antimony, arsenic, barium, beryllium, cadmium, calcium, copper, lead, magnesium, manganese, silver, and zinc in the equipment blank and tin in the method blank. Aluminum, cobalt, iron, nickel, potassium, sodium, thallium, and vanadium were detected in the equipment and method blanks.

## **5.0 DATA EVALUATION AND BACKGROUND COMPARISON**

This section describes the approach and technical methods used to determine types (nature) and areal extent of all chemicals present in site samples (CPSS) in soil and groundwater at Zone E AOCs and SWMUs. Nature and extent were evaluated to determine the overall distribution of constituents detected on micro (site-specific), and macro (zone-wide) scales. In addition, these data will be used to assess basewide conditions and the relationship of contaminants between zones across NAVBASE.

Types of compounds detected at Zone E include: VOCs, SVOCs, pesticides, herbicides, PCBs, organotins, dioxins, and inorganics. Concentrations of detected compounds were compared to corresponding listed values in the USEPA Region III *Risk-Based Concentration Table*, June 1996, to evaluate the significance of detected compounds, to determine where any additional sampling should be conducted to define the extent of contamination, and to develop investigative endpoints. Detected inorganic chemical concentrations were also compared to corresponding background reference concentrations. The comparisons pertain only to the protection of human health and do not address protection of ecological receptors. Risk to the ecosystem from the contaminants onsite is assessed in Section 8.

Site-specific nature and extent evaluations for AOCs and SWMUs in Zone E are detailed in Section 10 of this report.

### **5.1 Organic Compound Analytical Results Evaluation**

Organic compound concentrations in Zone E soil and groundwater samples were compared to RBCs. Each compound's frequency of detection and its average and range of detected concentrations were also compiled (see Section 10).

For screening purposes, concentrations of dioxin congeners and carcinogenic polynuclear aromatic hydrocarbons (cPAHs) were converted to 2,3,7,8-TCDD equivalency quotients (TEQs) and benzo(a)pyrene equivalents (BEQs), respectively, in accordance with recent EPA guidance. Section 5.1 of the Zone A RFI Report details the guidance and procedures followed during the Zone E RFI.

## **5.2 Inorganic Analytical Results Evaluation**

Sample analytical results for inorganics are often difficult to evaluate because inorganics are naturally occurring and ubiquitous in soil, and frequently present in groundwater as well. Compounding this difficulty is the fact that much of the soil at NAVBASE is dredge-fill material that has been placed onsite. The following describes the step-by-step procedures used to determine background for inorganics in soil and groundwater at Zone E and the statistical approach for comparing background data to site data.

Many chemicals, particularly carcinogenic metals such as arsenic and beryllium, are typically detected at concentrations that are much higher than their corresponding risk-based screening levels. It is usually necessary to supplement site-specific sampling efforts with an attempt to determine the non-site-related concentrations of these chemicals. The problem is how to determine these reference (or background) concentrations, and how much higher than background a parameter must be at a site before it is of concern. USEPA Region IV guidance on this subject recommends using twice the mean concentration of the background samples as an upper bound and considers any site-related sample higher than this upper bound to be contaminated. Although this method is appropriate with small datasets, it would be less appropriate to use with the large background datasets developed for soil and groundwater at Zone E. The larger datasets allowed the use of more sophisticated statistical tests. E/A&H used a dual testing procedure to compare AOC/SWMU inorganic constituent concentrations to those of the background datasets. Parametric or nonparametric upper tolerance limits (UTLs) were calculated and used as reference

concentrations in combination with Wilcoxon rank sum tests to make the comparisons. Background values for surface soil, subsurface soil, shallow groundwater, and deep groundwater were calculated in accordance with established procedures for NAVBASE.

### **5.2.1 Background Datasets**

The background dataset for Zone E soil collected from the upper interval consisted of 25 samples (GDESB00101 to GDESB02501). The lower-interval soil dataset was composed of 24 samples (GDESB00102 to GDESB02102 and GDESB02302 to GDESB02502). The background dataset for shallow groundwater consisted of samples from four sampling rounds in each of 25 wells (NBCEGDE001 to NBCEGDE025) for a total of 100 samples, as did the background dataset for deep groundwater (NBCEGDE01D to NBCEGDE25D).

Descriptive statistics were compiled for the original data values, including frequency distribution histograms and normal probability plots. Results were examined and, where appropriate (i.e., histogram positively skewed; normal probability plot concave upward; high skewness and kurtosis), data were transformed into natural logarithms (LN) or square roots of their original values to more closely approximate normal distributions. Descriptive statistics of the transformed data were compared to those of the originals to determine the most suitable data format. All datasets that could be treated as normally distributed required transformation before parametric analysis. Where normal distributions could not be approximated, nonparametric methods were used to evaluate the datasets.

It has been suggested that lognormal data indicate the presence of contamination in the samples at the high end of the range. However, "EPA's experience with environmental concentration data ... suggests that a lognormal distribution is generally more appropriate as a default statistical model than the normal distribution, a conclusion shared by researchers at the United States Geological Survey" (USEPA, 1992b).

Most of the background datasets examined were more nearly lognormal than normal. It is more reasonable to assume that lognormal background distributions of chemical concentrations are the norm for NAVBASE than to assume that the datasets document a background that is contaminated in comparable fashion by numerous chemicals at different depths in both soil and groundwater. Nevertheless, a few potential data outliers did appear at the high end of some datasets, and it was important to eliminate them to preserve the integrity and utility of the background data. Normally, outliers should be removed from a dataset only in unusual circumstances and for specific reasons. In lognormal or square-root distributions, even apparently extreme values may fit a straight line on a normal probability plot of transformed data. Statistical rules of thumb for outlier removal generally are based on the variance of the sample, and include methods such as the "rule of the huge error" (Taylor, 1990), in which all values greater than four standard deviations above the mean are discarded, as well as Rosner's test, Dixon's test, the Shapiro-Wilk test, and others (Gibbons, 1994).

Because of concerns about inadvertently including contaminated samples in the background datasets, outliers were eliminated more readily than many standard statistical guidelines would suggest. After consultation with the project team, outliers were removed on a chemical-by-chemical basis, descriptive statistics were recalculated for each chemical's dataset, and the resulting modified datasets were used for all further comparisons to background.

### **5.2.2 Nondetect Data**

Following guidelines presented in various USEPA documents, one-half of the sample quantitation limit (SQL) was used to represent nondetect values in the datasets. In practice, this meant using one-half of the *U* values reported by the analytical laboratory and confirmed by the validator. Analytical results qualified *R* or *UR* were considered unusable and were not included in the datasets.

### **5.2.3 Developing Datasets for Sites**

Results of laboratory analyses of soil and groundwater samples from the AOCs and SWMUs were assembled into datasets for each chemical of interest from upper and lower interval soils and from shallow and deep groundwater. These results were then compared to background.

### **5.2.4 Comparing Site Values to Background**

Section 5.2.4 of the Zone A RFI Report discusses statistical hypothesis testing for comparing site concentrations to background. It presents EPA's suggested "two times background" approach and compares it to more powerful statistical approaches that can be used in its place. It also recommends a dual testing strategy to detect different types of site contamination, involving a tolerance-interval test and the Wilcoxon rank sum test.

### **5.2.5 Tolerance Interval or Reference Concentration Test**

Individual data values from a site can be compared to a high percentile (95th, 98th, 99th) of background values. This operation can be done parametrically by comparing the values to a specified percentile of the distribution of background values, obtained either from a normal probability chart of original or transformed values or by using standard methods of estimating quantiles (e.g., Gilbert, 1987). It can also be done nonparametrically by comparing values to a percentile of the background data values themselves, rather than to an assumed distribution of the values.

Rather than comparing site values to specific percentiles of the background data, they can be compared to estimated tolerance intervals that enclose a specified percentage of the background population. A one-sided tolerance interval with 95% coverage and 95% confidence signifies that approximately 95% of individual population values fall below the upper limit of the interval, with 95% confidence. Once the interval is constructed, each site sample is compared to the upper tolerance limit (UTL), or reference concentration (RC), (USEPA, 1992b). Any value that exceeds the limit is considered evidence of contamination at that point.

A roughly lognormal distribution of background values allows the use of parametric tolerance intervals, using LN-transformed values, when the nondetect percentage is low. Individual sample values are compared to a UTL or reference concentration that is calculated using the expression:

$$\exp[X + k (s)]$$

where:

- X = mean of LN-transformed background values
- s = standard deviation of LN-transformed values
- k = tolerance factor

When a square-root data transformation is used, the comparable expression is:

$$[X + k (s)]^2$$

For original (untransformed) data values, the expression reduces to:

$$X + k (s)$$

The tolerance factor, k, is obtained from tables with specified levels of  $\alpha$  and  $P_0$ , where  $(1 - P_0)$  equals the proportion of the population within the tolerance intervals (the coverage). For a given set of  $\alpha$  and  $P_0$ , k depends on the sample size, n. For  $n = 25$  (the background sample size for upper interval soil in Zone E),  $k = 2.292$  when  $\alpha = 0.05$  and  $P_0 = 0.05$  (confidence = 95%, coverage = 95%). Based on these numbers, the UTL for original (untransformed) background concentration values of a given element is therefore:

$$\text{UTL} = \text{mean} + 2.292 (\text{standard deviation})$$

According to a USEPA statistical training course manual (USEPA, 1992c): "Tolerance intervals can be computed with as few as three data values; however, to have a valid estimate of the standard deviation, one should probably have at least 8 to 10 samples." Outliers were first identified and removed from the datasets, as explained in Section 5.2.1. A UTL or RC was then calculated for the revised dataset of each chemical in upper and lower interval soil and shallow and deep groundwater. The calculated UTL was then used for background comparisons.

Where a significant proportion of the samples were nondetect (> 50%), or where transformed values could not be made to approximate a normal distribution, means and standard deviations could not be computed accurately, and it was necessary to employ nonparametric tolerance intervals. In these cases, the UTLs or reference concentrations were taken directly from the sample sets, rather than from calculations based on the presumed data distributions. In practice, this meant using the largest observed background value (when n = 24 or 25) or the second-largest value (when n = 100) as the standards of comparison (USEPA, 1992b). As with the parametric calculations, the method was applied after removal of outliers from the datasets.

The following decision rule was applied to the background datasets for soil:

- Where NDs  $\leq 50\%$ , use the parametric UTL (where justified by data distribution).
- Where  $50\% < \text{NDs} < 90\%$ , use highest or second highest value in the dataset as the nonparametric UTL .
- Where NDs  $\geq 90\%$ , no valid background value can be determined.

The power of a tolerance-limit test is based on several factors, such as the number of samples that are assumed to have come from the distribution with the larger mean, the magnitude of the shift in the mean, and the distribution of the background sample values. It also depends on the sample size at each site and the sample size of the background.

### **5.2.6 Wilcoxon Rank Sum Test**

When values for most of a site's samples are higher than the mean background value, but none is dramatically higher, the site samples, as a group, must be significantly higher than the background samples, as a group, to be considered contaminated.

The most common method for comparing two populations is the Student's *t*-test, which determines whether the two population means differ significantly. However, the *t*-test was not used in this report to compare site values to background because it is parametric. Instead, a nonparametric counterpart to the *t*-test, the Wilcoxon rank sum test, also known as the Mann-Whitney U test, was used. Since it is nonparametric, the two datasets that are compared need not be drawn from normal or even symmetric distributions. The test can also accommodate a moderate number of nondetect values by treating them as ties (Gilbert, 1987). To use this test, each dataset representing site samples and background samples should contain at least four data values. Section 5.2.6 of the Zone A RFI Report further describes the Wilcoxon rank sum test and justifies its use.

### **5.2.7 Summary of Statistical Techniques Used**

Techniques that allow the use of statistical inference were chosen. Methods used are capable of detecting situations where: (a) individual site values are much higher than background, or (b) site values are generally higher than background. For situation a, all data values were transformed where appropriate to approximate normal distributions, then site values were compared to a parametric UTL consisting of mean plus *k* standard deviations of the background data values, where *k* depends on sample size. Where the percentage of nondetects is high or an approximately normal distribution could not be achieved, nonparametric UTLs were used; above 90% nondetects, no reliable tolerance limits can be determined. For situation b, the Wilcoxon rank sum test was applied to compare each group of site values to background.

### **5.2.8 Combined Results of the UTL (RC) and the Wilcoxon Rank Sum Tests**

Methods described in Section 5.2.5 identify individual site samples with concentrations significantly higher than background, while the method in Section 5.2.6 identifies entire sites. If the results from either test were positive (i.e., significantly higher than background), sample values were compared to the corresponding USEPA RBCs for soil and tap water and, where appropriate, carried forward into detailed human health risk assessment. Where background comparisons could not be carried out for a chemical due to lack of detections in background samples, site concentrations were screened against risk-based concentrations only.

### **5.2.9 Conclusion**

The overall approach documented here is conservative for the following reasons. One, the number of background samples for soil exceeds the minimum recommended in various guidance documents (USEPA RAGS, 1989a), producing greater confidence in the ability to characterize background and to distinguish background concentrations from those at sites. Two, following procedures described in Section 5.2.1, high values were removed from the background datasets whether they were true outliers or not in the conventional sense, thereby lowering the total background concentrations to which the site values were compared. Three, the use of two complementary tests increased the likelihood that any contamination would be identified and addressed further, since a positive result from either test triggered a detailed human health risk assessment whenever site concentrations exceeded corresponding USEPA RBC values.

### **5.2.10 Background Values**

Tables 5.1 through 5.4 summarize the steps taken to calculate UTL or RCs for Zone E surface soil, subsurface soil, shallow groundwater, and deep groundwater, respectively. UTLs were calculated for 19 inorganics in surface soil, 17 in subsurface soil, 14 in shallow groundwater, and 13 in deep groundwater. Table 5.5 presents the results of the calculations. In all of the background calculations, nondetect (ND) values were treated as discussed above in Section 5.2.2.

**Table 5.1**  
**Charleston Zone E Surface Soil (Upper Interval)**  
**Characteristics of Background Datasets**

<b>Chemical</b>	<b>n</b>	<b>Mean mg/kg</b>	<b>Data Transformation</b>	<b>Type of UTL</b>	<b>UTL mg/kg</b>
Aluminum	25	7,356	ln	parametric	26,600
Antimony	24	0.78	none	nonparametric	1.77
Arsenic	24	10.3	none	nonparametric	23.9
Barium	24	29.7	ln	parametric	130
Beryllium	25	0.49	sqrt	parametric	1.70
Cadmium	25	0.38	none	nonparametric	1.5
Chromium	23	17.6	ln	parametric	94.6
Cobalt	25	8.9	ln	parametric	19.0
Copper	19	18.4	sqrt	parametric	66.0
Lead	24	70.3	none	nonparametric	265
Manganese	24	106	none	nonparametric	302
Mercury	24	0.20	ln	parametric	2.60
Nickel	25	12.7	ln	parametric	77.1
Selenium	25	0.56	none	nonparametric	1.7
Silver	25		no UTL calculated (NDs > 90%)		
Thallium	25	0.49	none	nonparametric	2.8
Tin	25	8.1	ln	parametric	59.4
Vanadium	25	17.3	ln	parametric	94.3
Zinc	22	93.7	ln	parametric	827
Cyanide	25	0.15	none	nonparametric	0.5

**Notes:**

- n = number of samples
- mg/kg = milligrams per kilogram
- ln = natural logarithm
- sqrt = square root

**Table 5.2**  
**Charleston Zone E Subsurface Soil (Lower Interval)**  
**Characteristics of Background Datasets**

Chemical	n	Mean mg/kg	Data Transformation	Type of UTL	UTL mg/kg
Aluminum	24	8534	ln	parametric	41,100
Antimony	24	0.75	none	nonparametric	1.6
Arsenic	20	5.9	sqrt	parametric	19.9
Barium	24	26.3	ln	parametric	94.1
Beryllium	24	0.55	ln	parametric	2.71
Cadmium	24	0.31	none	nonparametric	0.96
Chromium	24	22.4	none	nonparametric	75.2
Cobalt	24	3.7	none	nonparametric	14.9
Copper	22	16.5	ln	parametric	152
Lead	23	39.6	none	nonparametric	173
Manganese	24	115	ln	parametric	881
Mercury	24	0.15	ln	parametric	1.59
Nickel	24	8.0	ln	parametric	57.0
Selenium	24	0.29	none	nonparametric	2.4
Silver	24		not detected		
Thallium	24		not detected		
Tin	22	3.6	sqrt	parametric	9.23
Vanadium	24	22.0	ln	parametric	155
Zinc	24	95.5	ln	parametric	886
Cyanide	24		no UTL calculated (NDs > 90%)		

**Notes:**

- n = number of samples
- mg/kg = milligrams per kilogram
- ln = natural logarithm
- sqrt = square root

**Table 5.3**  
**Charleston Zone E Shallow Groundwater**  
**Characteristics of Background Datasets**

<b>Chemical</b>	<b>n</b>	<b>Mean mg/kg</b>	<b>Data Transformation</b>	<b>Type of UTL</b>	<b>UTL mg/kg</b>
Aluminum	99	418	ln	parametric	2,810
Antimony	100		no UTL calculated (NDs > 90%)		
Arsenic	84	5.2	none	nonparametric	18.7
Barium	100	51.3	ln	parametric	211
Beryllium	100	0.31	none	nonparametric	0.43
Cadmium	100		no UTL calculated (NDs > 90%)		
Chromium	100	1.6	none	nonparametric	12.3
Cobalt	96	0.90	none	nonparametric	2.5
Copper	100	1.4	none	nonparametric	2.7
Lead	96	1.4	none	nonparametric	4.8
Manganese	100	455	none	nonparametric	2,560
Mercury	100		no UTL calculated (NDs > 90%)		
Nickel	100	2.3	none	nonparametric	15.2
Selenium	100		no UTL calculated (NDs > 90%)		
Silver	100		no UTL calculated (NDs > 90%)		
Thallium	100	2.3	none	nonparametric	5.4
Tin	100		no UTL calculated (NDs > 90%)		
Vanadium	100	2.8	ln	parametric	11.4
Zinc	97	7.5	none	nonparametric	27.3
Cyanide	100	1.8	none	nonparametric	7.9

**Notes:**

- n = number of samples
- mg/kg = milligrams per kilogram
- ln = natural logarithm
- sqrt = square root

**Table 5.4  
 Charleston Zone E Deep Groundwater  
 Characteristics of Background Datasets**

<b>Chemical</b>	<b>n</b>	<b>Mean mg/kg</b>	<b>Data Transformation</b>	<b>Type of UTL</b>	<b>UTL mg/kg</b>
Aluminum	100	27.2	none	nonparametric	319
Antimony	100		no UTL calculated (NDs > 90%)		
Arsenic	100	9.7	none	nonparametric	16.4
Barium	100	86.7	sqrt	parametric	218
Beryllium	100	0.44	none	nonparametric	1.2
Cadmium	100		no UTL calculated (NDs > 90%)		
Chromium	100	1.5	none	nonparametric	15.5
Cobalt	100	1.9	none	nonparametric	12.9
Copper	100		no UTL calculated (NDs > 90%)		
Lead	100		no UTL calculated (NDs > 90%)		
Manganese	100	302	sqrt	parametric	869
Mercury	100	0.08	none	nonparametric	0.2
Nickel	100	4.4	none	nonparametric	42.2
Selenium	100		no UTL calculated (NDs > 90%)		
Silver	100		no UTL calculated (NDs > 90%)		
Thallium	100	2.4	none	nonparametric	6.5
Tin	100		no UTL calculated (NDs > 90%)		
Vanadium	100	1.5	none	nonparametric	5.3
Zinc	100	4.1	none	nonparametric	11.8
Cyanide	100	5.5	none	nonparametric	37.3

**Notes:**

- n = number of samples
- mg/kg = milligrams per kilogram
- ln = natural logarithm
- sqrt = square root

**Table 5.5  
 Charleston Zone E  
 Background Reference Values (UTLs) for Soil and Groundwater**

<b>Inorganic chemical</b>	<b>Surface soil [mg/kg] (n = 25)</b>	<b>Subsurface soil [mg/kg] (n = 24)</b>	<b>Shallow GW [µg/L] (n = 100)</b>	<b>Deep GW [µg/L] (n = 100)</b>
Aluminum	26,600 P	41,100 P	2,810 P	319 N
Antimony	1.77 N	1.6 N	X	X
Arsenic	23.9 N	19.9 P	18.7 N	16.4 N
Barium	130 P	94.1 P	211 P	218 P
Beryllium	1.70 P	2.71 P	0.43 N	1.2 N
Cadmium	1.5 N	0.96 N	X	X
Chromium	94.6 P	75.2 N	12.3 N	15.5 N
Cobalt	19.0 P	14.9 N	2.5 N	12.9 N
Copper	66.0 P	152 P	2.7 N	X
Lead	265 N	173 N	4.8 N	X
Manganese	302 N	881 P	2,560 N	869 P
Mercury	2.60 P	1.59 P	X	0.2 N
Nickel	77.1 P	57.0 P	15.2 N	42.2 N
Selenium	1.7 N	2.4 N	X	X
Silver	X	ND	X	X
Thallium	2.8 N	ND	5.4 N	6.5 N
Tin	59.4 P	9.23 P	X	X
Vanadium	94.3 P	155 P	11.4 P	5.3 N
Zinc	827 P	886 P	27.3 N	11.8 N
Cyanide	0.5 N	X	7.9 N	37.3 N

**Notes:**

P = Parametric UTL

N = Nonparametric UTL

X = No UTL calculated (NDs > 90%)

ND = Not detected

## **6.0 FATE AND TRANSPORT**

Fate and transport assessment evaluates the ability of chemical constituents to become mobile or change in the environment, based on their chemical and physical properties and on processes that govern the interaction of the constituents with environmental media. Macroscopic physical characteristics of the site such as climate, hydrology, topography, and geology determine weathering and erosional transport processes. Microscopic characteristics of site soil, sediment, and water, as well as the chemical and physical properties of the constituents, govern the processes of infiltration, advection, diffusion, dispersion, erosion, and volatilization that move constituents between media or place to place within a medium. A discussion of fate and transport will help to identify potential receptors that may be impacted by constituent movement in the environment.

The AOCs and SWMUs at Zone E are located on flat, low-lying land, almost entirely covered with buildings and pavement. Precipitation falling on impervious surfaces drains into storm sewers, where it is transported to outfalls on the Cooper River. The small amount of rainwater that infiltrates the soil percolates into the unconfined surficial zone aquifer, the uppermost unit of the regional Wando Formation. Groundwater moves generally northeastward, eastward, and southeastward toward the river, as described in Section 2.3.2 and illustrated in Figures 2-6A and 2-6B. Groundwater in the northwestern portion of Zone E flows generally westward toward two water-level depressions described in Section 2.3.2.1 and referred to as anomalies E and F. After evaluating Zone E for the characteristics discussed in the previous paragraph, four potential routes of constituent migration have been identified for further investigation:

- Leaching of constituents from soil to groundwater
- Migration of constituents from groundwater into surface water bodies
- Surface soil erosion and runoff of constituents into catch basins and surface water bodies
- Air emissions resulting from VOCs released from surface soil

Discussion of surface water contaminant transport is deferred to the RFI report for Zone J. 1

**Definitions:** 2

*Infiltration* is the movement of water into and through the soil under the influence of gravity and capillary attraction. 3  
4

*Advection* is the process by which dissolved substances migrate with moving groundwater. 5  
Hydraulic conductivity, effective porosity, and hydraulic gradient are some of the aquifer 6  
characteristics that determine a chemical's rate of movement by advection. This process is 7  
generally the most important transport mechanism for compounds associated with groundwater. 8

*Diffusion* is the random process by which solutes are transported from regions of high 9  
concentration to regions of low concentration as a result of the concentration gradient. In very 10  
fine sediments with very low hydraulic conductivities, diffusive transport may be the dominant 11  
mode of migration. 12

*Dispersion* is the hydrodynamic process by which solutes are mixed with uncontaminated water, 13  
diluted, and transported preferentially due to heterogeneous properties of the aquifer. 14  
Longitudinal dispersion can cause an increase in contaminant concentration ahead of the advective 15  
front. 16

*Erosion* is the process by which particles are suspended and subsequently moved by the physical 17  
action of water and/or wind. Compounds adsorbed to particulate material are thereby moved 18  
along with the particulate. 19

*Volatilization* is the evaporation of contaminants dissolved in water or present as nonaqueous phase 20  
liquids, into soil gas in the vadose zone and/or into the atmosphere. Volatilization of solutes is 21  
controlled by their vapor pressures and Henry's law constants. 22

**6.1 Properties Affecting Fate and Transport**

Numerous chemical and physical properties of both the constituent and the surrounding media are used to evaluate fate and transport mechanisms.

**6.1.1 Contaminant Properties Affecting Fate and Transport**

Chemical and physical properties of constituents used to evaluate fate and transport include vapor pressure, density, solubility, half-life, Henry's law constant, organic carbon/water partitioning coefficient, and molecular weight. Table 6.1.1 provides an overview of chemical properties and expected behavior in environmental media based on these properties.

**Table 6.1.1  
 Constituent Characteristics Based On  
 Chemical and Physical Properties**

Property	Critical Value	High (>)	Low (<)
Vapor Pressure (VP)	10 <sup>-3</sup> mm Hg	volatile	nonvolatile
Density* (D)	1.0 g/cm <sup>3</sup>	sinks/falls	floats/rises
Solubility* (S)	0 to 100 mg/L	leaches from soil; mobile in water; does not readily volatilize from water	sorbs to soil; immobile in water; volatilizes from water
Henry's Law Constant (HL)	5x10 <sup>-6</sup> to 5x10 <sup>-3</sup> atm-m <sup>3</sup> /mole	resistance to mass transfer in the aqueous phase	resistance to mass transfer in the gas phase
Half-life (T <sub>1/2</sub> )	biologically dependent	does not degrade readily	degrades readily
Organic Carbon/Water Partitioning Coefficient* (K <sub>oc</sub> )	10 to 10000 kg <sub>oc</sub> /L <sub>water</sub>	tends to sorb to organic material in soil; immobile in the soil matrix	tends not to sorb to organic material in soil; mobile in the soil matrix
Molecular Weight (MW)	400 g/mole	characteristics listed above may not hold true; more detailed evaluation necessary	all of the above generally hold true

*Note:*

\* = Determinations of the Critical Values were based on literature review and professional judgment.

Compounds with similar chemical and physical properties display similar fate and transport behavior. These relationships facilitate the general grouping of contaminants into categories based on chemical and physical properties. Section 6.1.1 of the Zone A RFI Report details characteristics affecting fate and transport for the following groups of chemicals:

- VOCs
- SVOCs
- Pesticides/PCBs
- Chlorinated herbicides
- Chlorinated dibenzodioxins/dibenzofurans
- Inorganics

### 6.1.2 Media Properties Affecting Fate and Transport

The properties of environmental media used to evaluate fate and transport include TOC, normalized partitioning coefficient, CEC, redox conditions, pH, soil type, and retardation rate. The following briefly discusses these properties.

#### Total Organic Carbon

TOC indicates the soil's sorptive capabilities. The higher the TOC, the higher the potential for a given chemical to sorb to soil particles, particularly for organic compounds. TOC may also be expressed in unitless form as  $f_{oc}$ , or fraction organic carbon content of the soil (e.g., grams of solid organic carbon per gram of dry soil).

#### Normalized Partitioning Coefficient ( $K_d$ )

$K_d$  is used to predict the capacity for a constituent to partition between soil and water; it is a function of both the constituent and the soil. To estimate  $K_d$ , the constituent's organic

carbon/water partitioning coefficient ( $K_{oc}$ ) is adjusted by the soil's TOC:  $K_d = K_{oc} f_{oc}$ . 1  
Soil/constituent combinations with higher  $K_d$ s have a higher potential to sorb. 2

### Cation Exchange Capacity 3

CEC reflects the soil's capacity to adsorb ions, neutralizing ionic deficiencies on the surfaces of 4  
its particles. Generally, trivalent ions are preferentially adsorbed to soil over divalent ions, and 5  
divalent ions are preferentially adsorbed over monovalent ions. The process also depends on soil 6  
pH. Soils with high CEC values have the potential to adsorb inorganic ions and organic 7  
compounds with dipole moments. 8

### Redox Conditions 9

Redox is the process which includes oxidation (the loss of electrons), and reduction (the gain of 10  
electrons). The resultant change in oxidation state generates products that are different from the 11  
reactants in their solubilities, toxicities, reactivities, and mobilities. Extreme redox conditions 12  
tend to mobilize chemicals, especially transition metals. 13

### pH 14

The pH value is a negative inverse logarithmic measure of hydrogen ion concentration in the soil 15  
or groundwater, indicating the acidity or alkalinity of the medium. Chemicals react differently 16  
under changing pHs. Low pH conditions tend to mobilize chemicals, especially inorganics, while 17  
high pH conditions may lead to the formation of immobile metal hydroxides. 18

### Soil Type 19

The mineralogical composition, particle size distribution, and organic content of soil affect 20  
chemical fate and transport. Soil characteristics influence or determine hydraulic conductivity, 21  
effective porosity, and hydraulic gradient which, in turn, dictate groundwater flow. 22

**Retardation Factor (R)**

The retardation factor is a measure of the ability of an aquifer matrix to inhibit the movement of a chemical by preferentially binding contaminants with high organic carbon/water partitioning coefficients. Retardation factors are calculated as follows:

$$R = 1 + \frac{K_d \rho_b}{n}$$

Where:

R = Retardation factor

$K_d$  = Soil/water partitioning coefficient (L/kg)

$D_b$  = Dry soil bulk density (kg/L)

n = Soil total porosity

Table 6.1.2 summarizes the chemical and physical parameters of Zone E soil used to evaluate fate and transport. The average value for pH in Zone E soil samples was 7.89 standard units, with a range of 4.63 to 11.3. Only 28 of 237 sample results were below 7.0. These soil conditions indicate limited mobility for inorganics by the processes of advection, diffusion, and dispersion, except in localized areas of low pH. The average total porosity of the surficial aquifer in Zone E, as determined through analysis of 41 Shelby tube and split spoon samples collected from depths ranging from 2 to 72.5 feet bgs, is 45%. Geometric mean effective hydraulic conductivities for Zone E lithologic units range from 0.07 feet per day for Upper Tertiary sands, silts, and clays (Tu) to 120 feet per day for fill sand (Fs), as presented in Section 2.3.5.5. Geometric mean hydraulic conductivity for Quaternary sand (Qs), the most common aquifer matrix, is 11 feet per day, with total porosity of 40%.

**Table 6.1.2**  
**Soil Parameters Used to Evaluate Zone E Fate and Transport**

Parameter	Number of Soil Samples	Zone E Minimum Value	Zone E Maximum Value	Zone E Geometric Mean Value	Units
pH	237	4.63	11.3	7.89	(--)
CEC	32	22.8	333	92.2	meq/100g
TOC	32	1,500	292,000	10,400	mg/kg
Total Porosity <sup>b</sup>	41	0.29	0.74	0.45	(--)

**Note:**

<sup>b</sup> = Total porosity values are based on Zone E Shelby tube and split-spoon samples collected from the surficial aquifer.

Table 6.1.3 lists the approximate time of travel for advective groundwater flow from various SWMUs/AOCs to the Cooper River or anomalies E or F, depending on direction of flow, local groundwater gradient, and local hydraulic conductivity. Elevation end points were the three Cooper River surface water elevations and the groundwater elevations in wells NBCE538001 and NBCEGDE028 that were measured and recorded on October 16, 1996, as discussed in Section 2.3.2.

## 6.2 Fate and Transport Approach for Zone E

In Section 10, fate and transport discussion for each SWMU/AOC begins with a description of site characteristics that can affect constituent migration. As presented earlier in this section, four potential routes of constituent migration have been identified for Zone E. Each SWMU and AOC has been evaluated as to site conditions that promote these migration pathways. In some cases, it is logical to evaluate fate and transport for a combination of SWMUs/AOCs based on their proximity. Discussion centers on soil, sediment, and groundwater; results for concrete, asphalt, air, and wipe samples are covered separately in Section 10.

Table 6.1.3  
Travel Time Analysis  
Advective Transport Only  
NAVBASE Charleston, Zone E  
Charleston, South Carolina

SITE	Pathline	avg. i																			Total distance	Total time (days)	Total time (years)			
			L1	d1	K1	n1	v1	i1	L2	d2	K2	n2	v2	i2	L3	d3	K3	n3	v3	i3						
18	018-001	0.0465	Fs	45	120	0.4	13.94	3.227848	Qc	40	11	0.397	1.2876	31.0656										85	34	0.09
18	018-002	0.0229	Qs	105	11	0.397	0.633	165.7926																105	166	0.45
23	023-001 --> GDE-020	0.0007	Qc	170	0.84	0.371	0.002	107932.3	Qs	60	11	0.397	0.0193	3112.84										230	111045	304.23
23	023-001	0.0033	Qc	170	0.84	0.371	0.008	22525	Qs	660	11	0.397	0.0924	7146	Qm	55	0.42	0.562	0.0025	22078.6				885	51750	141.78
25	025-003 --> DD1	0.0086	Qs	70	11	0.397	0.239	292.4032	Qc	205	0.84	0.371	0.0196	10479.4										275	10772	29.51
25	025-004 --> DD1	0.0077	Qs	235	11	0.397	0.212	1107.926	Qc	200	0.84	0.371	0.0173	11539										435	12647	34.65
53	053-001	0.0041	Qs	840	11	0.397	0.114	7393.228	Qm	55	0.42	0.562	0.0031	17947.6										895	25341	69.43
54	054-002	0.0316	Qm	70	0.42	0.562	0.024	2966.817																70	2967	8.13
63	063-001	0.0093	Qs	750	11	0.397	0.257	2920.731	Qc	230	0.84	0.371	0.021	10961.1	Qm	55	0.42	0.562	0.0069	7941.13				1035	21823	59.79
65	065-003 --> 065-005	0.0803	Qs	20	11	0.397	2.224	8.992751	Qm	30	0.42	0.562	0.06	500.119	Pt	25	0.42	0.562	0.06	416.766				75	926	2.54
65	065-005	0.0167	Pt+Qm	95	0.42	0.562	0.012	7601.266	Fu	30	4.3	0.615	0.1169	256.568	Qs	770	11	0.397	0.4634	1661.74				895	9520	26.08
65	065-008	0.0392	Pt	30	0.42	0.562	0.029	1024.052	Fc	45	0.84	0.371	0.0888	507.015										75	1531	4.19
65	065-007	0.0684	Qs	30	11	0.397	1.895	15.82935	Fc	45	0.84	0.371	0.1549	290.57										75	306	0.84
65	065-002	0.0153	Qm	110	0.42	0.562	0.011	9635.031	Fc	125	0.84	0.371	0.0346	3613.92										235	13249	36.30
65	065-001 --> GDE-022	0.0152	+Qm+Q	130	0.42	0.562	0.011	11421.12																130	11421	31.29
65	065-001	0.0079	Qm+Qmp	255	0.42	0.562	0.006	43367.76	Fc	70	0.84	0.371	0.0178	3929.46	Fc	205	0.84	0.371	0.0178	11507.7				530	58805	161.11
65	065-004 --> 065-008	0.0303	Pt+Qm	60	0.42	0.562	0.023	2646.782																60	2647	7.25
65	065-004	0.0359	Pt+Qm	90	0.42	0.562	0.027	3356.894	Fc	70	0.84	0.371	0.0812	861.789										160	4219	11.56
67	067-002	0.0147	Qs	125	11	0.397	0.407	306.8391	Fc	60	0.84	0.371	0.0333	1802.39										185	2109	5.78
67	067-001 --> 538-001	0.0037	Qs	235	11	0.397	0.102	2293.43	Fu	30	4.3	0.615	0.0259	1160.24										265	3454	9.46
70	070-002 --> "E"	0.0015	Qs	390	11	0.397	0.04	9630.574																390	9631	26.39
83	083-001 --> DD2	0.0064	Qc	340	0.84	0.371	0.014	23616.23	Qs	320	11	0.397	0.1762	1816.29										660	25433	69.68
83	083-002 --> DD5	0.0088	Qc	565	0.84	0.371	0.02	28452.81	Qs	110	11	0.397	0.243	452.66										675	28905	79.19
84	084-001 --> DD1	0.0068	Qs	250	11	0.397	0.187	1335.832	Qc	250	0.84	0.371	0.0153	16347.4	Qs	70	11	0.397	0.1871	374.033				570	18057	49.47
97	097-001 --> DD5	0.0209	Qm	120	0.42	0.562	0.016	7690.203	Qs	130	11	0.397	0.5785	224.704										250	7915	21.68
102	102-001	0.0175	Qm	30	0.42	0.562	0.013	2296.308	Qs	240	11	0.397	0.4844	495.485										270	2792	7.65
106	106-001 --> DD3	0.0162	Qs	90	11	0.397	0.449	200.2304																90	200	0.55
145	145-003 --> GDE-013	0.0058	Qc	280	0.84	0.371	0.013	21481.06	Qs	255	11	0.397	0.1595	1598.6										535	23080	63.23
145	145-002 --> 145-001	0.0003	Qc	60	0.84	0.371	0.001	79500																60	79500	217.81
145	145-003 --> DD5	0.0123	Qc	290	0.84	0.371	0.028	10440.19	Qs	120	11	0.397	0.3399	353.016										410	10793	29.57
145	145-001 --> DD5	0.0137	Qc	210	0.84	0.371	0.031	6750.791	Qs	135	11	0.397	0.3807	354.627										345	7105	19.47
172	172-001 --> DD5	0.0116	Qc	180	0.84	0.371	0.026	6829.897	Qs	70	11	0.397	0.3225	217.042										250	7047	19.31
172	172-002 --> 002E	0.0221	Qc	140	0.84	0.371	0.05	2792.473																140	2792	7.65
525	525-001	0.0085	Qs	585	11	0.397	0.236	2479.346	Qm	55	0.42	0.562	0.0064	8642.38										640	11122	30.47
526	526-001	0.0049	Qs	720	11	0.397	0.135	5327.706	Qm	55	0.42	0.562	0.0036	15089										775	20417	55.94
526	526-002	0.0041	Qc	80	0.84	0.371	0.009	8593.152	Qs	670	11	0.397	0.1139	5880.86	Qm	55	0.42	0.562	0.0031	17898.5				805	32373	88.69
528	528-001	0.003	Qs	930	11	0.397	0.084	11097.22	Qc	130	0.84	0.371	0.0068	18983.3	Fc	60	0.84	0.371	0.0068	8761.52				1120	38842	106.42
530	530-001 --> 538-001	0.0053	Qs	75	11	0.397	0.146	512.655	Fu	50	4.3	0.615	0.0369	1354.39										125	1867	5.12
539	539-001 --> "E"	0.0014	Qs	170	11	0.397	0.037	4534.901																170	4535	12.42
542	542-002 --> 538-001	0.0043	Qs	165	11	0.397	0.12	1376.694	Fu	50	4.3	0.615	0.0302	1653.23										215	3030	8.30
542	542-001 --> 538-001	0.004	Qs	200	11	0.397	0.111	1804.545	Fu	40	4.3	0.615	0.028	1430.23										240	3235	8.86
542	542-004 --> 538-001	0.0033	Qs	300	11	0.397	0.091	3286.851	Fu	40	4.3	0.615	0.023	1736.71										340	5024	13.76
542	542-003 --> 538-001	0.003	Qs	305	11	0.397	0.083	3687.054	Fu	40	4.3	0.615	0.0209	1916.23										345	5603	15.35

Table 6.1.3  
Travel Time Analysis  
Advective Transport Only  
NAVBASE Charleston, Zone E  
Charleston, South Carolina

SITE	Pathline	avg. t	L1						L2						L3						Total distance	Total time (days)	Total time (years)	
			d1	K1	n1	v1	r1	d2	K2	n2	v2	r2	d3	K3	n3	v3	r3							
543	543-001 → 067-001	0.0412	Qc	45	0.84	0.371	0.093	482.4029	Qs	130	11	0.397	1.1416	113.879								175	596	1.63
543	543-001	0.0119	Qc	45	0.84	0.371	0.027	1672.33	Qs	155	11	0.397	0.3293	470.7								260	4373	11.98
549	549-001 → "E"	0.0011	Qs	640	11	0.397	0.032	20250.46													640	20250	55.48	
549	549-003 → "E"	0.0011	Qs	555	11	0.397	0.029	18842.21													555	18842	51.62	
549	549-001 → "E"	0.0011	Qs	675	11	0.397	0.03	22525.92													675	22526	61.71	
550	550-001	0.0384	Fc	75	0.84	0.371	0.087	862.6302													75	863	2.36	
551	551-001	0.0676	Fc	55	0.84	0.371	0.153	359.151													55	359	0.98	
551	551-002	0.0217	Fs	50	120	0.4	6.508	7.683215	Fc	180	0.84	0.371	0.0491	3664.89							230	3673	10.06	
559	559-003 → DD2	0.0133	Qs	140	11	0.397	0.369	378.9545	Qc	220	0.84	0.371	0.0302	7287.5							360	7666	21.00	
559	559-002 → DD1	0.0137	Qs	140	11	0.397	0.381	367.6867	Qc	170	0.84	0.371	0.0311	5463.81							310	5831	15.98	
559	559-001 → DD1	0.0114	Qs	70	11	0.397	0.317	220.7502	Qc	290	0.84	0.371	0.0259	11191.7							360	11412	31.27	
563	563-001 → DD2	0.0137	Qc	250	0.84	0.371	0.031	8071.394													250	8071	22.11	
563	563-002 → DD2	0.0156	Qc	200	0.84	0.371	0.035	5662.393													200	5662	15.51	
563	563-003 → DD2	0.0108	Qc	320	0.84	0.371	0.024	13109.18													320	13109	35.92	
566	566-001	0.02	Qc	120	0.84	0.371	0.045	2650													120	2650	7.26	
569	569-001 → DD2	0.0094	Qs	60	11	0.397	0.261	230.1449	Qc	380	0.84	0.371	0.0213	17837.4							440	18068	49.50	
569	569-002 → DD2	0.008	Qs	290	11	0.397	0.222	1308.295	Qc	350	0.84	0.371	0.0181	19322.9							640	20631	56.52	
570	570-004 → DD2	0.0063	Qs	180	11	0.397	0.175	1031.169	Qc	770	0.84	0.371	0.0143	53981.5							950	55013	150.72	
570	570-002 → 563-003	0.0071	Qc	450	0.84	0.371	0.016	28125													450	28125	77.05	
570	570-001 → DD2	0.0087	Qs	160	11	0.397	0.241	665.0148	Qc	440	0.84	0.371	0.0197	22380							600	23045	63.14	
570	570-003 → DD2	0.0087	Qs	370	11	0.397	0.242	1526.427	Qc	380	0.84	0.371	0.0198	19184.7							750	20711	56.74	
572	572-001 → DD2	0.008	Qs	260	11	0.397	0.221	1175.702	Qc	320	0.84	0.371	0.0181	17708							580	18884	51.74	
572	572-002 → DD2	0.0096	Qs	120	11	0.397	0.266	451.564	Qc	320	0.84	0.371	0.0217	14736.2							440	15188	41.61	
573	573-001 → DD2	0.0105	Qs	60	11	0.397	0.291	206.4995	Qc	310	0.84	0.371	0.0237	13056.5							370	13263	36.34	
574	574-001 → DD5	0.0109	Qsp	70	11	0.397	0.302	231.5833	Qc	420	0.84	0.371	0.0247	17004.2							550	17434	47.77	
574	574-002 → DD5	0.0158	Pt	30	0.42	0.562	0.012	2539.157	Qc	260	0.84	0.371	0.0358	7263.55	Qs	60	11	0.397	0.3023	198.5	420	10099	27.67	
574	574-003 → DD5	0.0093	Qs	50	11	0.397	0.256	194.9827	Qc	350	0.84	0.371	0.021	16702.9	Qs	130	11	0.397	0.438	296.772	510	17327	47.47	
576	576-002 → DD5	0.0252	Qc	40	0.84	0.371	0.057	702.3445	Qs	70	11	0.397	0.697	100.436							110	803	2.20	
576	576-001 → 172-001	0.0054	Qc	170	0.84	0.371	0.012	13819.02													170	13819	37.86	
580	580-001 → DD5	0.0082	Qc	395	0.84	0.371	0.018	21383.85	Qs	110	11	0.397	0.2261	486.614							505	21870	59.92	
580	580-002 → DD2	0.0062	Qc	180	0.84	0.371	0.014	12763.76	Qs	270	11	0.397	0.1726	1564.49	Qc	250	0.84	0.371	0.0141	17727.4	700	32056	87.82	
583	583-003 → DD5	0.0203	Qm	60	0.42	0.562	0.015	3950.228	Qs	125	11	0.397	0.5631	221.969							185	4172	11.43	
583	583-002 → DD5	0.025	Qs	115	11	0.397	0.691	166.3074													115	166	0.46	
583	583-001 → DD5	0.0188	Qc	50	0.84	0.371	0.043	1172.566	Qs	130	11	0.397	0.5218	249.123							180	1422	3.90	
586	586-001	0.0118	Qm	35	0.42	0.562	0.009	3956.609	Qs	245	11	0.397	0.328	747.02	Qmp	210	0.42	0.562	0.0088	23739.7	490	28443	77.93	
590	590-001	0.0133	Qm	50	0.42	0.562	0.01	5027.913	Qs	325	11	0.397	0.3687	881.479							375	5909	16.19	
596	596-001	0.013	Qc	110	0.84	0.371	0.029	3728.984	Qs	240	11	0.397	0.361	664.833							350	4394	12.04	
596	596-002	0.0131	Qc	85	0.84	0.371	0.03	2855.518	Qs	255	11	0.397	0.3643	700.018							340	3556	9.74	
596	596-003 → 596-002	0.006	Qc	205	0.84	0.371	0.014	14968.58													205	14969	41.01	
596	596-003	0.0105	Qc	290	0.84	0.371	0.024	12225.12	Qs	265	11	0.397	0.2903	912.86							555	13138	35.99	
596	596-004	0.0101	Qc	280	0.84	0.371	0.023	12255.26	Qs	270	11	0.397	0.2796	965.676							550	13221	36.22	
599	599-001	0.0381	Qm	75	0.42	0.562	0.028	2631.743													75	2632	7.21	
605	605-001	0.202	Qm	10	0.42	0.562	0.151	66.24234													10	66	0.18	

Table 6.1.3  
Travel Time Analysis  
Advective Transport Only  
NAVBASE Charleston, Zone E  
Charleston, South Carolina

SITE	Pathline	avg. <i>t</i>													Total distance	Total time (days)	Total time (years)						
			<i>L1</i>	<i>d1</i>	<i>K1</i>	<i>n1</i>	<i>v1</i>	<i>t1</i>	<i>L2</i>	<i>d2</i>	<i>K2</i>	<i>n2</i>	<i>v2</i>	<i>t2</i>				<i>L3</i>	<i>d3</i>	<i>K3</i>	<i>n3</i>	<i>v3</i>	<i>t3</i>
605	605-002 --> DD4	0.0322	<i>Fu</i>	90	4.3	0.615	0.225	399.4787												90	399	1.09	
605	605-003 --> DD4	0.1603	<i>Fs</i>	35	120	0.4	48.09	0.727867												35	1	0.00	
DE00	GDE-001 --> DD3	0.0188	<i>Qs</i>	175	11	0.397	0.521	335.9526												175	336	0.92	
DE00	GDE-002	0.0196	<i>Qc</i>	45	0.84	0.371	0.044	1014.031												45	1014	2.78	
DE00	GDE-003	0.0243	<i>Qc</i>	165	0.84	0.371	0.055	2998.022												165	2998	8.21	
DE00	GDE-004	0.0186	<i>Qs</i>	150	11	0.397	0.516	290.6268	<i>Qm</i>	105	0.42	0.562	0.0139	7542.63						255	7833	21.46	
DE00	GDE-006	0.0073	<i>Qs</i>	425	11	0.397	0.202	2100.726	<i>Qmp</i>	205	0.42	0.562	0.0055	37568.5						630	39669	108.68	
DE00	GDE-007	0.0045	<i>Qm</i>	490	0.42	0.562	0.003	145948.2	<i>Qs</i>	300	11	0.397	0.1245	2410.1	<i>Qmp</i>	205	0.42	0.562	0.0034	61059.9	995	209418	573.75
DE00	GDE-008	0.0034	<i>Qm</i>	630	0.42	0.562	0.003	250710.4	<i>Qs</i>	310	11	0.397	0.0932	3327.39	<i>Qmp</i>	205	0.42	0.562	0.0025	81580.4	1145	335618	919.50
DE00	GDE-009	0.005	<i>Qm</i>	330	0.42	0.562	0.004	89173.79	<i>Qs</i>	295	11	0.397	0.1372	2150.09	<i>Qmp</i>	205	0.42	0.562	0.0037	55395.8	830	146720	401.97
DE01	GDE-010	0.0124	<i>Qs</i>	120	11	0.397	0.344	349.2669	<i>Qmp</i>	205	0.42	0.562	0.0093	22121.7						325	22471	61.56	
DE01	GDE-011	0.0386	<i>Qmp</i>	85	0.42	0.562	0.029	2947.481												85	2947	8.08	
DE01	GDE-012 --> DD5	0.0313	<i>Qs</i>	55	11	0.397	0.866	63.47384												55	63	0.17	
DE01	GDE-013 --> DD5	0.0488	<i>Qs</i>	40	11	0.397	1.351	29.61305												40	30	0.08	
DE01	GDE-016 --> DD1	0.0148	<i>Qc</i>	230	0.84	0.371	0.033	6871.814												230	6872	18.83	
DE01	GDE-017 --> DD1	0.0549	<i>Qc</i>	70	0.84	0.371	0.124	563.5851												70	564	1.54	
DE01	GDE-018 --> "E"	0.0015	<i>Qs</i>	510	11	0.397	0.042	12034.93												510	12035	32.97	
DE01	GDE-019	0.0039	<i>Qc</i>	310	0.84	0.371	0.009	35517.36	<i>Qs</i>	600	11	0.397	0.1068	5617.38	<i>Qm</i>	55	0.42	0.562	0.0029	19091.2	965	60226	165.00
DE02	GDE-020	0.0043	<i>Qs</i>	600	11	0.397	0.118	5083.773	<i>Qm</i>	55	0.42	0.562	0.0032	17277.7						655	22362	61.26	
DE02	GDE-021	0.0088	<i>Qs</i>	255	11	0.397	0.243	1049.486	<i>Qm</i>	70	0.42	0.562	0.0066	10681.3						325	11731	32.14	
DE02	GDE-022	0.0052	<i>Qm</i>	150	0.42	0.562	0.004	38951.4	<i>Fc</i>	70	0.84	0.371	0.0117	5999.81	<i>Fs</i>	205	120	0.4	1.5459	132.61	425	45084	123.52
DE02	GDE-024	0.0663	<i>Fc</i>	40	0.84	0.371	0.15	266.6667												40	267	0.73	
DE02	GDE-025	0.026	<i>Qs</i>	90	11	0.397	0.72	124.9301												90	125	0.34	
DE02	GDE-026	0.0106	<i>Qc</i>	245	0.84	0.371	0.024	10235.92	<i>Fc</i>	70	0.84	0.371	0.0239	2924.55						315	13160	36.06	
DE02	GDE-027 --> "E"	0.001	<i>Qs</i>	200	11	0.397	0.029	6874.459												200	6874	18.83	
DE03	GDE-030 --> 569-002	0.0098	<i>Qs</i>	225	11	0.397	0.271	830.501												225	831	2.28	

Notes: K and v have units of feet/day; total distance has units of feet  
All pathlines to Cooper River unless otherwise noted (other wells or drydocks [DD\*] are receptors)  
Flowpaths are a layer on shallow well groundwater contour map, although not presented in Section 2.2  
Lithology abbreviations refer to text in Section 2.1  
"E" is the anomalous groundwater sink labeled "E" on Figure 2-6A (shallow groundwater contour map)

Evaluation of an individual constituent's ability to migrate is based on four cross-media transfer mechanisms: soil to groundwater, groundwater to surface water, surface soil to air, and/or surface soil to sediment. Cases can be made for each of these potential transfer mechanisms based on empirical data available for each environmental medium sampled. For example, if a constituent is found in soil as well as in groundwater, it is reasonable to conclude that the soil constituent may be leaching to the groundwater. In support of such conclusions, Zone E fate and transport phenomena were evaluated using constituent-specific chemical and physical properties and risk-based screening concentrations or grid-based background reference levels.

Fate and transport were evaluated considering the unique conditions of Zone E:

- Nearly all surfaces covered with buildings or pavement
- Minimal exposure to soil
- Precipitation carried away by storm drains and sewers
- Minimal infiltration
- Historical, current, and probable future use as an industrial area
- No potential use of or exposure to groundwater
- Virtually no areas receiving transported sediment other than water bodies and catch basins in drains

The primary migration pathway for chemicals released into the environment at AOCs and SWMUs in Zone E is from surface soil downward through subsurface soil to the surficial aquifer, and thence downgradient through the aquifer to a discharge point into the Cooper River. Given the unique conditions listed above, threats to soil and groundwater quality caused by migration of contaminants are less critical in Zone E than in other parts of NAVBASE because potential exposure to contaminated soil or groundwater within the zone is much more limited.

Consequently, the principal migration threat was identified as potential degradation of surface water in the Cooper River, the ultimate receptor.

Potential contaminant migration problems were identified using a two-tiered screening approach. The first tier was a comparison of site constituent concentrations in soil and groundwater samples to conventional criteria for protection of human health and the environment. Results of this screen identified constituents with elevated concentrations and allowed comparison to results of fate and transport analyses in other parts of NAVBASE. For those constituents exceeding first-tier screening values, the second-tier screen examined site concentrations with respect to their ability to negatively impact surface water quality after allowing for dilution of groundwater by surface water upon discharge into the river.

Given the focus on Cooper River water quality, development of appropriate second-tier screening criteria for site media followed a reverse order. Although chemicals of interest migrate from soil to groundwater to surface water, acceptable site media constituent concentrations were determined by starting with acceptable surface water concentrations in the Cooper River and working backward, making conservative assumptions about:

- Dilution of groundwater by surface water as it discharges into the river
- Amount of groundwater discharge attributable to each site
- Dilution of leachate by groundwater as it percolates downward into the aquifer
- Amount of rainwater infiltration possible beneath paved surfaces
- Relationship between soil and leachate constituent concentrations

The following discussions describe the methods used to evaluate the potential migration of constituents identified at each SWMU/AOC. In some cases, specific migration pathways do not exist for a site. When a particular pathway was not identified for a site, no screening or formal

assessment was performed. Fate and transport were not evaluated for essential nutrients (calcium, iron, magnesium, potassium, and sodium), chlorides, or sulfur, which are abundant in shallow coastal/estuarine environments. Section 10 contains discussions of SWMU- or AOC-specific fate and transport, migration pathways and potential receptors.

### 6.2.1 Soil to Groundwater Cross-Media Transport: Tier One

A phased screening approach was used to evaluate the potential for soil to groundwater migration of constituents, focusing attention on chemicals that have the greatest potential for impacting the surficial aquifer. Due to the nature and age of most SWMU/AOC operations, it might be assumed that any compounds with the potential to migrate from soil into the surficial aquifer would have done so already. This assumption would also be appropriate in light of the thin, relatively permeable soil layer above the water table at Zone E. However, all soil constituents were evaluated for their potential threat to groundwater regardless of whether the constituent was detected in groundwater. The screening process may be summarized as follows:

*Quantitative* — Maximum soil constituent concentrations for each SWMU/AOC (or group thereof) were compared to the greater of:

1. Leachability-based generic soil-to-groundwater screening levels (SSLs) as presented in the USEPA *Soil Screening Guidance: Technical Background Document*, May 1996. Leachability-based SSLs were modified from those in the guidance or calculated independently, as described below, assuming a dilution attenuation factor (DAF) of 10.
2. Soil background reference values for inorganics in Zone E, determined in consultation with the Zone E project team technical subcommittee.

Maximum groundwater constituent concentrations for each SWMU/AOC (or group thereof) were compared to the greater of:

1. Tap water risk-based screening concentrations as presented in USEPA Region III RBC Table (June 1996), assuming a total hazard quotient (THQ) of 1.0.
2. Groundwater background reference values for inorganics in Zone E, determined in consultation with the Zone E project team technical subcommittee; selected as described below.

Quantitative screening defines the list of chemicals to be considered for detailed fate and transport assessment. It reveals constituents in soil with the potential to impact the surficial aquifer, identifying areas where relatively recent or immobile releases may not have impacted samples from existing monitoring wells. A conservative screening approach was employed using generic SSLs to provide the most comprehensive list of constituents with the potential to impact groundwater. It was assumed that if soil concentrations do not exceed conservative leachability-based screening levels or background, no significant migration potential exists. Likewise, if current groundwater concentrations do not exceed risk-based screening values or background, the conclusion was made that existing soil/groundwater equilibria are sufficiently protective of human health relative to potential groundwater ingestion exposure pathways. Although ingestion of groundwater is not considered an issue in the Zone E fate and transport evaluation, screening against risk-based values helped identify potential migration threats and facilitated comparisons to results in other zones at NAVBASE.

The soil to groundwater migration pathway was assessed using generic SSLs that assume a DAF of 10, rather than site-specific SSLs. DAFs significantly higher than 10 would be justified for Zone E SWMUs and AOCs, based on site-specific values of hydraulic conductivity, hydraulic

gradient, aquifer thickness, and estimated infiltration rate. Higher DAF values translate into higher SSLs. Section 6.3 compares assumptions underlying the fate and transport screening process with site-specific conditions. As a screening tool, generic SSLs are used to compile a list of potential fate and transport concerns, with site-specific evaluation conducted in the detailed fate and transport assessment to facilitate risk management decisions.

Table 6.2 contains physical site characteristics along with chemical and physical properties and regulatory standards for each constituent detected in Zone E soil and groundwater samples, enabling calculation of soil screening levels for protection of groundwater. Where generic SSLs for organics were not listed in the *Technical Background Document*, they were calculated using the values shown in Table 6.2. Values of Henry's law constant and  $K_{oc}$  not available in the *Technical Background Document* or the USEPA *Soil Screening Guidance: User's Guide*, April 1996, were obtained from various standard references. Where calculated SSLs in Table 6.2 differed from EPA's generic values, the EPA values prevailed. Differences in the two types of SSL were generally due to EPA's use of nonstandard target leachate concentrations as starting points for their calculations: rather than starting with listed RBCs or MCLs, EPA sometimes rounds them off to one or two significant figures. EPA's starting-point values are listed in Attachment D, "Regulatory and Human Health Benchmarks for SSL Development," of the *User's Guide*. Where no generic SSL was listed for an inorganic, its background reference value appeared in the first-tier screening tables.

Although the *Technical Background Document* indicates 19 mg/kg as the SSL for total chromium, chromium's background reference value of 94.6 mg/kg was used as the first-tier screening value. EPA's prescribed value of 19 mg/kg is equal to the SSL for hexavalent chromium, on the conservative assumption that any detected chromium may be hexachrome. For all of Zone E,

**Table 6.2**  
**Calculation of Soil-to-Groundwater Soil Screening Levels**  
**NAVBASE-Charleston, Zone E**  
**Charleston, South Carolina**

Site-Specific Parameters:								
Fraction Organic Carbon (→) :	0.002	Dimension- less Henry's Law Constant (→)	Organic Carbon Water Part. Coeff. (L/kg)	Tap Water RBC (mg/L)	Unadjusted Target MCL/ MCLG (mg/L)	Target Leachate Conc. (mg/L)	Target Leachate Conc. (mg/L)	Soil to Groundwater SSL (mg/kg)
Dilution Factor (→) :	10							
Dry Soil Bulk Density (kg/L) :	1.5							
Water-filled Soil Porosity (→) :	0.3							
Air-filled Soil Porosity (→) :	0.13							
Soil Porosity (→) :	0.43							
Volatile Organic Compounds								
Acetone	1.59E-03		5.75E-01	3.7	NA	3.7	37	7.45
Benzene	2.28E-01		5.89E+01	0.00036	0.005	0.005	0.05	0.0169
2-Butanone	1.90E-03		3.88E+00	1.9	NA	1.9	19	3.95
Carbon disulfide	1.24E+00		4.57E+01	1	NA	1	10	3.99
Chlorobenzene	1.52E-01		2.19E+02	0.039	NA	0.039	0.39	0.254
2-Chloroethyl vinyl ether	1.03E-02		2.20E+01	0.15	NA	0.15	1.5	0.367
Chloromethane	3.60E-01		1.40E+00	0.0014	NA	0.0014	0.014	0.00328
Dichlorodifluoromethane	9.23E+00		2.00E+02	0.39	NA	0.39	3.9	5.45805
1,1-Dichloroethane	2.30E-01		3.16E+01	0.81	NA	0.81	8.1	2.29
1,2-Dichloroethane	4.01E-02		1.74E+01	0.00012	0.005	0.005	0.05	0.0119
1,1-Dichloroethene	1.07E+00		5.89E+01	4.4E-05	0.007	0.007	0.07	0.0287
cis-1,2-Dichloroethene	1.67E-01		3.55E+01	0.061	0.07	0.07	0.7	0.200
trans-1,2-Dichloroethene	3.85E-01		5.25E+01	0.12	0.1	0.1	1	0.338
Ethylbenzene	3.23E-01		3.63E+02	1.3	0.7	0.7	7	6.68
2-Hexanone	7.18E-02		1.35E+02	2.9	NA	2.9	29	13.81
4-Methyl-2-pentanone	1.61E-04		6.17E+00	2.9	NA	2.9	29	6.16
Methylene chloride	8.98E-02		1.17E+01	0.0041	NA	0.0041	0.041	0.00948
1,1,1,2,2-Tetrachloroethane	1.41E-02		9.33E+01	5.2E-05	NA	5.2E-05	0.00052	0.000202
Tetrachloroethene	7.54E-01		1.55E+02	0.011	0.005	0.005	0.05	0.0288
Toluene	2.72E-01		1.82E+02	0.75	1	1	10	5.88
1,1,1-Trichloroethane	7.05E-01		1.10E+02	0.79	0.2	0.2	2	0.96
Trichloroethene	4.22E-01		1.66E+02	0.0016	0.005	0.005	0.05	0.0284
Trichlorofluoromethane	4.51E+00		1.58E+02	1.3	NA	1.3	13	11.7893
Vinyl chloride	1.11E+00		1.86E+01	1.9E-05	0.002	0.002	0.02	0.00667
Xylene (total)	2.91E-01		2.43E+02	12	10	10	100	71.1
o-Xylene	2.13E-01		3.63E+02	1.4	10	10	100	94.4
m-Xylene	3.01E-01		4.07E+02	1.4	10	10	100	104
Semivolatile Organic Compounds								
Acenaphthene	6.36E-03		7.08E+03	2.2	NA	2.2	22	316
Acenaphthylene	8.20E-03		4.79E+03	1.5	NA	1.5	15	147
Anthracene	2.67E-03		2.95E+04	11	NA	11	110	6512
Benzo(a)pyrene	4.63E-05		1.02E+06	9.2E-06	0.002	0.002	0.02	40.8
Benzo(a)anthracene	1.37E-04		3.98E+05	9.2E-05	NA	9.2E-05	0.00092	0.733
Benzo(b)fluoranthene	4.55E-03		1.23E+06	9.2E-05	NA	9.2E-05	0.00092	2.26
Benzo(k)fluoranthene	3.40E-05		1.23E+06	0.00092	NA	0.00092	0.0092	22.6
Benzo(g,h,i)perylene	5.74E-06		7.76E+06	1.5	NA	1.5	15	232803
Benzyl alcohol	9.35E-06		5.00E+00	11	NA	11	110	23
4-Bromophenyl-phenylether	4.80E-03		1.70E+04	2.1	NA	2.1	21	718
Butylbenzylphthalate	5.17E-05		5.75E+04	7.3	NA	7.3	73	8410
Carbazole	6.26E-07		3.39E+03	0.0034	NA	0.0034	0.034	0.237
4-Chloro-3-methylphenol	7.30E-05		7.76E+02	0.18	NA	0.18	1.8	3.154
Chrysene	3.88E-03		3.98E+05	0.0092	NA	0.0092	0.092	73.3
Dibenzo(a,h)anthracene	6.03E-07		3.80E+06	9.2E-06	NA	9.2E-06	9.2E-05	0.699
Dibenzofuran	NDA		1.00E+04	0.15	NA	0.15	1.5	NDA
1,2-Dichlorobenzene	7.79E-02		6.17E+02	0.27	0.6	0.6	6	8.64
1,3-Dichlorobenzene	1.48E-01		1.70E+02	0.54	NA	0.54	5.4	2.99
1,4-Dichlorobenzene	9.96E-02		6.17E+02	0.00044	0.075	0.075	0.75	1.08
Dimethylphthalate	2.17E-03		4.40E+01	370	NA	370	3700	1066.30
Di-n-octylphthalate	2.74E-03		8.32E+07	0.73	NA	0.73	7.3	1214721
bis(2-Ethylhexyl)phthalate	4.18E-06		1.51E+07	0.0048	0.006	0.006	0.06	1812
Fluoranthene	6.60E-04		1.07E+05	1.5	NA	1.5	15	3213

Table 6.2  
 Calculation of Soil-to-Groundwater Soil Screening Levels  
 NAVBASE-Charleston, Zone E  
 Charleston, South Carolina

Site-Specific Parameters:		Dimension- less Henry's Law Constant (-)	Organic Carbon Water Part. Coeff. (L/kg)	Tap Water RBC (mg/L)	Unadjusted MCL/ MCLG (mg/L)	Target Leachate Conc. (mg/L)	Target Leachate Conc. (mg/L)	Soil to Groundwater SSL (mg/kg)
Fraction Organic Carbon (-):	0.002							
Dilution Factor (-):	10							
Dry Soil Bulk Density (kg/L):	1.5							
Water-filled Soil Porosity (-):	0.3							
Air-filled Soil Porosity (-):	0.13							
Soil Porosity (-):	0.43							
Fluorene	2.61E-03	1.38E+04	1.5	NA	1.5	15	417	
Indeno(1,2,3-cd)pyrene	6.56E-05	3.47E+06	9.2E-05	NA	9.2E-05	0.00092	6.38	
2-Methylnaphthalene	1.98E-02	2.00E+03	1.5	NA	1.5	15	63.0	
4-Methylphenol (p-cresol)	4.92E-05	9.12E+01	0.18	NA	0.18	1.8	0.7	
Naphthalene	1.98E-02	2.00E+03	1.5	NA	1.5	15	63.0	
1-Naphthylamine	NDA	NDA	5.2E-07	NA	5.2E-07	5.2E-06	NDA	
4-Nitrophenol	1.23E-03	2.14E+02	2.3	NA	2.3	23	14.4	
N-Nitroso-methylethylamine	1.74E-05	4.00E+00	3.1E-06	NA	3.1E-06	3.1E-05	0.0	
Phenanthrene	1.60E-03	2.29E+04	1.5	NA	1.5	15	690	
Pyrene	4.51E-04	1.05E+05	1.1	NA	1.1	11	2312	
1,2,4,5-Tetrachlorobenzene	4.00E-09	6.65E+03	0.0018	NA	0.0018	0.018	0	
1,2,4-Trichlorobenzene	5.82E-02	1.78E+03	0.19	0.07	0.07	0.7	2.64	
<b>Polychlorinated Dibenzodioxins/dibenzofurans</b>								
TCDD Equivalents	1.31E-03	1.58E+06	4E-10	3E-08	3E-08	3E-07	0.000951	
<b>Pesticide/PCB Compounds</b>								
Aldrin	6.97E-03	2.45E+06	4E-06	NA	4E-06	4E-05	0.196	
Aroclor 1260	NA	3.09E+05	8.7E-06	0.0005	NA	NA	1.00	
delta-BHC	3.05E-05	1.26E+03	3.7E-05	NA	3.7E-05	0.00037	0.00101	
gamma-BHC (Lindane)	5.74E-04	1.07E+03	5.2E-05	0.0002	0.0002	0.002	0.00468	
alpha-Chlordane	1.99E-03	1.20E+05	5.2E-05	0.002	0.002	0.02	4.80	
gamma-Chlordane	1.99E-03	1.20E+05	5.2E-05	0.002	0.002	0.02	4.80	
4,4'-DDD	1.64E-04	1.00E+06	0.00028	NA	0.00028	0.0028	5.60	
4,4'-DDE	8.61E-04	4.47E+06	0.0002	NA	0.0002	0.002	17.9	
4,4'-DDT	3.32E-04	2.63E+06	0.0002	NA	0.0002	0.002	10.5	
Dieldrin	6.19E-04	2.14E+04	4.2E-06	NA	4.2E-06	4.2E-05	0.00181	
Endosulfan	4.59E-04	2.14E+03	0.22	NA	0.22	2.2	9.86	
Endrin	3.08E-04	1.23E+04	0.011	0.002	0.002	0.02	0.496	
Heptachlor	6.07E+01	1.41E+06	2.3E-06	0.0004	0.0004	0.004	11.3	
<b>Inorganic Compounds</b>								
		<i>Kd (6.8 pH)</i>						
Aluminum	NA	1.50E+03	37	NA	37	370	555074.00	
Antimony	NA	4.50E+01	0.015	0.006	0.006	0.06	2.71	
Arsenic	NA	2.90E+01	4.5E-05	0.05	0.05	0.5	14.6	
Barium	NA	4.10E+01	2.6	2	2	20	824	
Beryllium	NA	7.90E+02	1.6E-05	0.004	0.004	0.04	31.6	
Cadmium	NA	7.50E+01	0.018	0.005	0.005	0.05	3.76	
Chromium (III)	NA	1.80E+06	37	0.1	0.1	1	1800000	
Chromium (VI)	NA	1.90E+01	0.18	0.1	0.1	1	19.2	
Cobalt	NA	4.70E+01	2.2	NA	2.2	22	1038.40	
Copper	NA	3.50E+01	1.5	1.3	1.3	13	457.60	
Lead	NA	NA	0.015	NA	0.015	0.15	Background	
Manganese	NA	6.50E+01	0.84	NA	0.84	8.4	547.68	
Mercury	NA	5.20E+01	0.011	0.002	0.002	0.02	1.04	
Nickel	NA	6.50E+01	0.73	0.1	0.1	1	65.2	
Selenium	NA	5.00E+00	0.18	0.05	0.05	0.5	2.60	
Silver	NA	8.30E+00	0.18	NA	0.18	1.8	15.3	
Thallium	NA	7.10E+01	0.0029	0.0005	0.0005	0.005	0.356	
Tin	NA	2.50E+02	22	NA	22	220	55044.00	
Vanadium	NA	1.00E+03	0.26	NA	0.26	2.6	2601	
Zinc	NA	6.20E+01	11	NA	11	110	6842	

hexachrome was detected in only four of 59 surface soil samples (maximum concentration = 0.586 mg/kg) and in none of the 27 subsurface soil samples where it was analyzed, indicating that the total chromium detected in Zone E samples is almost entirely trivalent. According to the *Technical Background Document*, trivalent chromium as a contaminant in soil is not considered a threat to groundwater at any concentration.

The greater value of the background RCs for surface soil or subsurface soil was used as the screening alternative to SSLs for inorganics. Since constituent migration is from surface or near-surface soil downward through subsurface soil to the aquifer, and since the SSL methodology assumes zero attenuation of constituents during migration, the higher of the two background values is always appropriate for comparison to SSLs. Similarly, the greater of the background reference values for shallow and deep groundwater was used as the screening alternative to tap water RBCs. The lithology of the surficial aquifer in Zone E is complex, with no apparent widespread aquitards. Over distances involved in migration from SWMUs/AOCs to surface water, aquifer units at all depths down to the confining unit (Ashley Formation or Qco) are assumed to be interconnected, so that the higher background value is always relevant.

*Detailed Assessment* — Upon completion of the quantitative first-tier screening process, site constituent concentrations exceeding the screening values were examined to delineate the magnitude and areal extent of soil impacts potentially affecting groundwater. Maximum constituent concentrations in surface soil were compared to those in subsurface samples to estimate the extent of downward migration. The number and spatial distribution of exceedances were noted. Relative concentrations in soil and groundwater were compared. Corresponding exceedances in nearby SWMUs/AOCs were examined as possible sources or as indicators of lateral migration.

To evaluate potential impact on ecological receptors, maximum shallow and deep groundwater analytical results for each SWMU/AOC (or group thereof) were compared to USEPA saltwater surface water chronic screening values for hazardous waste sites, from *Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment*, November 1995. Since surface water samples were not collected as part of the Zone E RFI (except for AOC 556), no background values for surface water constituents could be determined for use as alternatives to surface water screening standards.

The first-tier quantitative assessment identifies chemicals detected in groundwater with the potential to disperse within the aquifer, increasing the areal extent of groundwater concentrations that exceed human health-based standards, or impacting surface water via groundwater migration and discharge. If groundwater concentrations do not exceed tap water risk-based screening levels or background concentrations, no significant threat relative to migration potential exists. If reported concentrations in groundwater do not exceed saltwater surface water chronic screening levels, no threat exists relative to ecological impacts resulting from groundwater discharge to surface water. This assessment does not consider potential dilution/attenuation factors affecting transport between the affected well and the surface water discharge point, or the dilutional capacity of the receiving water body. Omitting these factors from the first-tier quantitative screening ensures that a conservative list of potential groundwater to surface water concerns is developed.

*Detailed Assessment* — Upon completion of the quantitative first-tier screening process, detailed assessments were performed to delineate the magnitude and areal extent of groundwater impacts that may adversely affect human or ecological receptors. Maximum constituent concentrations in shallow groundwater were compared to those in deep groundwater to estimate the extent of downward migration. The number and spatial distribution of exceedances were noted. Corresponding exceedances in nearby SWMUs/AOCs were examined as possible sources or as indicators of lateral migration.

The detailed assessments helped to determine the significance of groundwater impacts and potential impacts. In addition, inferences were drawn about the potential for significant impacts on surface water. The Zone J RFI results will be used to confirm or refute preliminary conclusions. Detailed first-tier assessments were also used to determine which areas of groundwater contamination may require supplemental investigation and/or modeling applications during the CMS as part of the remedial alternatives development process.

### 6.2.3 Soil and Groundwater to Surface Water Transport: Tier Two

Constituent concentrations exceeding first-tier screening criteria were carried over to a second-tier screen. The second screening tier focuses on surface water quality in the Cooper River, which is the destination of groundwater flow for most of Zone E. Although groundwater in the northwestern portion of Zone E flows westward toward two water-level depressions (anomalies E and F, described in Section 2.3.2.1), the worst-case ultimate destination of groundwater migrating to these depressions is also the Cooper River. Transport of constituents from SWMUs/AOCs to the depressions has been treated as occurring in generic plumes draining to the depressions as if to the river. The screening process may be summarized as follows:

*Quantitative* — The tier-two screening process begins by establishing acceptable constituent concentrations for Cooper River water as endpoints for comparisons. To protect both human health and aquatic organisms, “combined ecological/human health surface water RBCs” (“combined eco/HH surface water RBCs”) were determined to be the lesser of:

1. Tap water risk-based screening levels as presented in USEPA Region III RBC tables (June 1996).
2. USEPA saltwater surface water chronic screening values, from *Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment*, November 1995.

Erosion of surface soil in Zone E leading to subsequent deposition in the Cooper River is minimal. 1  
The primary vehicle for transport of SWMU/AOC site constituents to the river is groundwater 2  
discharging into surface water. To account for the discharge process, theoretical contaminant 3  
plumes originating at each SWMU or AOC (or group thereof) were modeled, using estimated 4  
values of hydraulic conductivity, hydraulic gradient, and aquifer thickness averaged over the 5  
assumed migration pathway from site to river. When these quantities were combined with 6  
theoretical plume widths at the discharge point, Darcy's law allowed calculation of the estimated 7  
groundwater discharge into the river that was attributable to each SWMU/AOC. 8

As the relatively small volume of groundwater from each SWMU/AOC discharges into the river, 9  
it is immediately diluted by a much larger volume of river water. As a rough approximation of 10  
the magnitude of dilution over short distances, the calculated groundwater discharge rates were 11  
compared to 5% of the 7Q10 net flow of the Cooper River. The 7Q10 net flow is the lowest 12  
expected 7-day flow rate in a 10-year period, adjusted for tidal influence. For the Cooper River, 13  
the recent 7Q10 net flow rate (obtained from SCDHEC) is 2,565 ft<sup>3</sup>/sec (72.6 m<sup>3</sup>/sec); 5% of the 14  
7Q10 net flow rate is 128 ft<sup>3</sup>/sec. Use of 5% of the 7Q10 flow to estimate dilution was considered 15  
conservative because cross-sectional profiles of the Cooper River in the vicinity of Zone E show 16  
that the bulk of the flow volume occurs on the west side of the channel at this point, adjoining 17  
Zone E (the cut bank of the river as it curves eastward). 18

The estimated groundwater discharge rate attributable to each SWMU/AOC was divided into 5% 19  
of the river's 7Q10 net flow rate to obtain a corresponding site-specific surface water dilution 20  
factor (SWDF), as shown in Table 6.2.1. Hydraulic conductivities, hydraulic gradients, and net 21  
aquifer thicknesses were averaged over the migration route from site to discharge point. Where 22  
control points were sparse, hydraulic conductivity values were based on subzone averages. 23  
Hydraulic gradients were based on an assumed average elevation of 0.5 feet for water in the 24  
Cooper River. Net saturated aquifer thicknesses were measured down to the first significant 25  
aquitard in the area around the SWMU/AOC. Each site's surface water dilution factor also 26  
appears in a note at the end of its tier-two screening table, if a second-tier table was required. 27

Table 6.2.1  
Derivation of Surface Water Dilution Factors Used in Adjusted RBC Calculations  
Site-specific Physical and Hydrogeological Parameters  
NAVBASE Charleston, Zone E  
Charleston, South Carolina

Site Groups	K	i	da	Wp	A	Q	Fr	SWDF
	Hydraulic Conductiv. (ft/day)	Hydraulic Gradient (--)	Aquifer Thickness (ft)	Plume Width At River (ft)	Cross-sect. Area (ft <sup>2</sup> )	GW Discharge (ft <sup>3</sup> /day)	5% of 7Q10 River Flow (ft <sup>3</sup> /sec)	Surf. Wtr. Dilution (--)
1. 5, 18, 605	7.62	0.014	7	200	1400	149	128	7.40E+04
2. 21, 54	11	0.011	21.6	240	5184	627	128	1.76E+04
3. 22, 25, 554	11.9	0.0035	26.1	300	7830	326	128	3.39E+04
4. 23, 63, 540 - 543	10.9	0.003	29.7	240	7128	233	128	4.74E+04
5. 53, 526	5.6	0.004	20	240	4800	108	128	1.03E+05
6. 65,544,546	6.8	0.02	10	200	2000	272	128	4.07E+04
7. 67	10.8	0.009	20	200	4000	389	128	2.84E+04
8. 70, 548, 549	12.6	0.002	20	200	4000	101	128	1.10E+05
9. 81								
10. 83, 84, 574	7	0.01	10	200	2000	140	128	7.90E+04
11. 87, 172, 564	5.5	0.014	10	150	1500	116	128	9.58E+04
12. 97	4	0.017	10	150	1500	102	128	1.08E+05
13. 100	6	0.005	10	200	2000	60	128	1.84E+05
14. 102	4	0.016	10	200	2000	128	128	8.64E+04
15. 106, 603	4	0.01	10	200	2000	80	128	1.38E+05
16. 145	5.5	0.006	10	200	2000	66	128	1.68E+05
17. 170, 171	6	0.005	10	200	2000	60	128	1.84E+05
18. 173	7	0.005	10	200	2000	70	128	1.58E+05
19. 525	8.3	0.008	20	240	4800	319	128	3.47E+04
20. 528	10.4	0.003	20	240	4800	150	128	7.38E+04
21. 530	15.6	0.006	20	200	4000	374	128	2.95E+04
22. 531	15.6	0.001	20	200	4000	62	128	1.77E+05
23. 538, 539	15.6	0.005	20	200	4000	312	128	3.54E+04
24. 550	5.6	0.006	10	200	2000	67	128	1.65E+05
25. 551, 552	10.6	0.01	10	150	1500	159	128	6.96E+04
26. 555	10.6	0.01	10	150	1500	159	128	6.96E+04
27. 556								
28. 558								
29. 559, 560, 561	13	0.009	15.6	200	3120	365	128	3.03E+04
30. 562	7	0.01	15	150	2250	158	128	7.02E+04
31. 563	7	0.006	7	200	1400	59	128	1.88E+05
32. 566	0.838	0.02	9.5	100	950	16	128	6.95E+05
33. 567	7.6	0.013	12.5	100	1250	123	128	8.95E+04
34. 569, 570, 578	6.5	0.005	12	200	2400	78	128	1.42E+05
35. 571	7	0.005	12.3	200	2460	86	128	1.28E+05
36. 572	7	0.005	12.3	200	2460	86	128	1.28E+05
37. 573	7	0.006	12.3	200	2460	103	128	1.07E+05
38. 576	7	0.009	12	200	2400	151	128	7.31E+04
39. 579	7	0.004	17	200	3400	95	128	1.16E+05
40. 580	7	0.005	14	200	2800	98	128	1.13E+05
41. 583	7	0.009	12.5	200	2500	158	128	7.02E+04
42. 586	7	0.012	6	200	1200	101	128	1.10E+05
43. 590	7	0.013	6	200	1200	109	128	1.01E+05
44. 592	7	0.004	6	200	1200	34	128	3.29E+05
45. 596	7	0.01	6	200	1200	84	128	1.32E+05

Table 6.2.1

Derivation of Surface Water Dilution Factors Used in Adjusted RBC Calculations  
 Site-specific Physical and Hydrogeological Parameters  
 NAVBASE Charleston, Zone E  
 Charleston, South Carolina

Site Groups	K Hydraulic Conductiv. (ft/day)	i Hydraulic Gradient (--)	da Aquifer Thickness (ft)	Wp Plume Width At River (ft)	A Cross-sect. Area (ft <sup>2</sup> )	Q GW Discharge (ft <sup>3</sup> /day)	Fr 5% of 7Q10 River Flow (ft <sup>3</sup> /sec)	SWDF Surf. Wtr. Dilution (--)
46. 597	5	0.02	6	90	540	54	128	2.05E+05
47. 598, 599	5	0.03	6	160	960	144	128	7.68E+04
48. 602	5	0.007	6	200	1200	42	128	2.63E+05
49. 604	5	0.009	6	200	1200	54	128	2.05E+05

The surface water dilution factor for each SWMU/AOC was multiplied by each second-tier constituent's combined ecological/human health surface water RBC to obtain an "adjusted ecological/human health groundwater RBC" ("adjusted eco/HH RBC") for the constituent. These values represent site-specific groundwater constituent concentrations that are protective of surface water quality in the Cooper River. Given that groundwater quality within Zone E is of concern as it affects surface water quality, the values also represent acceptable groundwater constituent concentrations at the SWMU or AOC. After migrating through the surficial aquifer (with zero dilution or attenuation), discharging into the river, and becoming diluted with 5% of the 7Q10 flow of the river, any groundwater constituent appearing at an original site concentration below its adjusted eco/HH groundwater RBC should subsequently appear in Cooper River water at a concentration below its corresponding combined eco/HH surface water RBC. The second-tier screen compares groundwater constituent concentrations at SWMUs/AOCs to adjusted eco/HH groundwater RBCs to identify chemicals with the potential to impact surface water quality.

Modified SSLs were also formulated to help identify soil constituent concentrations with the potential to yield corresponding groundwater concentrations higher than the acceptable adjusted eco/HH groundwater RBCs. To this end, EPA's generic SSLs based on DAF=1 were modified by using the adjusted eco/HH groundwater RBCs as target leachate concentrations in place of the MCLs or RBCs used in the original calculations, yielding "adjusted SSLs." Since all other default values used to calculate the SSLs remained unchanged, it was possible to divide each adjusted eco/HH groundwater RBC by the corresponding target leachate concentration used by EPA in the original SSL calculation to yield an "SSL multiplier" which, when multiplied by the original generic SSL, produced the adjusted SSL. The adjusted SSL calculation in the tier-two tables introduces a factor of 10 to account for the change from DAF=10 in the first-tier screen to DAF=1 in the second tier. To reflect the carrying capacity of Zone E soils, adjusted SSLs for organic constituents were limited to concentrations equivalent to the geometric mean TOC concentration (1.04E+04 mg/kg, based on 32 TOC analyses zonewide).

Background reference values were not used as starting points to calculate adjusted eco/HH groundwater RBCs or adjusted SSLs for inorganics. These adjusted standards are multiples of original standards (tap water RBCs, saltwater surface water chronic screening values, and generic SSLs) that are based on human health and ecological impacts. The proper use of background values would be in place of the adjusted standards if the background values exceed them, but none did. For inorganics without listed generic SSLs, generic SSLs were calculated based on values of  $K_d$  available in the literature, assuming (as does EPA) a pH of 6.8. To calculate adjusted SSLs, the new generic SSLs were assumed to be a function of the corresponding tap water RBCs.

Although the methodology for calculating adjusted SSLs and adjusted eco/HH groundwater RBCs worked well in most cases, results were somewhat misleading for several inorganics such as arsenic and copper. Arsenic, for example, has a generic SSL of 14.6 mg/kg (assuming DAF=10) that is based on its MCL of 50  $\mu\text{g/L}$ . Because its combined eco/HH surface water RBC (the acceptable surface water concentration used in the described calculation) is its tap water RBC of 0.045  $\mu\text{g/L}$  rather than its MCL, arsenic's starting point (that is, its eco/HH surface water RBC) to calculate its adjusted RBC and adjusted SSL is more than three orders of magnitude lower than its starting point used by EPA to calculate its generic SSL. Consequently, a site such as combined SWMU 21 that has a relatively low surface water dilution factor (SWDF=17,600) exhibits a low adjusted SSL, in this case 23.1 mg/kg (assuming DAF=1), because its low SSL multiplier reflects the large discrepancy between the starting points of the two calculations. This problem could have been avoided by using MCLs preferentially over tap water RBCs to determine combined eco/HH surface water RBCs. The problem is magnified because the second-tier screening process assumes that DAF=1 when calculating adjusted SSLs.

Adjusted SSLs represent acceptable soil constituent concentrations, protective of surface water quality through the soil to groundwater to surface water migration pathway. The second-tier

screen compares surface and subsurface soil constituent concentrations at SWMUs/AOCs to adjusted SSLs to identify chemicals with the potential to impact surface water quality.

*Detailed Assessment* — Upon completion of the quantitative second-tier screening process, detailed assessments were performed to delineate the magnitude and areal extent of soil and groundwater impacts that may adversely affect human or ecological receptors in Cooper River water. The number and spatial distribution of second-tier exceedances were noted. The significance of the exceedances was evaluated in terms of the underlying assumptions of the second-tier screening process versus the actual conditions at the site, as discussed at greater length in Section 6.3.

As with first-tier detailed assessments, detailed assessments following the second-tier screen helped determine the significance of soil impacts relative to the surficial aquifer and the Cooper River, and of groundwater impacts relative to the river. They were also used to help decide which areas of soil or groundwater contamination may require supplemental investigation and/or modeling applications during the CMS as part of the remedial alternatives development process.

#### **6.2.4 Surface Soil to Sediment Cross-Media Transport**

To evaluate surface soil to sediment erosional migration, a phased screening approach was used to identify chemicals that have the potential to cause contamination in sediments following surface soil erosion. The screening process may be summarized as follows:

*Qualitative* — The CPSS lists (excluding essential nutrients) for surface soil and sediment were compared to determine which chemicals were present in both media.

Sediments are formed by the erosion of surface soil with accumulation in depositional areas. Normally, site topography and ground cover would be used to identify areas with erosional potential and the corresponding expected areas of deposition. Because erosional/depositional

processes within Zone E are severely limited at most locations due to the almost universal presence of buildings or paved surfaces, migration of constituents from surface soil to sediment has been rare. Zone E sediment samples were all collected from catch basins or from sediment at the bottom of slips or the Cooper River, immediately adjoining SWMUs/AOCs. Nevertheless, sediment results were compared to data for proximate surface soil representing possible points of origin for sediment contaminants. At most sites, it was concluded that constituents present in both surface soil and sediment likely came from a common or similar source.

*Semiquantitative* — The maximum concentration in surface soil was compared to the maximum concentration in sediment for constituents present in both media. The purpose of the semiquantitative assessment was to provide additional evidence in support of this possible migration pathway.

Evaluation of fate and transport for sediments in Zone E was limited to sediments as contaminant receptors. Any impacts of contaminated Zone E surface water sediments on ecological receptors will be addressed in the Zone J RFI. Fate and transport for constituents originating in Zone E catch-basin sediments will be provided in the RFI report for Zone L.

#### **6.2.5 Soil to Air Cross-Media Transport**

To evaluate the potential for soil to air migration of volatile contaminants, a screening approach was used to focus attention on chemicals that have the greatest potential to volatilize in sufficient quantities to create a human health threat in ambient air. The screening process may be summarized as follows:

*Quantitative* — The maximum concentrations of volatile organics detected in surface soil at each SWMU/AOC were compared to soil-to-air screening concentrations as presented in the USEPA Region III RBC tables (April 1996).

The quantitative assessment further refines the list of chemicals under consideration for formal fate and transport evaluation. If soil concentrations do not exceed soil-to-air volatilization screening concentrations, no significant migration potential exists, and current soil conditions are considered protective of human health relative to potential inhalation exposure pathways.

*Detailed Assessment* — After completing the quantitative screening process, detailed assessments were performed to delineate the magnitude and areal extent of surface soil impacts potentially affecting ambient air. The number and spatial distribution of exceedances were noted, as were site-specific conditions possibly affecting release of volatiles into the air.

The outcome of the detailed assessments was used to determine the significance of soil impacts relative to ambient air. In some instances, isolated areas of soil contamination above soil-to-air volatilization-based concentrations could have the potential for localized ambient air impacts but not be of a magnitude to pose a long-term or widespread threat through inhalation pathways. The detailed assessment was used to identify these cases as well as to determine which areas of soil contamination may require supplemental investigation and/or modeling applications during the CMS as part of the remedial alternatives development process.

### **6.3 Fate and Transport Screening Assumptions Versus Site Conditions**

The two-tiered fate and transport screening procedure was designed as a conservative method to identify and evaluate soil and groundwater constituents with the potential to impact groundwater and surface water quality in the Cooper River. The screening tables identify the constituents, while the detailed assessments evaluate their significance. The procedure depends heavily on EPA's soil screening methodology, and makes many simplifying assumptions that come directly from the 1996 *Soil Screening Guidance*. This section compares some of the assumptions of the two-tiered screening procedure with actual conditions encountered at SWMUs and AOCs in

Zone E in an attempt to demonstrate the conservative nature of the method. The screening assumptions are shown in italics, followed by commentary.

*1. The contaminant source is infinite (i.e., steady-state concentrations are maintained during the exposure period).* At virtually every site, the original source — prior to soil contamination — has been removed. As constituent molecules migrate through the system or degrade, they are generally not replaced from the original source.

*2. Each soil contaminant is uniformly distributed from the surface to the top of the aquifer, at a concentration equal to the maximum value reported from any of the samples.* Site conditions vary greatly, as seen in sample analytical results. Most often, first-tier or second-tier exceedances are reported from a relatively small percentage of samples, as presented in the detailed assessments.

*3. There is no contaminant attenuation (i.e., adsorption, biodegradation, chemical degradation) as leachate moves downward through soil.* Dissolved organic compounds and metallic ions originating in the upper soil horizons are not particularly mobile, due to sorption. Because of their origins in back-barrier, lagoonal, and other low-energy environments (Section 2.2.3.2), many NAVBASE soils and lithologic units exhibit clay content varying from moderate to very high. The geometric mean CEC of 32 Zone E soil samples, including some from the saturated zone, was 92.2 meq/100g. For comparison, CEC for pure montmorillonite clay (smectite) ranges from 80 to 150 meq/100g. Other clays such as illite (10-40 meq/100g) and kaolinite (3-15 meq/100g) have lower values. The geometric mean TOC of the same 32 samples was 10,400 mg/kg ( $f_{oc} = 0.01$ ). The default value of  $f_{oc}$  used by EPA to calculate generic SSLs is 0.002, indicating that Zone E soils have on average five times the organic carbon available to bind contaminants to soil particles, versus the soils assumed in the generic model's partitioning equation for migration to groundwater.

EPA's generic SSLs are based on reference values of  $K_{oc}$  for ionizing organics and  $K_d$  for inorganics. The listed reference values assume a soil pH of 6.8. For Zone E, the geometric mean pH for 237 soil samples is considerably higher at 7.89.  $K_{oc}$  for most ionizing organics is moderately lower at pH=7.89 than at pH=6.8; for inorganics, however,  $K_d$  for pH=7.89 may be several orders of magnitude higher than for pH=6.8, depending on the metal involved. The effect of these pH differences between generic assumptions and Zone E conditions is that, all other factors being equal, SSLs for some ionizing organics (e.g., benzoic acid, pentachlorophenol) may be somewhat lower than generic SSLs, but SSLs for many inorganics (e.g., beryllium, cadmium, nickel) may be significantly higher than indicated by EPA's generic values.

4. *The generic SSLs used in the first-tier screen are based on a dilution attenuation factor (DAF) of 10.* Since EPA's methodology assumes zero attenuation for migration of leachate through the vadose zone and groundwater through the aquifer, the default DAF of 10 used in the tier-one tables is actually a dilution factor only. Using equations presented in the 1996 *Soil Screening Guidance: User's Guide*, site-specific and semi-site-specific dilution factors were calculated for 17 of the first 20 Zone E site groups (sites where soil samples were collected). Entirely site-specific values for all equation inputs were used for the first five sites; subzone-specific values of hydraulic conductivity and aquifer thickness and site-specific values for other components were used for the rest (Table 6.3.1). Calculated dilution factors range from 14 (AOC 528) to 237 (AOC 525). The calculations assume rainfall infiltration rates equal to or greater than those assigned by the ongoing USGS groundwater modeling study to the semi-industrial areas of the base — Zones A, H, and I — rather than the zero infiltration that the model assumes for all of Zone E.

5. *The calculated SSLs used in the second-tier screen are based on a DAF of 1.* This extremely conservative approach assumes that not only is there no attenuation of contaminants as leachate moves downward through soil, but there is also no dilution of leachate by groundwater already

Table 6.3.1  
 Derivation of Site-Specific Dilution Factors for SSL Calculations  
 Site-specific Physical and Hydrogeological Parameters  
 NAVBASE Charleston, Zone E: Site Groups 1 - 20  
 Charleston, South Carolina

Site Groups (SWMUs, AOCs)	K Hydraulic Conductiv. (m/yr)	i Hydraulic Gradient (--)	da Aquifer Thickness (m)	L Source Length (m)	I Infiltration Rate (m/yr)	dc Calc. Mixing Zone Depth (m)	d Mixing Zone Depth (m)	DF Dilution Factor (--)
1. 5, 18, 605	848	0.014	2.13	94	0.01524	10.39	2.13	18.65
2. 21, 54	1220	0.011	6.59	107	0.02286	11.54	6.59	37.16
3. 22, 25, 554	919	0.003	7.96	46	0.00762	4.99	4.99	40.28
4. 23, 63, 540, 541, 542, 5	1210	0.002	9.05	122	0.00762	13.24	9.05	24.56
5. 53, 526	626	0.007	14.8	37	0.00762	3.95	3.95	62.40
6. 65,544,546	846	0.02	6.1	61	0.00762	6.49	6.10	223.05
7. 67	846	0.002	6.1	91	0.00762	10.15	6.10	15.88
8. 70, 548, 549	846	0.002	6.1	40	0.00762	4.46	4.46	25.79
9. 81			Sediment and concrete samples only					
10. 83, 84, 574	846	0.02	3.05	67	0.00762	7.17	3.05	102.08
11. 87, 172, 564	846	0.004	3.05	30	0.00762	3.35	3.05	46.15
12. 97	846	0.014	3.05	15	0.00762	1.61	1.61	168.10
13. 100	846	0.002	3.05	15	0.00762	1.76	1.76	27.08
14. 102	846	0.006	3.05	41	0.00762	4.50	3.05	50.55
15. 106, 603	846	0.007	3.05	90	0.00762	9.82	3.05	27.34
16. 145	846	0.005	3.05	27	0.00762	2.98	2.98	62.34
17. 170, 171			Sediment and surface water samples only					
18. 173			Concrete and wipe samples only					
19. 525	846	0.02	6.1	15	0.00762	1.60	1.60	237.30
20. 528	846	0.001	6.1	15	0.00762	1.76	1.76	14.04

in the aquifer. In fact, Zone E geochemical data imply high rates of attenuation (item number 3 above), while calculated site-specific dilution factors indicate much higher dilution ratios (item number 4).

6. *There is no contaminant attenuation as groundwater moves through the aquifer.* The lithology and the CEC and TOC values of the aquifer samples indicate otherwise:

- Substantial amounts of clay are present
- Geometric mean CEC of nine aquifer samples = 35.1 meq/100g
- Geometric mean TOC of nine aquifer samples = 6,880 mg/kg ( $f_{bc} = 0.007$ )

7. *The contaminant concentration in the entire theoretical groundwater plume from each site to the discharge point into the river is equal to (a) the concentration of leachate produced by the maximum detected soil concentration and diluted 10:1 by groundwater (first-tier screen) or undiluted (second-tier screen); or (b) maximum groundwater concentration.* This assumption should be compared to analytical results from soil and groundwater samples collected at each SWMU/AOC and from groundwater samples collected downgradient from each site. High constituent concentrations in both soil and groundwater samples were generally reported from a few isolated locations rather than across entire sites. The number and spatial distribution of first-tier and second-tier screening exceedances are discussed in the detailed assessments for each site.

8. *The quay wall has little or no effect on groundwater discharge into the Cooper River.* In most places, the quay wall may constitute a nearly impermeable barrier to groundwater. More data about the wall's construction features, gaps, cracks, etc. are necessary to detail discharge into the river.

9. *Contaminants in groundwater are diluted by 5% of the 7Q10 net flow of the Cooper River before comparison with ecological and human health standards (5% x 2565 ft<sup>3</sup>/sec [72.6 m<sup>3</sup>/sec] = 128 ft<sup>3</sup>/sec [3.63 m<sup>3</sup>/sec]). The reality of the process by which surface water dilutes groundwater discharging into the Cooper River is much more complex, including factors such as variable lithology, effects of the quay wall, effects of piers on surface water flow, and tidal flux. The choice of 5% of the river's 7Q10 net flow was meant to be a conservative approximation only. Detailing the process would require complex modeling and considerably more data.*

10. *An appropriate human health screen for groundwater is EPA's Region III tap water RBCs using a total hazard quotient of 1.0. Since the focus of the fate and transport analysis was on individual chemical concentrations and behavior rather than risk, a THQ of 1.0 was considered appropriate. The many built-in conservatisms discussed above should more than make up for any possible compounding effects of multiple contaminants in environmental media.*

11. *An appropriate ecological screen for Cooper River water is EPA's saltwater surface water chronic screening values for hazardous waste sites (Supplemental Guidance to RAGS, Region 4 Bulletins: Ecological Risk Assessment, November 1995). These published values include the "Criteria to Protect Aquatic Life" incorporated by reference into SCDHEC's Water Classifications and Standards (Regulation 61-68), plus additional values.*

12. *An appropriate human health screen for Cooper River water is EPA's tap water RBCs (Region III, Risk-Based Concentration Table, June 1996). Use of these values to screen for human health concerns is extremely conservative, since they imply that the Cooper River is a drinking water source. For more realistic screening (not used in this report), EnSafe calculated "swimmer's RBCs" for incidental ingestion of river water by swimmers, fishermen, dock workers, etc.:*

- For carcinogens: Tap water RBC x 495
- For noncarcinogens: Tap water RBC x 560

<b>7.0 HUMAN HEALTH RISK ASSESSMENT</b>	1
<b>7.1 Introduction</b>	2
Section 7.1 of the Zone A RFI Report details the general guidelines used during the Zone E RFI.	3
The objectives of the human health risk assessment (HHRA) are detailed below.	4
<b>Objectives</b>	5
The objectives of the HHRA are to:	6
• Characterize the source media and determine the COPCs for affected environmental media;	7
• Identify potential receptors and quantify potential exposures for those receptors under current and future conditions for all affected environmental media;	8 9
• Qualitatively and quantitatively evaluate the adverse effects associated with the site-specific COPCs in each medium;	10 11
• Characterize the potential baseline carcinogenic risk and noncarcinogenic hazards associated with exposure to impacted environmental media at Zone E under current and future conditions;	12 13 14
• Evaluate the uncertainties related to exposure predictions, toxicological data, and resultant carcinogenic risk and noncarcinogenic hazard predictions; and	15 16
• Establish remedial goal options (RGOs) for chemicals of concern (COCs) in each environmental medium based on risk/hazard to facilitate risk management decision-making.	17 18 19

**Organization**

An HHRA, as defined by Risk Assessment Guidance for Superfund (RAGS) Part A (1989) and USEPA Region IV supplemental guidance, includes the following steps:

- *Data collection:* analyzing environmental media samples, including background/reference samples.
- *Data evaluation:* statistically analyzing analytical data to identify the nature and extent of contamination and to establish a preliminary list of COPCs based on risk-based and background screening. This list will subsequently be refined to identify COCs.
- *Exposure assessment:* identifying potential receptors under current and predicted conditions, visualizing potential exposure pathways, calculating exposure point concentrations (EPCs), and quantifying chemical intakes.
- *Toxicity assessment:* qualitatively evaluating the adverse effects of the COPCs, and quantitatively estimating the relationship between exposure and the probability of an effect.
- *Risk characterization:* combining the outputs of the exposure assessment and the toxicity assessment to quantify the total noncancer and cancer risk to the hypothetical receptors.
- *Uncertainty:* discussing and evaluating the areas of recognized uncertainty in human health risk assessments in addition to medium- and exposure pathway-specific influences.
- *Risk/Hazard Summary:* presenting and discussing the results of the quantification of exposure (risk and hazard) for the potential receptors and their exposure pathways identified under current and future conditions.

- *Remedial Goal Options:* computing exposure concentrations corresponding to risk projections within the USEPA target risk range of  $10^{-6}$  to  $10^{-4}$  for carcinogenic COCs and Hazard Quotient (HQ) goals of 0.1, 1, and 3 for noncarcinogenic COCs.

This general process was followed in preparing the HHRA for Zone E at NAVBASE.

## 7.2 Human Health Risk Assessment Methods

### 7.2.1 Data Evaluation

Section 7.3.1 of the Zone A RFI report details data evaluation and data sources used in the Zone E RFI.

### Data Validation

Section 7.3.2 of the Zone A RFI report details the data validation process used for the Zone E RFI. Data collected for the Zone E RFI were validated in accordance with the USEPA CLP Functional Guidelines and are discussed in Section 4 of this report. Complete data validation reports for the Zone E dataset are included in Appendix I.

### Management of Site-Related Data

All environmental sampling data were evaluated for usability in the quantitative HHRA. Data obtained via the following methods were not appropriate for the quantitative HHRA:

- Analytical methods that are not specific for a particular chemical, such as TOC or total organic halogen.
- Field screening instruments including total organic vapor monitoring units and organic vapor analyzers.

Because duplicate samples were collected for QA/QC, in some instances more than one analytical result existed for a single sample location. One objective of data management was to provide one result per sample location per analyte. The maximum of duplicate sample results was used as the applicable value, unless the analyte was detected in only one duplicate sample. In such cases, the detection results were used.

In addition, the HHRAs addressed limitations of analytical results by including estimated concentrations for nondetected parameters. A nondetect indicates that the analyte was not detected above the quantitation limit of the sample (*U*-qualified results), which is determined by the analytical method, the instrument used, and possible matrix interferences. However, a nondetected analyte could be present at any concentration between zero and the quantitation limit. For this reason, one-half the *U* value could serve as an unbiased estimate of the nondetect. In some cases, particularly for organic analytes, the analytical method was capable of detecting concentrations lower than the quantitation limits resulting in estimated or *J*-qualified data. One-half of each *U* value was compared to one-half of the lowest detected value (normally *J*-qualified) at the same site. The lesser of these two values was used as the best estimate of the concentration that was potentially present below the estimated quantitation limit, and was inserted into the adjusted dataset.

For inorganic chemicals, the decision rule was less complex: one-half of each *U* value represented the concentration of the corresponding sample when compiling the adjusted dataset. If two nondetects were reported for any one location (a result of QA/QC samples), one-half the lesser of the *U* values was compared to the lowest detection at the site (for organics, as above) or applied directly (for inorganics) to estimate a concentration value to be used in the Zone E RFI risk calculations. If a parameter was not detected at a SWMU/AOC, neither data management method was applied, and the parameter was not considered in screening or formal assessment.

Once the dataset was complete (i.e., after eliminating faulty data, consolidating duplicate data values, and quantifying censored values), statistical methods were used to evaluate the RFI analytical results to identify COPCs and to establish EPCs at potential receptor locations. The statistical methods used in data evaluation are discussed below. The rationale used to develop this method and the statistical techniques to implement it are based on the following sources:

- RAGS Part A
- *Statistical Methods for Environmental Pollution Monitoring* (Gilbert, 1987)
- *Supplemental Guidance to RAGS: Calculating the Concentration Term* (USEPA, 1992e)

Microsoft FoxPro, Borland Quattro Pro, and SPlus for Windows<sup>1</sup> were used to manage data and calculate statistics. For each set of data describing the concentration of chemicals in a contaminated area, the following information was tabulated: frequency of detection, range of detected values, average of detected concentrations, and the calculated 95% upper confidence limit (UCL) for the mean of log-transformed values of the concentration. In accordance with RAGS, the lesser of either the maximum concentration detected or the UCL was used to quantify potential exposure.

### 7.2.2 Selection of Chemicals of Potential Concern

The objective of this section of the HHRA is to screen the available information on the chemicals present in site samples (CPSSs) detected at each SWMU or AOC in order to develop a list or group of COPCs. COPCs are those chemicals selected by comparison with screening concentrations (risk-based and background), intrinsic toxicological properties, persistence, fate and transport characteristics, and cross-media transport potential. The nature and general extent

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<sup>1</sup> Reference to specific software products are not to be construed as an endorsement by the U.S. Navy or E/A&H.

of CPSSs at each site are detailed in Section 10 of the RFI. To reduce the list of CPSSs and thereby focus the risk assessment on COPCs, two comparisons were performed as described below.

### **Comparison of Site-Related Data to Risk-Based Screening Concentrations**

The maximum concentrations of CPSSs detected in samples were compared to risk-based screening values. These values were obtained from *Determination of COCs by Risk-Based Screening* (USEPA Region III, March 1994), and subsequent versions. The version used for Zone E was released in April 1996. As stated in the USEPA Region III document, a target HQ of 0.1 and a risk goal of  $10^{-6}$  were used to calculate screening concentrations for noncarcinogens and carcinogens, respectively. Since the recent version of USEPA Region III RBC tables uses a target HQ of 1, noncarcinogenic chemical values had to be adjusted to equate with an HQ of 0.1.

Groundwater results were compared to tap water screening values, and reported soil concentrations were compared to both industrial and residential soil ingestion screening values. The residential soil screening value for lead was set equal to 400 milligrams per kilogram (mg/kg), consistent with recent Office of Solid Waste and Emergency Response (OSWER) directives considering protection of a hypothetical child resident. The industrial soil screening value for lead was set equal to 1,300 mg/kg, as provided in the USEPA review of the Zone H RFI (submitted under a SCDHEC cover, *Review of Final RCRA Facility Investigation Report for Zone H*, May 1996), based on industrial exposure. The lead groundwater screening value used was the USEPA Office of Water treatment technique action level (AL) of 15 micrograms per liter ( $\mu\text{g/L}$ ).

A soil screening value of 1 micrograms per kilogram ( $\mu\text{g/kg}$ ) (as 2,3,7,8-TCDD toxicity equivalents [TEQs]) was applied to chlorinated dibenzodioxins and dibenzofurans, based on a worker/industrial scenario and a target risk of  $1\text{E-}04$ . USEPA Region IV has determined this to be an appropriate cleanup level although normally a residential scenario and a target risk of  $1\text{E-}06$

are the bases for screening values. USEPA develops and justifies the dioxin screening value in the comments that are referenced in the above paragraph. For groundwater, the TEQ value computed for each sample was compared to the 2,3,7,8-TCDD tap water RBC.

In accordance with recent carcinogenic polynuclear aromatic hydrocarbons (cPAH) guidance (USEPA Region IV, 1993), benzo(a)pyrene equivalents (BEQs) were computed, where appropriate, by multiplying the reported concentration of each cPAH by its corresponding toxicity equivalent factor (TEF). The BEQ values were then summed for each sample, and the total was compared to the benzo(a)pyrene RBC value during the screening process. Subsequent exposure quantification and risk/hazard projections for cPAHs in soil and groundwater used total BEQ values for each sampling location rather than individual compound concentrations.

CPSSs with maximum detected concentrations exceeding their corresponding goals, levels, and/or standards were retained for further evaluation and reference screening in the risk assessment. Screening values based on surrogate compounds were used if no screening values were available in the USEPA table. Surrogate compounds were selected based on structural, chemical, or toxicological similarities.

Additional risk-based screening was performed for the fate and transport assessment. This mechanism identified CPSSs with the potential to indirectly contribute to overall site risk through cross-media transfer. Fate and transport methods are addressed in Section 6 and site-specific discussions are in Section 10.

### **Comparison of Site-Related Data to Background Concentrations**

Soil and groundwater background concentrations were determined on a zonewide basis in Zone E, using results from the grid-based soil and groundwater background sampling locations. Surface soil, subsurface soil, shallow groundwater, and deep groundwater were all addressed separately

as discussed in Section 5 of this report. Statistical methods and rationale for determining background concentrations and comparing site data to background were proposed in the May 12, 1995, technical memorandum *Proposed Method for Comparing Site Sample Values to Background Values for Surface and Subsurface Soils I: Inorganics* (E/A&H, May 1995). USEPA Region IV and SCDHEC approved this technical approach. After risk- and hazard-based screening values were compared, CPSSs whose maximum detected concentrations exceeded corresponding background concentrations, or whose overall site concentrations were significantly greater than corresponding overall background concentrations as determined by Wilcoxon rank sum test procedures, were retained for further consideration as COPCs in the HHRA. The two statistical background comparisons were conducted as parallel analyses. If either method suggested that site-specific concentrations deviated from naturally occurring levels, the chemical was retained for formal risk assessment. These comparisons help account for chemicals that are common in nature, such as aluminum, manganese, and arsenic. By virtue of this process, risk and/or hazard associated with naturally occurring chemicals is not addressed where their concentrations are below corresponding background.

The background concentration is a fixed value determined to represent the upper bound of naturally occurring levels for a chemical in a specific matrix. Comparisons using background concentrations are most effective in identifying "hot spots" or limited areas with pronounced impacts. Population tests, in this case performed using the Wilcoxon rank sum method, are used to determine whether values from one population (the site samples) are consistently higher or lower than those from another (the background dataset). Ideally, population tests identify general elevations in chemical concentrations absent definable hot spots. Section 5 discusses statistical methods, upper tolerance limit (UTL) calculations, Wilcoxon rank sum test outputs, and general background sample information. In the RFI, if the maximum concentration of a CPSS was determined to be less than either background (via background concentration comparison *and* population test) or the risk-based screening value, the CPSS was not considered further in the risk

assessments unless deemed appropriate based on chemical-specific characteristics (e.g., degradation product with greater toxicity).

**Elimination of Essential Elements: Calcium, Iron, Magnesium, Potassium, and Sodium**

In accordance with RAGS Part A, essential elements that are potentially toxic only at extremely high concentrations may be eliminated from further consideration as COPCs in a risk assessment. Specifically, an essential nutrient may be screened out of a risk assessment if it is present at concentrations that are not associated with adverse health effects. Based on RAGS, the lack of risk-related data, and USEPA Region IV's recommendations, the following essential nutrients were eliminated from the human health risk assessment: calcium, iron, magnesium, potassium, and sodium.

**Summary of COPCs**

The results of the screening evaluations are presented on a medium-specific basis in each HHRA in Section 10. In summary, the risk information usually obtained from the Integrated Risk Information System (IRIS) or Health Effects Assessment Summary Tables (HEAST) is necessary to calculate risk and hazard estimates (and risk-based screening values). This information is based on toxicological and epidemiological data which are critiqued and approved by the scientific and regulatory community (i.e., listed in IRIS and/or HEAST). Risk or hazard could not be calculated for some CPSS due to lack of risk information for those chemicals. For each environmental medium sampled at a SWMU or AOC, the data were screened using risk-based and background values. The results of the screening process are tabulated in each HHRA. Chemicals determined to be COPCs through the screening process are designated with an asterisk. Total isomer concentrations reported for chlorinated dibenzodioxins and dibenzofurans (e.g., Total HxCDD) were not specifically used in formal assessment per USEPA protocol. No toxicological data, and therefore no risk-based screening values, are available for the generic group of total petroleum

hydrocarbons (TPH). As a result, TPH assessment was handled consistent with state underground storage tank (UST) regulations and the NAVBASE soil AL of 100 mg/kg.

### **7.2.3 Exposure Assessment**

This section of the HHRA determines the magnitude of contact that a potential receptor may have with site-related COPCs. Exposure assessment involves four stages:

- Characterizing the physical setting and land use of the site;
- Identifying COPC release and migration pathway(s);
- Identifying the potential current and future receptors, under various land use or site condition scenarios, and the pathways through which they might be exposed; and
- Quantifying the intake rates, or contact rates, of COPCs.

### **Exposure Setting and Land Use**

This section of each HHRA describes the basic layout of the SWMU or AOC as well as the suspected source(s) of contamination. Where multiple SWMUs and AOCs were combined for the RFI, the rationale for grouping is discussed. The future use of the site is discussed if information was available. Zone E is described in the RFI work plan as a highly secured area surrounded by a perimeter fence. For the last 50 years, significant portions of Zone E have been and remain covered with asphalt, buildings, and concrete surfaces. Base reuse plans call for the Zone E area to remain a marine terminal and drydocking facility maintaining most of the current features. Figures 7.2.1 through 7.2.11 are aerial photographs showing surface conditions in Zone E. These figures define the areas covered with asphalt, concrete, and/or buildings, supporting exposure potentials used in the site-specific risk assessments.



### ZONE E - LAND COVER

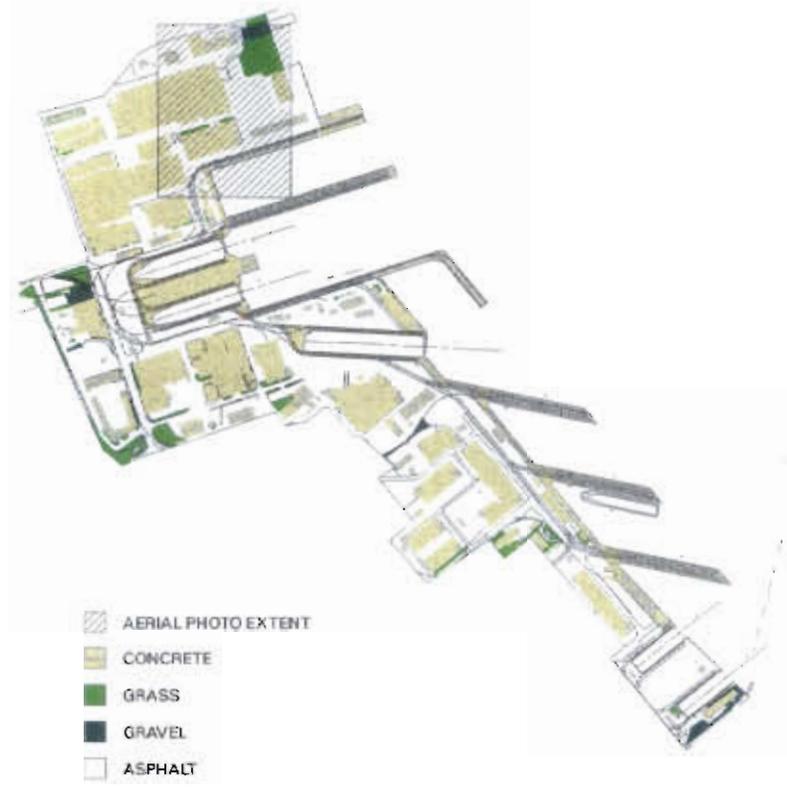
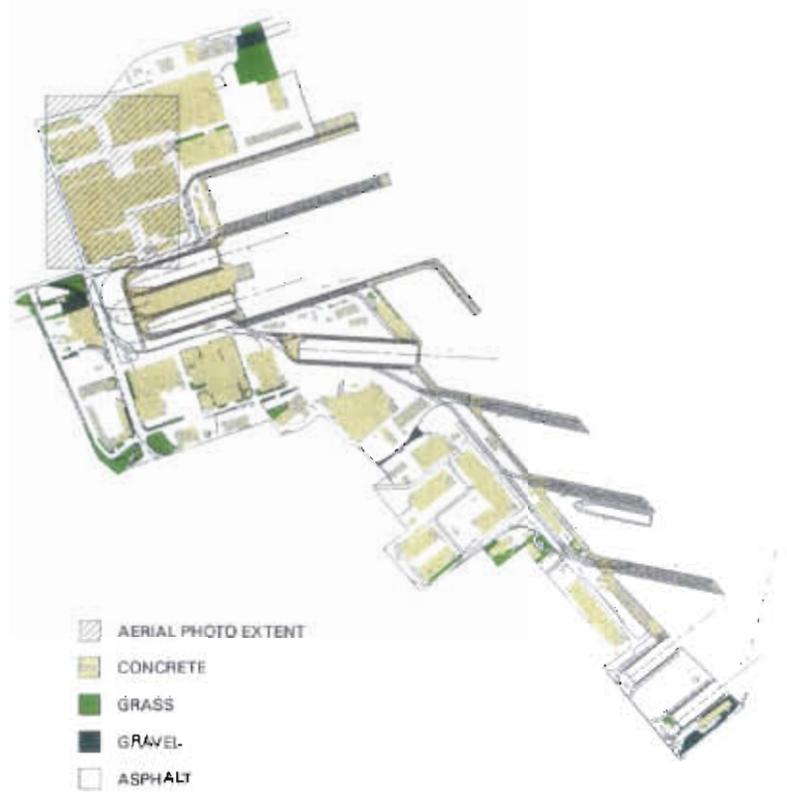




PHOTO SCALE



### ZONE E - LAND COVER





### ZONE E - LAND COVER

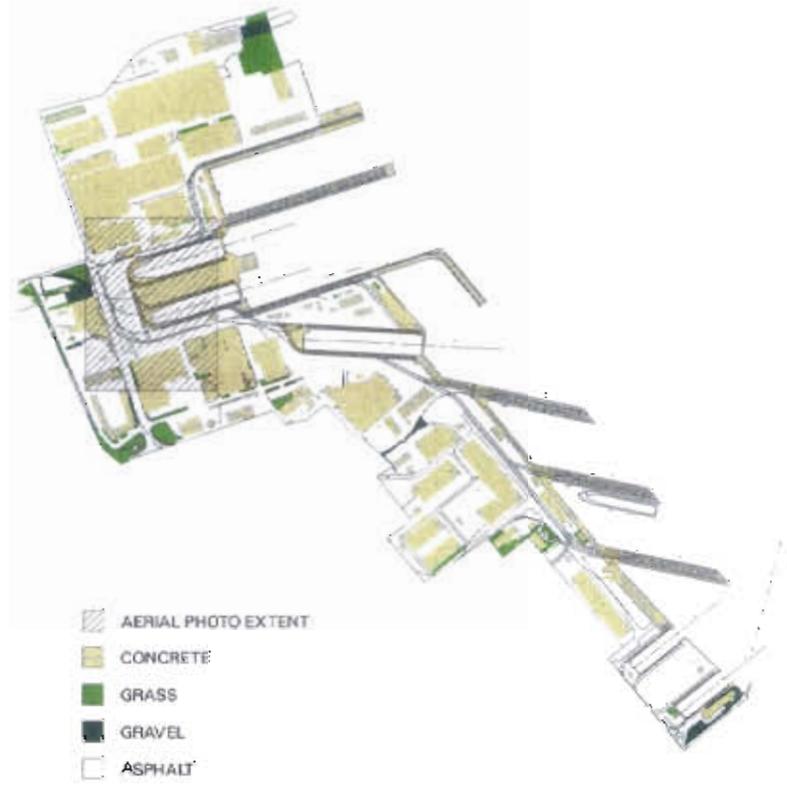


PHOTO SCALE





### ZONE E - LAND COVER



NAVAL BASE CHARLESTON  
ZONE E RFI REPORT  
CHARLESTON, S.C.

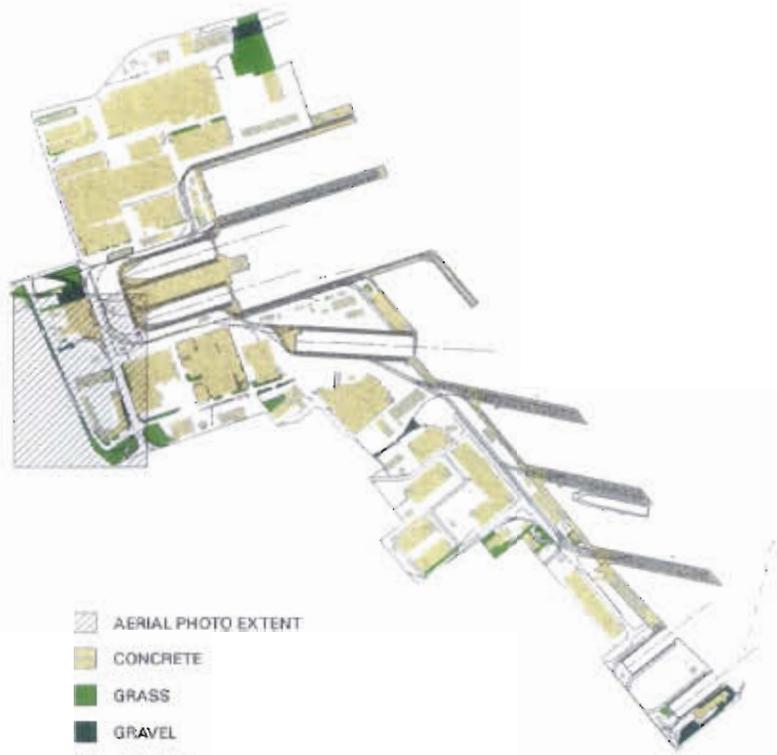
FIGURE 7.2.4  
ZONE E  
SURFACE CONDITIONS



PHOTO SCALE



### ZONE E - LAND COVER



-  AERIAL PHOTO EXTENT
-  CONCRETE
-  GRASS
-  GRAVEL
-  ASPHALT

 NAVAL BASE CHARLESTON  
ZONE E RFI REPORT  
CHARLESTON, S.C.

FIGURE 7.2.5  
ZONE E  
SURFACE CONDITIONS



### ZONE E - LAND COVER



-  AERIAL PHOTO EXTENT
-  CONCRETE
-  GRASS
-  GRAVEL
-  ASPHALT

PHOTO SCALE



 NAVAL BASE CHARLESTON  
ZONE E RFI REPORT  
CHARLESTON, S.C.

FIGURE 7.2.6  
ZONE E  
SURFACE CONDITIONS



### ZONE E - LAND COVER



-  AERIAL PHOTO EXTENT
-  CONCRETE
-  GRASS
-  GRAVEL
-  ASPHALT

PHOTO SCALE



NAVAL BASE CHARLESTON  
ZONE E RFI REPORT  
CHARLESTON, S.C.

FIGURE 7.2.7  
ZONE E  
SURFACE CONDITIONS



PHOTO SCALE



### ZONE E - LAND COVER



-  AERIAL PHOTO EXTENT
-  CONCRETE
-  GRASS
-  GRAVEL
-  ASPHALT

 NAVAL BASE CHARLESTON  
ZONE E RFI REPORT  
CHARLESTON, S.C.

FIGURE 7.2.8  
ZONE E  
SURFACE CONDITIONS



PHOTO SCALE



### ZONE E - LAND COVER



NAVAL BASE CHARLESTON  
 ZONE E RFI REPORT  
 CHARLESTON, S.C.

FIGURE 7.2 B  
 ZONE E  
 SURFACE CONDITIONS

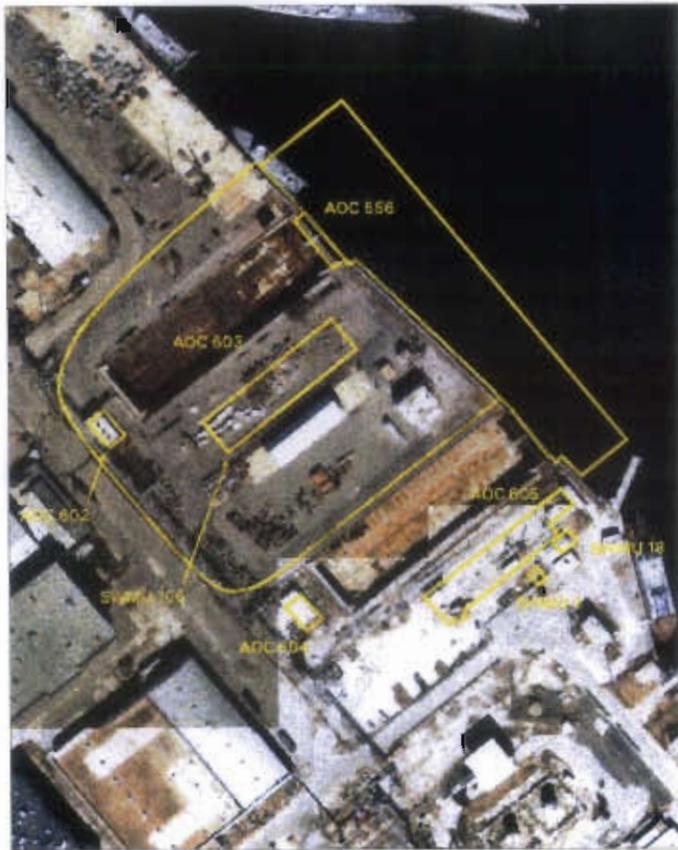


PHOTO SCALE:



### ZONE E - LAND COVER




 NAVAL BASE CHARLESTON  
 ZONE E RFI REPORT  
 CHARLESTON, S.C.

FIGURE 7.2.10  
 ZONE E  
 SURFACE CONDITIONS



PHOTO SCALE



### ZONE E - LAND COVER



NAVAL BASE CHARLESTON  
ZONE E RFI REPORT  
CHARLESTON, S.C.

FIGURE 7.2.11  
ZONE E  
SURFACE CONDITIONS

Features such as asphalt surfaces, buildings, fixed machinery, and fences would prevent and/or minimize current exposures to impacted media. Future exposures to impacted media would be minimized if these features are maintained under base reuse plans. As part of each site-specific HHRA, the potential influences of site features on exposure were evaluated. Where site features affect how an individual might be exposed, detailed analyses were performed to calculate alternative EPCs and to derive factors to account for fraction ingested/contacted (FI/FC) from the contaminated source. Current features are assessed as an additional exposure scenario within the quantification of exposure and risk characterization sections of the site-specific HHRA.

### **Potentially Exposed Populations**

In each site-specific HHRA, this section describes who may be exposed to contaminants in environmental media. For the Zone E HHRA, the potentially exposed populations addressed were current and future site workers, as well as hypothetical future site residents. The adolescent trespassers will not be significantly exposed to Zone E site conditions due to the perimeter fence and the limited area of exposed soil. Worker-related exposure was addressed exclusively for maximally exposed future site workers, since current workers at most Zone E sites would be expected to have limited contact with contaminated media. The future site worker scenario assumes that groundwater exposures will include both ingestion and inhalation via showering. This approach, while providing a reasonably conservative assessment of future site worker risk/hazard, also renders a highly conservative approximation of risk/hazard for current site workers. It also accounts for the fact that the specific nature of future industrial uses cannot be definitively stated.

### **Exposure Pathways**

This section of each HHRA summarizes how potential receptors (site workers, residents, etc.) may be exposed to contaminated media. In general, soil matrix-related pathways include incidental

ingestion and dermal contact. For groundwater, ingestion and inhalation of volatilized contaminants were the primary exposure pathways evaluated.

### Exposure Point Concentrations

The EPC is the concentration of a contaminant in an exposure medium that will be contacted by a real or hypothetical receptor. Determining the EPC depends on factors such as:

- Availability of data
- Amount of data available to perform statistical analysis
- Reference concentrations not attributed to site impacts
- Location of the potential receptor

USEPA Region IV guidance calls for assuming lognormal distributions for environmental data and calculating the 95% UCL for the mean of concentrations to quantify exposure. Applying the UCL is generally inappropriate with fewer than 10 samples, so the maximum concentration detected was used for each dataset with fewer than 10 samples. In general, outliers were included when calculating the UCL because high values seldom appear as outliers for a lognormal distribution. Including outliers increases the overall uncertainty of the calculated risk and conservatively biases the estimate of the human health threat.

For sample sets of 10 and greater, the UCL was calculated for a lognormal distribution as follows:

$$\left( \bar{a} + 0.5s_a^2 + \frac{H_{0.95} \times s_a}{\sqrt{n-1}} \right)$$

UCL = e

where:

- $\bar{a}$  =  $a/n$  = sample arithmetic mean of the log-transformed data,  $a = \ln(x)$  1  
 $s_a$  = sample standard deviation of the log-transformed data 2  
 $n$  = number of samples in the dataset 3  
 $H_{0.95}$  = value for computing the one-sided 95% upper confidence limit for a 4  
lognormal mean from standard statistical tables (Gilbert, 1987) 5

The calculated values for the 95% UCL are tabulated (where applicable) in each HHRA. The tables statistically summarize COPCs identified in each environmental medium. Included for each COPC are the number of samples analyzed, mean and standard deviation of the natural log-transformed data (including the nondetect values), the H-statistic, the maximum of detected concentrations, and background concentrations (where available). For media from which fewer than 10 samples were collected, the maximum of positive detections of each COPC identified was used as the EPC to compute exposure.

Modified EPCs were calculated for some SWMUs/AOCs because site features or skewed contaminant distributions had to be considered in quantifying exposure potential. The modified EPCs were derived to account for the fraction of impacted areas covered with asphalt surface, buildings, and the like. Should site features be maintained under the future industrial use, direct exposure to affected areas (surface soil) would be effectively precluded. In some instances, factors were derived to modify the EPC to account for the FI/FC from the contaminated source. This approach was used where impacts were found to be extremely limited in areal extent (hot spots). Where this approach was taken, the basis for the decision is discussed in the site-specific HHRA.

As previously discussed in Section 7.2.1 of this document, analytical results are presented as "nondetects" whenever chemical concentrations in samples do not exceed the detection or quantitation limits for the analytical procedures as applied to each sample. Generally, the

quantitation limit is the lowest concentration of a chemical that can be reliably quantified above the normal, random noise of an analytical instrument or method. To apply the above-mentioned statistical procedures to a dataset with reported nondetects for organic compounds, the lesser of one-half of the nondetect value for the sample or one-half of the lowest *J*-qualified value at the site was assumed to be the applicable default concentration. For inorganic chemicals, one-half of the nondetect value was assumed to be the applicable concentration. Using this method is a reasonable compromise between use of zero and using the sample quantitation limit, to reduce the bias (positive or negative) in the calculated UCL.

### **Quantification of Exposure**

This section describes the models, equations, and input parameter values used to quantify doses or intakes of the COPCs for the surface soil and groundwater exposure pathways. The models are designed to estimate route- and medium-specific factors, which are multiplied by the EPC to estimate chronic daily doses. The intake model variables generally reflect 50th or 95th percentile values which, when applied to the EPC, ensure that the estimated intakes represent the reasonable maximum exposure (RME). Formulae were derived from RAGS Part A unless otherwise indicated. Table 7.2.1 lists input parameters used to compute chronic daily intake (CDI) for potential receptors exposed to surface soil and/or groundwater contaminants. These soil and groundwater pathway assumptions were applied for each SWMU and AOC in Zone E. Where other exposure routes/pathways were found (or predicted) to exist, additional exposure quantification formulae are presented. Because Zone E is part of the Base Closure and Realignment Act (BRAC) III, future site use cannot be assumed with any certainty. Therefore, conservative assumptions were used to account for any reasonable future use. Zone E media analytical results and exposure methods have been formatted to allow for fine-tuning of exposure estimates based on actual conditions as base reuse plans materialize.

Age-adjusted ingestion factors were derived for the potential future residential receptors (resident adult and resident child combined) for carcinogenic endpoints. These factors consider the difference in daily ingestion rates for soil and drinking water, body weights, and exposure durations for children (ages 1 to 6) and adults (ages 7 to 30). The exposure frequency is assumed to be identical for the adult and child exposure groups.

**Table 7.2.1  
 Parameters Used to Estimate CDI at RME**

Pathway Parameters	Resident Adult	Resident Child	Adult Worker	Units
<b>Surface Soil Ingestion and Dermal Contact</b>				
Ingestion Rate (soil)	100 <sup>a</sup>	200 <sup>a</sup>	50 <sup>a</sup>	mg/day
Ingestion Rate (water)	2	1	1	L/day
Exposure Frequency	350 <sup>b</sup>	350 <sup>b</sup>	250 <sup>b</sup>	days/year
Exposure Duration	24 <sup>c</sup>	6 <sup>c</sup>	25 <sup>c</sup>	years
Dermal Contact Area	4,100 <sup>d</sup>	2,900 <sup>d</sup>	4,100 <sup>d</sup>	cm <sup>2</sup>
Skin Adherence Factor	1	1	1	mg/cm <sup>2</sup>
Absorbance Factor	0.01 (organics) 0.001 (inorganics)	0.01 (organics) 0.001 (inorganics)	0.01 (organics) 0.001 (inorganics)	unitless
Dermal Adjustment Factor	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	unitless
Conversion Factor	1E-6	1E-6	1E-6	kg/mg
Body Weight	70 <sup>a</sup>	15 <sup>a</sup>	70 <sup>a</sup>	kg

**Table 7.2.1  
 Parameters Used to Estimate CDI at RME**

Pathway Parameters	Resident Adult	Resident Child	Adult Worker	Units
<b>Surface Soil Ingestion and Dermal Contact</b>				
Averaging Time, Noncancer	8,760 <sup>e</sup>	2,190 <sup>e</sup>	9125 <sup>c</sup>	days
Averaging Time, Cancer	25,550 <sup>f</sup>	25,550 <sup>f</sup>	25,550 <sup>f</sup>	days

**Notes:**

- a = USEPA (1989a) "Risk Assessment Guidance for Superfund Vol. I, Human Health Evaluation Manual (Part A)."
- b = USEPA (1991b) "Risk Assessment Guidance for Superfund Vol. I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors," Interim Final, OSWER Directive: 9285.6-03.EPA/600/8-89/043.
- c = USEPA (1991a), "Risk Assessment Guidance for Superfund: Vol. I – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)," OSWER Directive 9285.7-01B.
- d = Resident Adult accounts for head, hands, and forearms at 90th percentile values from Table 4B.1, Exposure Factors Handbook; assumes individual is clothed with shoes, long pants, and short sleeves; rounded up from 4,090 cm<sup>2</sup>.  
  
 Resident Child accounts for head, hands, forearms, lower leg, and feet using 90th percentile total body surface area values for male children 1 to 6 year olds (6,000 cm<sup>2</sup> assumed for 1 to 2 years old); because individual body part information is not available for 5 to 6 year olds, mean of other groups was assumed. Forearm surface area set equal to 46% of full arm; lower leg set equal to 41% of full leg measurement.
- e = Calculated as the product of exposure duration (years) x 365 days/year.
- f = Calculated as the product of 70 years (assumed lifetime) x 365 days per year.
- NA = Not applicable
- mg/day = milligrams per day
- L/day = liters per day
- mg/cm<sup>2</sup> = milligrams per square centimeters
- kg/mg = kilograms per milligram

**Surface Soil Pathway Exposure — Ingestion**

The following equation is used to estimate the ingestion of COPCs in soil:

$$CDI_s = (C_s)(IR)(EF)(ED)(F)(FI)/(BW)(AT)$$

1  
2  
3  
4

where:

$CDI_s$	= ingested dose (mg/kg-day)	1
$C_s$	= concentration of contaminant in soil (mg/kg)	2
IR	= ingestion rate (mg/day)	3
EF	= exposure frequency (days/year)	4
ED	= exposure duration (years)	5
F	= conversion factor ( $10^{-6}$ kg/mg)	6
FI	= fraction ingested from contaminated source (unitless)	7
BW	= body weight (kg)	8
AT	= averaging time (days)	9

**Surface Soil Pathway Exposure — Dermal Contact**

The following equation is used to estimate intake due to dermal contact with COPCs in soil:

$$CDI_{sd} = (C_s)(DCA)(EF)(ED)(F)(FC)(ABS)(AF)/(BW)(AT)$$

where:

$CDI_{sd}$	= dermal dose (mg/kg-day)	11
$C_s$	= concentration of contaminant in soil (mg/kg)	12
DCA	= dermal contact area (cm <sup>2</sup> )	13
EF	= exposure frequency (days/year)	14
ED	= exposure duration (years)	15
F	= conversion factor ( $10^{-6}$ kg/mg)	16
FC	= fraction contacted from contaminated source (unitless)	17
ABS	= absorption factor (unitless value, specific to organic versus inorganic compounds)	18
AF	= adherence factor (mg/cm <sup>2</sup> )	19
BW	= body weight (kg)	20
AT	= averaging time (days)	21

**Groundwater Pathway Exposure — Ingestion and Inhalation**

The following equation is used to estimate the ingestion and/or inhalation of COPCs in groundwater:

$$CDI_w = (C_w)(IR)(EF)(ED)(FI)/(BW)(AT)$$

**where:**

$CDI_w$	=	ingested/inhaled dose (mg/kg-day)	2
$C_w$	=	concentration of contaminant in water (mg/L)	3
IR	=	ingestion rate (L/day)	4
EF	=	exposure frequency (days/year)	5
ED	=	exposure duration (years)	6
FI	=	fraction ingested from contaminated source (unitless)	7
BW	=	body weight (kg)	8
AT	=	averaging time (days)	9

Figures 7.2.12 and 7.2.13 provide the formulae for calculating the CDI for soil pathways for residential and industrial scenarios, respectively. Figure 7.2.14 provides formulae for calculating the CDI for groundwater exposure pathways for industrial and residential scenarios. Tables provided in each SWMU or AOC HHRA quantify exposure to environmental media through all applicable pathways. Future site worker and hypothetical site resident exposure projections are provided separately. In accordance with USEPA guidance, the potential exposure to volatiles originating from groundwater during showering and domestic use has been estimated to be equivalent to that ingested through consumption of 2 liters/day of contaminated groundwater. Although the inhalation CDI computed on this basis is equal to that for ingestion exposures, risk and/or hazard associated with inhaled volatile contaminants are characterized using toxicological values specific to the inhalation pathway (e.g., inhalation slope factors [SFs] and reference doses [RfDs]).

#### 7.2.4 Toxicity Assessment

##### Carcinogenicity and Noncancer Effects

Section 7.3.7 of the Zone A RFI report details the toxicity assessment process used for the Zone E RFI.

Figure 7.2.12  
 Formulae for Calculating CDI for Soil – Residential Scenario

**SOIL INGESTION PATHWAY**

**Noncarcinogens**

$$CDI_{NC-C} = \frac{C_s \cdot IR_{soil/child} \cdot EF_{res} \cdot F \cdot FI \cdot ED_{child}}{AT_{NC-C} \cdot BW_{child}} \qquad CDI_{NC-A} = \frac{C_s \cdot IR_{soil/adult} \cdot EF_{res} \cdot F \cdot FI \cdot ED_{adult}}{AT_{NC-A} \cdot BW_{adult}}$$

**Carcinogens (based on a lifetime weighted average) -**

$$CDI_C = \frac{C_s}{AT_C} \left[ \frac{IR_{soil/child} \cdot EF_{res} \cdot F \cdot FI \cdot ED_{child}}{BW_{child}} + \frac{IR_{soil/adult} \cdot EF_{res} \cdot F \cdot FI \cdot ED_{adult}}{BW_{adult}} \right]$$

**SOIL DERMAL CONTACT PATHWAY**

**Noncarcinogens**

$$CDI_{NC-C} = \frac{C_s \cdot DCA_{soil/child} \cdot EF_{res} \cdot F \cdot FC \cdot AF \cdot ABS \cdot ED_{child}}{AT_{NC-C} \cdot BW_{child}} \qquad CDI_{NC-A} = \frac{C_s \cdot DCA_{soil/adult} \cdot EF_{res} \cdot F \cdot FC \cdot AF \cdot ABS \cdot ED_{adult}}{AT_{NC-A} \cdot BW_{adult}}$$

**Carcinogens (based on a lifetime weighted average) -**

$$CDI_C = \frac{C_s}{AT_C} \left[ \frac{DCA_{soil/child} \cdot EF_{res} \cdot F \cdot FC \cdot AF \cdot ABS \cdot ED_{child}}{BW_{child}} + \frac{DCA_{soil/adult} \cdot EF_{res} \cdot F \cdot FC \cdot AF \cdot ABS \cdot ED_{adult}}{BW_{adult}} \right]$$

Variable	Description
$C_s$	chemical concentration in surface soil (mg/kg)
$CDI_{NC-C}$	chronic daily intake - noncancer child
$CDI_{NC-A}$	chronic daily intake - noncancer adult
$CDI_C$	chronic daily intake - cancer (lifetime weighted average)
$BW_{child}$	average child body weight (ages 1-6) (kg)
$BW_{adult}$	average adult body weight (kg)
ABS	absorbance factor (unitless value specific to organic versus inorganic compounds)
AF	adherence factor (1 mg/cm <sup>2</sup> )
$ED_{child}$	child exposure duration during; ages 1-6 (yr)
$ED_{adult}$	adult exposure duration during; ages 7-30 (yr)
$EF_{res}$	residential exposure frequency (days/year)
$IR_{soil/child}$	child soil intake rate (mg/day)
$IR_{soil/adult}$	adult soil intake rate (mg/day)
FC	fraction contacted from contaminated source (unitless)
$DCA_{soil/child}$	child soil dermal contact area (cm <sup>2</sup> )
$DCA_{soil/adult}$	adult soil dermal contact area (cm <sup>2</sup> )
$AT_C$	averaging time (carcinogen)
$AT_{NC-A}$	averaging time (noncarcinogen adult)
$AT_{NC-C}$	averaging time (noncarcinogen child)
FI/FC	fraction ingested/contacted from contaminated source (unitless)
F	conversion factor (10 <sup>-6</sup> kg/mg)

Figure 7.2.13  
 Formulae for Calculating CDI for Soil – Worker Scenario

**SOIL INGESTION PATHWAY**

*Noncarcinogens*

$$CDI_{NC-W} = \frac{C_s * IR_{soil/worker} * EF_w * F * FI * ED_w}{AT_{NC-W} * BW_w}$$

*Carcinogens (based on a lifetime weighted average)*

$$CDI_C = \frac{C_s * IR_{soil/worker} * EF_w * F * FI * ED_w}{BW_w * AT_C}$$

**SOIL DERMAL CONTACT PATHWAY**

*Noncarcinogens*

$$CDI_{NC-W} = \frac{C_s * DCA_{soil/worker} * EF_w * F * FC * AF * ABS * ED_w}{AT_{NC-W} * BW_w}$$

*Carcinogens (based on a lifetime weighted average)*

$$CDI_C = \frac{C_s * DCA_{soil/worker} * EF_w * F * FC * AF * ABS * ED_w}{AT_C * BW_w}$$

Variable	Description
$CDI_{NC-W}$	chronic daily intake - noncancer worker
$CDI_C$	chronic daily intake - cancer (lifetime weighted average)
$BW_{worker}$	average adult body weight (kg)
ABS	absorbance factor (unitless value specific to organic versus inorganic compounds)
AF	adherence factor (1 mg/cm <sup>2</sup> )
$ED_w$	exposure duration; worker (yr)
$EF_w$	worker exposure frequency (days/year)
$IR_{soil/worker}$	worker soil intake rate (mg/day)
FC	fraction contacted from contaminated source (unitless)
$DCA_{soil/worker}$	worker soil dermal contact area (cm <sup>2</sup> )
$AT_C$	averaging time (carcinogen)
$AT_{NC-W}$	averaging time (noncarcinogen worker)
$C_s$	chemical concentration in surface soil (mg/kg)
FI/FC	fraction ingested/contacted from contaminated source (unitless)
F	conversion factor (10 <sup>-6</sup> kg/mg)

Figure 7.2.14  
 Formulae for Calculating CDI for Groundwater

**GROUNDWATER INGESTION PATHWAY**

**Residential Scenario**

*Noncarcinogens*

$$CDI_{NC-C} = \frac{C_w \cdot IR_{water/child} \cdot EF_{res} \cdot FI \cdot ED_{child}}{AT_{NC-C} \cdot BW_{child}}$$

$$CDI_{NC-A} = \frac{C_w \cdot IR_{water/adult} \cdot EF_{res} \cdot FI \cdot ED_{adult}}{AT_{NC-A} \cdot BW_{adult}}$$

*Carcinogens (based on a lifetime weighted average)*

$$CDI_C = \frac{C_w}{AT_C} \left\{ \frac{IR_{water/child} \cdot EF_{res} \cdot FI \cdot ED_{child}}{BW_{child}} + \frac{IR_{water/adult} \cdot EF_{res} \cdot FI \cdot ED_{adult}}{BW_{adult}} \right\}$$

**Worker Scenario**

*Noncarcinogens*

$$CDI_{NC-w} = \frac{C_w \cdot IR_{water/worker} \cdot EF_w \cdot FI \cdot ED_w}{AT_{NC-w} \cdot BW_w}$$

*Carcinogens (based on a lifetime weighted average)*

$$CDI_C = \frac{C_w \cdot IR_{water/worker} \cdot EF_w \cdot FI \cdot ED_w}{AT_C \cdot BW_w}$$

**GROUNDWATER INHALATION WHILE SHOWERING**

In accordance with Technical Memorandum Guidance on Estimating Exposure to VOCs During Showering, USEPA/ORD, July 10, 1991:

$$CDI_{ingestion} = CDI_{inhalation}$$

Variable	Description
$C_w$	chemical concentration in groundwater (mg/L)
$CDI_{NC-C}$	chronic daily intake - noncancer child (mg/kg-day)
$CDI_{NC-A}$	chronic daily intake - noncancer adult (mg/kg-day)
$CDI_{NC-w}$	chronic daily intake - noncancer worker (mg/kg-day)
$CDI_C$	chronic daily intake - cancer (mg/kg-day)
$BW_{child}$	average child body weight (ages 1-6) (kg)
$BW_{adult}$	average adult body weight (kg)
$BW_w$	average worker body weight (kg)
$ED_{child}$	child exposure duration during ages 1-6 (yr)
$ED_{adult}$	adult exposure duration during ages 7-30 (yr)
$ED_w$	adult worker exposure duration (yr)
$EF_{res}$	residential exposure frequency (days/year)
$EF_w$	worker exposure frequency (days/year)
$IR_{water/child}$	child water intake rate (L/day)
$IR_{water/adult}$	adult water intake rate (L/day)
$IR_{water/worker}$	worker water intake rate (L/day)
$FI$	fraction ingested from contaminated source (unitless)
$AT_C$	averaging time (carcinogen)
$AT_{NC-A}$	averaging time (noncarcinogen adult)
$AT_{NC-C}$	averaging time (noncarcinogen child)
$AT_{NC-w}$	averaging time (noncarcinogen worker)

### **7.2.5 Risk Characterization**

Risk characterization combines the results of the exposure assessment and toxicity assessment to yield qualitative and quantitative expressions of risk and/or hazard for the exposed receptors. The quantitative component estimates the probability of developing cancer, or compares estimated dose with an RfD for noncancer effects. These quantitative estimates are developed for individual chemicals, exposure pathways, transfer media, and source media, and for each receptor for all media to which one may be exposed. The qualitative component usually involves comparing COC concentrations in media with established criteria or standards for chemicals for which there are no corresponding toxicity values. The risk characterization is used to guide risk management decisions.

Generally, the risk characterization follows the method prescribed by RAGS Part A, as modified by more recent information and supplemental guidance cited earlier. The USEPA methods are, appropriately, designed to be health-protective, and tend to overestimate, rather than underestimate, risk. The risk results, therefore, are generally overly conservative, because risk characterization involves multiplying the conservative assumptions built into the exposure and toxicity assessments.

This section of each HHRA characterizes the potential excess health risks associated with the intake of chemicals originating from the respective site. The USEPA methods used to estimate the types and magnitudes of health effects associated with exposure to chemicals have been supplemented, where appropriate, by graphical representations of risk and hazard. This supplemental information is presented to more clearly depict the problem areas at the relevant sites on scales specific to individual sampling locations.

### **Risk Characterization Method**

Potential excess risk to humans following exposure to COPCs is estimated using methods established by USEPA, when available. These health-protective methods are likely to overestimate risk. Risk from hazardous chemicals is calculated for either carcinogenic or noncarcinogenic effects. Some carcinogenic chemicals may also pose a noncarcinogenic hazard. The potential human health effects associated with chemicals that produce systemic toxic and carcinogenic influences are characterized for both types of health effects. As mentioned in Section 7.2.6, inhalation exposure-related risk and hazard were computed using appropriate route-specific (inhalation) SFs and RfDs (where available).

Unlike the methods for estimating inhaled or ingested dose of COPCs, which quantify the dose presented to the barrier membranes (the pulmonary or gastrointestinal mucosa, respectively), dermal dose is estimated as that which crosses the skin and is systemically absorbed. For this reason, oral toxicity values must be adjusted to reflect the dermally absorbed dose.

Dermal RfD values and SFs are derived from the corresponding oral values. In deriving a dermal RfD, the oral RfD is multiplied by an oral absorption factor (ABF), expressed as a decimal fraction. The resulting dermal RfD is based on the absorbed dose, the appropriate value with which to compare a dermal dose, because dermal doses are expressed as absorbed rather than administered (intake) doses. For the same reasons, a dermal SF is derived by dividing the oral SF by the ABF. The oral SF is divided rather than multiplied because SFs are expressed as reciprocal doses.

Appendix A of RAGS Part A states that in the absence of specific data, an assumption of 5% oral absorption efficiency would be relatively conservative. Supplemental Guidance to RAGS: Region IV Bulletin indicates that in the absence of specific data, USEPA Region IV suggests an oral- to dermal-absorption factor of 80% for VOCs, 50% for SVOCs, and 20% for inorganics.

These percentages (or associated fractions) were used in the HHRA and are reflected in the applicable risk/hazard results.

### Carcinogenic Effects of Chemicals

The risk attributed to exposure to carcinogens is estimated as the probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. In the low-dose range, which would be expected for most environmental exposures, cancer risk is estimated from the following linear equation (RAGS Part A):

$$ILCR = (CDI)(SF)$$

where:

ILCR = incremental lifetime excess cancer risk, a unitless expression of the probability of developing cancer, adjusted for reference incidence

CDI = chronic daily intake, averaged over 70 years (mg/kg-day)

SF = cancer slope factor (mg/kg-day)<sup>-1</sup>

For a given pathway with simultaneous exposure of a receptor to several carcinogens, the following equation is used to sum cancer risks:

$$Risk_p = ILCR(chem_1) + ILCR(chem_2) + \dots ILCR(chem_n)$$

where:

Risk<sub>p</sub> = total pathway risk of cancer incidence

ILCR(chem<sub>i</sub>) = incremental lifetime excess cancer risk for a specific chemical

Cancer risk for a given receptor across pathways and across media is summed in the same manner.

## Noncarcinogenic Effects of Chemicals

The risks associated with the noncarcinogenic effects of chemicals are evaluated by comparing an exposure level or intake with a reference dose. The HQ, defined as the ratio of intake to RfD, is defined as (RAGS Part A):

$$HQ = CDI/RfD$$

### where:

- HQ = hazard quotient (unitless)
- CDI = intake of chemical (mg/kg-day)
- RfD = reference dose (mg/kg-day)

Chemical noncarcinogenic effects are evaluated on a chronic basis, using chronic RfD values. An HQ of unity or 1 indicates that the estimated intake equals the RfD. If the HQ is greater than unity, potential adverse health effects may be a concern.

For simultaneous exposure of a receptor to several chemicals, an HI will be calculated as the sum of the HQs by:

$$HI = HQ_1 + HQ_2 + \dots HQ_n$$

### where:

- HI = Hazard Index (unitless)
- HQ = Hazard Quotient (unitless)

Risk and hazard projections are tabulated for each medium following the general discussions of risk and hazard quantification methods. For most SWMUs and AOCs, the following subsections are included.

### **Surface Soil Pathways**

This section of each HHRA summarizes estimated surface soil risk/hazard for each receptor group. In addition, the primary contributors to carcinogenic risk and/or noncarcinogenic hazard are discussed.

### **Groundwater Pathways**

This section of each HHRA summarizes estimated groundwater risk/hazard for each receptor group. In addition, the primary contributors to carcinogenic risk and/or noncarcinogenic hazard are discussed.

### **Other Applicable Pathways**

This section appears in HHRA's for sites where pathways other than soil and groundwater were identified. It summarizes estimated risk/hazard for each receptor group and discusses the primary contributors to carcinogenic risk and/or noncarcinogenic hazard.

### **COCs Identified**

This section summarizes the outcome of risk/hazard projections by identifying COCs for each impacted environmental medium. COCs are identified for each medium based on cumulative (all pathway) risk and hazard projected for each site, and are tabulated (where necessary). USEPA has established a generally acceptable risk range of  $10^{-4}$  to  $10^{-6}$ , and an HI threshold of 1.0 (unity). In Zone E HHRA's, a COC was considered to be any chemical contributing to a cumulative risk level of  $10^{-6}$  or greater and/or a cumulative HI above 1.0, and whose individual ILCR exceeds  $10^{-6}$  or whose HQ exceeds 0.1. For carcinogens, this approach is relatively conservative, as a cumulative risk of  $10^{-4}$  (and individual ILCR of  $10^{-6}$ ) is generally recognized by USEPA Region IV as the trigger for establishing COCs. This COC selection method more comprehensively evaluating chemicals contributing to carcinogenic risk or noncarcinogenic hazard during the RGO development process.

Under the traditional risk-based COC trigger provisions, no carcinogenic COCs would be identified for a particular receptor group/pathway combination if the overall cumulative site risk is less than  $10^{-4}$ . However, the cumulative risk threshold used to identify COCs in the following HHRA is two orders of magnitude more conservative,  $10^{-6}$ .

### **Risk/Hazard Maps**

In addition to the standard tabulation of risk/hazard, point maps summarizing risk and hazard were plotted for applicable environmental media to provide a visual supplement. As an extension of conventional risk/hazard interpretations, excess cancer risk and/or hazard were calculated for each sample location by summing the contributions of each COC detected in the corresponding sample. Each mapped sample location was then color-coded to signify a cumulative range of risk or hazard. If COCs were not identified in the HHRA for a specific site, risk point maps were not developed for that site.

ArcView, a standard graphical data presentation and geographic information system package, was used to plot the risk/hazard projections on SWMU/AOC base maps. Section 7.2.6 discusses the uncertainties of mapping risk/hazard. The point maps illustrate risk or hazard associated with COCs in the subject medium. The risk/hazard for individual locations were based exclusively on chemicals detected. Tables summarize the data used to generate graphical presentations. This information allows the reviewer to make determinations regarding the nature of the contaminants identified, and also facilitates remedial alternatives screening as part of the CMS.

### **7.2.6 Risk Uncertainty**

This section of the HHRA presents and discusses the uncertainty and/or variability inherent in the risk assessment process in addition to medium-specific and exposure pathway-specific influences. Risk assessment sections are discussed separately below, and specific examples of uncertainty sources are included where appropriate.

**General**

Uncertainty is a factor in each step of the exposure and toxicity assessments summarized above. Overall, uncertainties associated with the initial stages of the risk assessment process become magnified when they are combined with other uncertainties. Together, the use of high-end estimates of potential exposure concentrations, frequencies, durations, and rates leads to conservative estimates of CDI. Toxicological values for chemicals derived from USEPA databases and other sources are generally derived from animal studies. Uncertainty and modifying factors are applied to extrapolate the results of these studies to predict potential human responses, providing a margin of safety based upon confidence in the studies. During the risk characterization process, individual chemical risk is added to determine the incremental excess cancer risk for each exposure pathway. If the individual exposure predictions were calculated based on the upper limit estimates of exposure to each chemical, the margin of safety of the cumulative incremental risk is the sum of all the individual safety margins applied throughout the process. Use of these safety margins during all exposure and risk/hazard computations provides an extremely conservative means of predicting potential human health effects. The margins of safety or "conservatisms" inherent in each step of the human health risk assessment are addressed in the Risk Uncertainty discussions. It is not possible to eliminate all uncertainties or potential variability in the risk assessment process; however, recognizing the influences of these factors is fundamental to understanding and subsequently using risk assessment results.

The risk uncertainty section of each HHRA presents the uncertainty and/or variability of site-specific and medium/pathway-specific factors introduced as part of the risk assessment process, in addition to other factors influencing the uncertainty of the calculated incremental excess cancer risks and hazard quotients/indices. Calculated risk/hazard levels reflect the underlying variability of the analytical results that they are based on; they also embody uncertainty about potentially unsampled maxima and minima in the analytes. The exposure pathways considered for selection in the exposure assessment sections of the HHRA are extremely conservative.

CPSSs were eliminated from the formal assessment on this basis. Although potential cumulative effects associated with multiple chemicals dismissed through this process are a valid concern, the fact that maximum detected concentrations were used in the screening comparison in concert with low range risk/hazard goals alleviates much uncertainty. More than 10 constituents would have to be present at near-RBC concentrations to substantiate a concern for cumulative effects. Although the screening method is highly conservative, inhalation and dermal exposure are not incorporated into the USEPA soil screening values. If these pathways were the primary concern (as opposed to ingestion), the screening method could eliminate contaminants that should otherwise be considered COPCs. Any constituents omitted based on comparison to residential RBCs that have the potential to significantly contribute to risk via other exposure pathways were reinstated on the list of COPCs.

#### **Comparison to Reference Concentrations (Background)**

Because the intent of the HHRA is to estimate the excess cancer risk or health hazard posed by COPCs, individual sample data values of inorganic chemicals were compared to background reference concentrations for Zone E after comparing the data to risk-based screening values. As a corollary background screening method, the Wilcoxon rank sum test was used to compare inorganic COPC data populations at individual sites with corresponding reference data populations. The outcomes of the fixed point and Wilcoxon tests were used to determine whether concentrations differed significantly between onsite and background locations. The dual approach to background screening reduces the probability that a COPC would be improperly dismissed from formal assessment.

Additional uncertainty is introduced by comparing site data to nonspecific screening reference data. Although the background concentrations are specific to Zone E, they are not individual SWMU or AOC-specific. The use of zone-specific background reference standards, however,

decreases the uncertainty that would result from using a single set of standards across the entire base.

**Elimination of Essential Nutrients**

Calcium, sodium, potassium, magnesium, and iron were eliminated from Zone E HHRA's. Toxicity from overexposure to these nutrients is possible only if human receptors are exposed to extremely high doses. USEPA recommends eliminating these nutrients from formal risk assessment. Because no screening comparison was performed, the HIs calculated in the HHRA could be positively influenced by the nutrient concentrations detected onsite. Therefore, the HIs are possibly underestimates.

**Characterization of Exposure Setting and Identification of Exposure Pathways**

The potential for high bias is introduced through the exposure setting and pathway selection due to the highly conservative assumptions (e.g., future residential use) recommended by USEPA Region IV when assessing potential future and current exposure. The exposure assumptions made in the site worker scenario are also very conservative and would tend to overestimate exposure. Current site workers are not exposed to site groundwater. They are infrequently exposed to surface soil when walking across the site, using commercial facilities, or mowing the grass. Site workers would not be expected to work onsite in contact with affected media for eight hours per day, 250 days per year as assumed in the exposure assessment. Mowing grass 52 days per year would result in approximately one-fifth the projected risk/hazard for site workers.

Residential use of the sites in Zone E is not likely, based on current site uses, the nature of surrounding buildings, and reuse plans. If this area were developed as residential sites, most of the present buildings would be demolished and the surface soil conditions would likely change — the existing soil could be covered with roads, paved driveways, landscaping soil, and/or houses, or parts of the property could be made into playgrounds. Consequently, exposure to current

surface soil conditions would not be likely under a true future residential scenario. These factors indicate that exposure pathways assessed in the HHRA would generally overestimate the risk and hazard posed to current site workers and future site residents.

Groundwater is not currently used at any Zone E location as a source of potable or process water. A basewide system provides drinking and process water to buildings throughout Zone E. This system is to remain in operation under the current base reuse plan. As a result, shallow groundwater would not be expected to be used under future site use scenarios. Therefore, the scenario established to project risk/hazard associated with shallow groundwater exposure is highly conservative, and associated pathways are not expected to be completed.

In addition, the shallow aquifer, monitored during the RFI process, naturally contains significant concentrations of chlorides and total dissolved solids (TDS). As a result, this water-bearing zone's potential as a source of potable water is questionable. Absent potential potable uses, the applicability of tap water-based screening or remedial standards is questionable.

#### **Statistical Estimation of Exposure Point Concentrations**

The USEPA *Supplemental Guidance to RAGS: Calculating the Concentration Term* guidance, (May 1992), document outlines a statistical estimation of EPC. These calculated concentrations are 95% UCLs for the mean, which are based on certain assumptions. USEPA assumes that most (if not all) environmental data are lognormally distributed. This assumption can over- or underestimate the concentration term because many environmental data are neither normally nor lognormally distributed.

The UCL calculation method includes a statistical value, the H-statistic, which is based on the number of samples analyzed for each COPC and the standard deviation of the results. To obtain this number, a table must be referenced, and the value must be interpolated (an estimation) from

the table. The equation for the H-statistic has not been provided in the supplemental guidance, nor does the document referred to in the guidance provide the equation. Although the statistic appears to be nonlinear, local linearity was assumed to facilitate interpolation of the statistic for each COPC addressed in the HHRAs.

Linear interpolation provides a good estimate of H; however, both the UCL formula and H are natural log values. The effect of multiplying natural log numbers is not equivalent to multiplying untransformed values. When data are log-transformed, adding two numbers is the equivalent of multiplying the two numbers if they were not transformed. The effect of multiplying a number while in log form is exponential; and here, H is applied as a multiplier. In summary, using this method to calculate the UCL has the effect of overestimating, and often provides concentrations greater than the maximum detected onsite. For all datasets having fewer than 10 total samples for a specific medium, the maximum concentrations detected were used as EPCs. The limited number of soil and groundwater samples used to assess site conditions often resulted in considerable variability between data locations, and thus relatively high standard deviations about the mean. The high standard deviation elevates UCL projections.

Although RAGS advocates using neither worst-case scenarios nor maximum concentrations as EPCs, the use of the H-statistic often necessitates using the reported maximum concentration as the EPC. In accordance with RAGS, the lesser of either the maximum concentration or the UCL is used as the EPC. As reviewed above, summation of risk based on maximum concentrations can overestimate exposure, especially in the case of low detection frequency or spatially segregated COPCs. This concept is further discussed below.

### **Frequency of Detection and Spatial Distribution**

Because of the influence of standard deviation on EPC, low frequency of detection can cause COPCs to be addressed inappropriately in the risk assessment. More specifically, COPCs detected

only once or twice in all samples analyzed (having concentrations exceeding the RBCs and reference concentrations) would be expected to have relatively higher standard deviations as concentration variability or range widens. Higher standard deviation results in a high H-statistic, typically leading to a UCL greater than the maximum concentration detected onsite. If that is the case, then using the UCL or maximum concentration detected as EPC (or possibly the inclusion of the COPC in question as a COC) may not be appropriate when EPC is assumed to be widely distributed spatially. It is not feasible for a receptor to be simultaneously exposed to maximum concentrations of different contaminants at several locations. The use of the maximum concentrations (or the UCL) is questionable for these contaminants, and the calculated risk and hazard could be skewed upward due to the low frequency of detection.

In some instances, it is possible to define hot spots within the investigation area. A hot spot is an isolated area of concentrated contamination within a larger area which is not impacted, or much less so. Exposure quantification in the presence of a hot spot may be achieved by calculating an FI/FC from contaminated source factor based on the percentage of the total exposure area encompassed by the hot spot, then using this term to modify the maximum (or restricted area average) contaminant concentration to derive the EPC.

### **Toxicity Assessment Information**

There is a generally recognized uncertainty in human toxicological risk values developed from experimental data primarily due to the uncertainty of data extrapolation in the areas of: (1) high-to-low-dose exposure and (2) animal data to human experience. The site-specific uncertainty is mainly in the degree of accuracy of the exposure assumptions. Most of the assumptions used in this and any risk assessment have not been verified. For example, the degree of chemical absorption from the gut or through the skin or the amount of soil contact is not known with certainty.

The uncertainty of toxicological values from the IRIS and HEAST databases provided by USEPA is summarized (where available) in each HHRA. The uncertainty factors assigned to these values account for acute to chronic dose extrapolation, study inadequacies, and sensitive subpopulations, among other factors. Although uncertainty factors for a specific compound may be 1,000 or higher, these safety factors are applied by USEPA to help guarantee that the overall assessment of risk/hazard is conservative toward human health concerns. In the presence of such uncertainty, the USEPA and the risk assessor are obligated to make conservative assumptions so that the chance is very small for the actual health risk to be greater than what is determined through the risk assessment process. On the other hand, the process is not intended to yield overly conservative risk values that have no basis in actual conditions. This balance was kept in mind in developing exposure assumptions and pathways and in interpreting data and guidance for Zone E HHRAs.

### **Evaluation of Dioxin Congeners as 2,3,7,8-TCDD Equivalentents**

Where chlorinated dibenzodioxins and dibenzofurans (dioxins) were detected in soil, TEQs were derived by multiplying the concentration of each dioxin congener by its corresponding USEPA TEF. The resulting TEQs were then summed for each sample, and the total was compared to the 1  $\mu\text{g}/\text{kg}$  AL. If the total TEQ value was found to be less than 1  $\mu\text{g}/\text{kg}$ , it was concluded that soil dioxins do not pose an unacceptable risk. Groundwater exposure was quantified using TEQ values computed for each monitoring well.

### **Evaluation of Chemicals for Which No Toxicity Values Are Available**

In addition to the typical uncertainties inherent in toxicity values, parameters that do not have corresponding RBCs due to the lack of approved toxicological values were not included in the CDI calculation data. This does not indicate that chemicals lacking approved toxicological values pose no risk or hazard. As stated previously, essential nutrients were eliminated based on their low potential for toxicity. Therefore, these chemicals were not assessed further in the HHRA.

### **Quantification of Risk/Hazard**

This section of each HHRA discusses potential sources of uncertainty or variability identified in the quantification of risk and hazard that are not covered in preceding sections. Each exposure medium addressed in the formal risk assessment process is discussed briefly.

### **Mapping Risk/Hazard**

Risk and hazard maps developed to present site-specific HHRA results are in Section 10. Point maps were constructed to show the cumulative risk/hazard computed at specific points, based on the location-specific data for the medium of interest. Location-specific totals were summed and plotted to illustrate ranges of total risk and/or hazard at sites where data supported such a representation. Risk and hazard point mapping is useful for determining whether hot spots (or isolated areas of gross contamination) exist within an otherwise unimpacted area. This information is important because heterogeneous contaminant concentrations can affect the manner in which receptors are exposed to the affected media. As discussed earlier, it is sometimes appropriate to estimate the FI/FC from the contaminated source in computing CDI. Point maps allow for visual analysis of risk and hazard distributions and facilitate estimation of the extent of hot spots relative to the overall site area. These maps also support preliminary scoping of remedial requirements as well as assessment of potential cleanup alternatives in the CMS.

#### **7.2.7 Risk Summary**

Each site-specific HHRA in Section 10 of this report summarizes the site-specific risk and hazard projected for each receptor group, exposure medium, and exposure pathway.

#### **7.2.8 Remedial Goal Options**

Section 7.3.11 of the Zone A RFI report details the RGO process used for the Zone E RFI.

### **7.3 Fixed-Point Risk Evaluation**

HHRAs conducted for SWMUs and AOCs identified for Zone E are designed to facilitate risk management decisions. Current conditions at Zone E are such that direct contact to environmental media is effectively precluded for many sites due to buildings, fixed machinery, infrastructure, asphalt, and concrete. However, part of the HHRA process is to anticipate the future uses of Zone E that may complete exposure pathways. It is reasonable to envision continued industrial use of the area where some of the barriers to exposure are removed; hence, industrial exposure is considered. In instances where the future use is unknown, residential land use is assumed since this is the most conservative risk assessment exposure scenario. Due to the highly industrialized nature of Zone E, it is difficult to accurately define the exposure parameters or exposure area under any future setting. As a result, generic industrial and residential scenarios were appropriate for most Zone E SWMUs and AOCs.

As described in the Final Zone E RFI work plan, Zone E is in the west-central portion of NAVBASE and includes the CIA and the base power plant. The Cooper River forms the northern boundary and the CIA perimeter forms the southern, eastern, and western boundaries. Zone E is predominantly covered with buildings, machinery, concrete, and pavement, which limit direct contact to soil. Due to the industrialized nature of Zone E, subsurface utility conduits and right-of-ways are prevalent. As a consequence, any redevelopment activities are likely to drastically change current soil conditions, calling into question the applicability of current data to risk assessment under future land use scenarios. To address this uncertainty with respect to future use scenarios, the risk assessments for SWMUs and AOCs in the most industrialized portions of Zone E have been presented as Fixed-point Risk Evaluations (FREs). The underlying methods and assumptions of risk assessment are maintained under FRE; however, they are applied to individual sample points rather than statistically derived EPCs. As a result, certain site-specific risk assessments will consist of only risk/hazard maps (residential and industrial) and associated discussion, drawing on the risk methods presented in Section 7.2. This structure drastically

reduces the amount of redundant information presented in this report while providing a screening level risk evaluation appropriate for directing remedial decisions and redevelopment activities. This section discusses development of FREs.

Risk assessments for individual SWMUs and AOCs were handled either as an FRE or as a baseline HHRA, based on exposure potentials and COPCs. As previously mentioned, some SWMUs and AOCs were investigated as a group. These same groupings are maintained for the risk assessment. Generally, SWMUs and AOCs or groups thereof that did not require site-specific analysis beyond the generic risk assessment method presented in Section 7.2 were evaluated using FRE method. Three site groupings required full baseline HHRAs. They are identified as follows:

- SWMUs 5 and 18 and AOC 605
- SWMUs 83 and 84 and AOC 574
- AOCs 559, 560, and 561

The general outline for Zone E FREs includes site background and investigational approach, determination of COPCs, calculation of point risk/hazard, plotting risk/hazard maps, and discussion of uncertainty. This general procedure is followed for residential and industrial exposure to surface soil and residential exposure to groundwater. Lead is considered separately in using concentration maps to illustrate spatial distribution relative to the residential soil cleanup level considered protective of children (400 mg/kg), the industrial soil cleanup level (1,300 mg/kg), the treatment technique action level for groundwater (15 µg/L), and background concentrations.

### COPCs

Tables are included for each SWMU/AOC used to determine COPC, as described in Section 7.2.2. These tables summarize nondetected concentration range, detected concentration

range, average detected concentration, residential and industrial RBCs, and background for CPSSs. Separate summary tables are provided for surface soil and groundwater.

### Fixed-Point Risk Evaluation

#### Surface Soil

Risk and/or hazard resulting from ingestion and dermal contact of COPCs in soil are calculated for residential and industrial exposure scenarios by the following equations:

$$Risk = \frac{1E-06}{RGO_R} * C_s \qquad Hazard = \frac{1}{RGO_{HI}} * C_s$$

where:

- Risk = COPC point risk
- Hazard = COPC point hazard
- RGO<sub>R</sub> = RGO that equates with a risk of 1E-06
- RGO<sub>HI</sub> = RGO that equates with an HI of 1
- C<sub>s</sub> = COPC concentration in soil at a given sample location

Residential and industrial soil RGOs were determined for all of the COPCs identified for Zone E assuming both incidental ingestion and dermal contact exposure pathways. Table 7.3.1 presents the RGOs based on residential exposure, Table 7.3.2 presents RGOs based on industrial exposure. Tables 7.3.1 and 7.3.2 calculate the RGOs that equate with a risk of 1E-06 and an HI of 1, which were used to calculate point risk/hazard. Inserting residential RGOs into the above equations will yield residential risk/hazard while industrial RGOs will yield industrial risk/hazard. COPC concentrations and RGOs should be entered in the same units (mg/kg or µg/kg). The following equations were used to calculate RGOs based on the exposure scenarios presented in Section 7.2.4 and the exposure parameters given on Table 7.2.1.

**Table 7.3.1  
Residential-Based Remedial Goal Options Surface Soil  
Naval Base Charleston, Zone E  
Charleston, South Carolina**

<b>Chemical</b>	<b>Slope Factor (mg/kg-day)<sup>-1</sup></b>	<b>Reference Dose (mg/kg-day)</b>	<b>Dermal Absorption Factor (-)</b>	<b>Absorption Efficiency (-)</b>	<b>Hazard-Based Remedial Goal Option (mg/kg)</b>	<b>Risk-Based Remedial Goal Option (mg/kg)</b>	<b>Surface Soil Background Concentration (mg/kg)</b>
<b>Inorganics</b>							
Aluminum	NA	1	0.001	0.2	72,927	ND	26,600
Antimony	NA	0.0004	0.001	0.2	29	ND	1.77
Arsenic	1.5	0.0003	0.001	0.2	22	0.38	23.9
Barium	NA	0.07	0.001	0.2	5,105	ND	130
Beryllium	4.3	0.005	0.001	0.2	365	0.13	1.7
Cadmium	NA	0.001	0.001	0.2	73	ND	1.5
Chromium (III)	NA	1	0.001	0.2	72,927	ND	94.6
Chromium (VI)	NA	0.005	0.001	0.2	365	ND	ND
Cobalt	NA	0.06	0.001	0.2	4,376	ND	19
Copper	NA	0.04	0.001	0.2	2,917	ND	66
Manganese	NA	0.14	0.001	0.2	10,210	ND	302
Mercury	NA	0.0003	0.001	0.2	22	ND	2.6
Nickel	NA	0.02	0.001	0.2	1,459	ND	77.1
Thallium	NA	8E-05	0.001	0.2	5.8	ND	2.8
Vanadium	NA	0.007	0.001	0.2	510	ND	94.3
Zinc	NA	0.3	0.001	0.2	21,878	ND	827
<b>Semivolatile Organics</b>							
Benzo(a)pyrene equivalent	7.3	NA	0.01	0.5	ND	0.060	NA
ibenzofuran	NA	0.004	0.01	0.5	243	ND	NA
fluoranthene	NA	0.04	0.01	0.5	2,425	ND	NA
N-Nitrosomethylamine	22	NA	0.01	0.5	ND	0.020	NA
Phenanthrene	NA	0.03	0.01	0.5	1819	ND	NA
Pyrene	NA	0.04	0.01	0.5	2,425	ND	NA
<b>Pesticides/PCBs</b>							
Aldrin	17	3E-05	0.01	0.5	1.8	0.026	NA
Aroclor 1248	2	NA	0.01	0.5	ND	0.220	NA
Aroclor 1250	2	2E-05	0.01	0.5	1.2	0.220	NA
Aroclor 1260	2	NA	0.01	0.5	ND	0.220	NA
Dieldrin	16	5E-05	0.01	0.5	3.0	0.028	NA

**EXPOSURE ASSUMPTIONS:**

- Body weight-child (kg) - 15
- Averaging time-cancer (days) - 25,550
- Averaging time-noncancer, child (days) - 2,190
- Conversion factor (mg/kg) - 1,000,000
- Exposure frequency (days/year) - 350
- Exposure duration-child (years) - 6
- Ingestion rate-child (mg/day) - 200
- Ingestion rate-age adjusted (mg/day) - 114.29
- Skin surface area-child (cm<sup>2</sup>/day) - 2,900
- Skin surface area-age adjusted (cm<sup>2</sup>/day) - 2,566
- Adherence factor (mg/cm<sup>2</sup>) - 1
- Target risk (-) - 1.00E-06
- Target hazard index (-) - 1

**Table 7.3.2  
Industrial-Based Remedial Goal Options Surface Soil  
Naval Base Charleston, Zone E  
Charleston, South Carolina**

<b>Chemical</b>	<b>Slope Factor (mg/kg-day)<sup>-1</sup></b>	<b>Reference Dose (mg/kg-day)</b>	<b>Dermal Absorption Factor (-)</b>	<b>Absorption Efficiency (-)</b>	<b>Hazard-Based Remedial Goal Option (mg/kg)</b>	<b>Risk-Based Remedial Goal Option (mg/kg)</b>	<b>Background Concentration (mg/kg)</b>
<b>Inorganics</b>							
Aluminum	NA	1	0.001	0.2	1,449,645	ND	26,600
Antimony	NA	0.0004	0.001	0.2	580	ND	1.77
Arsenic	1.5	0.0003	0.001	0.2	435	1.4	23.9
Barium	NA	0.07	0.001	0.2	101,475	ND	130
Beryllium	4.3	0.005	0.001	0.2	7,248	0.49	1.7
Cadmium	NA	0.001	0.001	0.2	1,450	ND	1.5
Chromium (III)	NA	1	0.001	0.2	1,449,645	ND	94.6
Cobalt	NA	0.06	0.001	0.2	86,979	ND	19
Copper	NA	0.04	0.001	0.2	57,986	ND	66
Manganese	NA	0.14	0.001	0.2	202,950	ND	302
Mercury	NA	0.0003	0.001	0.2	435	ND	2.6
Nickel	NA	0.02	0.001	0.2	28,993	ND	77.1
Thallium	NA	8E-05	0.001	0.2	116	ND	2.8
Vanadium	NA	0.007	0.001	0.2	10,148	ND	94.3
Zinc	NA	0.3	0.001	0.2	434,894	ND	827
<b>Semivolatile Organics</b>							
Benzo(a)pyrene equivalents	7.3	NA	0.01	0.5	ND	0.20	NA
2-benzofuran	NA	0.004	0.01	0.5	3,097	ND	NA
Fluoranthene	NA	0.04	0.01	0.5	30,970	ND	NA
N-Nitrosomethylamine	22	NA	0.01	0.5	ND	0.066	NA
Phenanthrene	NA	0.03	0.01	0.5	23,227	ND	NA
Pyrene	NA	0.04	0.01	0.5	30,970	ND	NA
<b>Pesticides/PCBs</b>							
Aldrin	17	3E-05	0.01	0.5	23	0.086	NA
Aroclor 1248	7.7	NA	0.01	0.5	ND	0.19	NA
Aroclor 1250	7.7	2E-05	0.01	0.5	15	0.19	NA
Aroclor 1260	7.7	NA	0.01	0.5	ND	0.19	NA
Dieldrin	16	5E-05	0.01	0.5	39	0.091	NA

**EXPOSURE ASSUMPTIONS:**

- Body weight-adult (kg) - 70
- Averaging time-cancer (days) - 25,550
- Averaging time-noncancer (days) - 9,125
- Conversion factor (mg/kg) - 1,000,000
- Exposure frequency (days/year) - 250
- Exposure duration (years) - 25
- Ingestion rate (mg/day) - 50
- Skin surface area (cm<sup>2</sup>/day) - 4,100
- Adherence factor (mg/cm<sup>2</sup>) - 1
- Target risk (-) - 1E-06
- Target hazard index (-) - 1

**Residential**

Equation 1

Equation 2

$$RGO_R = \frac{TR \cdot AT_c \cdot 1E-06 \text{ mg/kg}}{EF_r \cdot ((IR_{adj} \cdot SF_o) + [SSA_{adj} \cdot DA \cdot AF \cdot SF_d])}$$

$$RGO_{HI} = \frac{THQ \cdot AT_{nc} \cdot 1E-06 \text{ mg/kg}}{EF_r \cdot ED_{child} \cdot ((IR_{child}/RfD_o) + [SSA_{child} \cdot DA \cdot AF/RfD_d])}$$

**Industrial**

Equation 3

Equation 4

$$RGO_R = \frac{TR \cdot AT_c \cdot 1E-06 \text{ mg/kg}}{EF_i \cdot ED_i \cdot ((IR_i \cdot SF_o) + [SSA_i \cdot DA \cdot AF \cdot SF_d])}$$

$$RGO_{HI} = \frac{THQ \cdot AT_{nc} \cdot 1E-06 \text{ mg/kg}}{EF_i \cdot ED_i \cdot ((IR_i/RfD_o) + [SSA_i \cdot DA \cdot AF/RfD_d])}$$

Where:

$RGO_R$	= Risk-based RGO for a target risk of 1E-06	5
$RGO_{HI}$	= Hazard-based RGO for a target HQ of 1	6
THQ	= Target hazard quotient; 1	7
TR	= Target risk; 1E-06	8
$AT_c$	= Averaging time - cancer; 25,550 days (upper-bound lifetime)	9
$AT_{nc}$	= Averaging time - noncancer; 2,190 days (child)	10
$AT_{oci}$	= Industrial averaging time - noncancer; 9,125 days	11
EF <sub>r</sub>	= Residential exposure frequency; 350 days/yr	12
ED <sub>child</sub>	= Exposure duration child; 6 yrs	13
ED <sub>i</sub>	= Industrial exposure duration; 25 yrs	14
IR <sub>adj</sub>	= Age-adjusted ingestion rate 114.29 mg*yr/kg*day	15
IR <sub>child</sub>	= Child ingestion rate; 200 mg/day	16
IR <sub>i</sub>	= Industrial ingestion rate; 100 mg/day	17
SSA <sub>adj</sub>	= Age adjusted skin surface area; 2,566 cm <sup>2</sup> *yr/kg*day	18
SSA <sub>child</sub>	= Child skin surface area; 2,900 cm <sup>2</sup> /day	19
SSA <sub>i</sub>	= Industrial skin surface area; 4,100 cm <sup>2</sup> /day	20
DA	= Dermal absorption efficiency; 0.1 for organics, 0.01 for inorganics	21
AF	= Adherence factor; 1 mg/cm <sup>2</sup>	22
SF <sub>o</sub>	= Oral slope factor; compound specific	23
SF <sub>d</sub>	= Dermal slope factor; SF <sub>o</sub> * ABS	24
RfD <sub>o</sub>	= Oral reference dose; compound specific	25
RfD <sub>d</sub>	= Dermal reference dose; RfD <sub>o</sub> * ABS	26
ABS	= Gastrointestinal absorption efficiency; 0.2 for inorganics, 0.5 for semivolatiles, 0.8 for volatiles	27

Parameter-specific risk/hazard are summed for each sample location and the site mean and maximum risk/hazard are determined to provide a risk/hazard range for each SWMU/AOC. Tables summarizing COPC risk and hazard estimates are presented to aid in interpreting risk/hazard maps. Tables provide total risk/hazard for each sample location, individual risk/hazard for each COPC detected at each sample location, and the contribution of each COPC to total risk/hazard expressed as percentages. Using the table in conjunction with the risk/hazard map, it is possible to determine significant contributors to risk and hazard as well as the spatial distribution of individual COPCs.

**Groundwater**

Risk and/or hazard resulting from exposure to compounds in groundwater are calculated using the following equations.

$$Risk = \frac{1E-06}{RGO_R} * C_w$$

$$Hazard = \frac{1}{RGO_{HI}} * C_w$$

**where:**

- Risk = COPC point risk
- Hazard = COPC point hazard
- RGO<sub>R</sub> = RGO that equates with a risk of 1E-06
- RGO<sub>HI</sub> = RGO that equates with a HI of 1
- C<sub>w</sub> = COPC concentration in groundwater at a given sample location

Groundwater RGOs are provided in Table 7.3.3, which provides the RGOs that equate with a risk of 1E-06 and an HI of 1. Exposure to inorganic, SVOCs, pesticides, PCBs, and dioxin congeners is assumed to occur through ingestion of groundwater as a potable source. Exposure to VOCs is assumed to occur through ingestion of groundwater as a potable source and inhalation of VOCs

**Table 7.3.3**  
**Residential-Based Remedial Goal Options Groundwater**  
**Naval Base Charleston, Zone E**  
**Charleston, South Carolina**

<b>Chemical</b>	<b>Oral SF (mg/kg-day)</b>	<b>Oral RfD (mg/kg-day)</b>	<b>Inhalation SF (mg/kg-day)-1</b>	<b>Inhalation RfD (mg/kg-day)</b>	<b>Hazard-Based Remedial Goal Option (mg/l)</b>	<b>Risk-Based Remedial Goal Option (mg/l)</b>	<b>MCL (mg/l)</b>	<b>Shallow GW Background Concentration (mg/l)</b>
<b>Inorganics</b>								
Aluminum	NA	1	NA	NA	16	ND	NA	2.81
Antimony	NA	0.0004	NA	NA	0.0063	ND	0.006	ND
Arsenic	1.5	0.0003	NA	NA	0.0047	0.000045	0.05	0.0187
Barium	NA	0.07	NA	NA	1.1	ND	2	0.211
Beryllium	4.3	0.005	NA	NA	0.078	0.000016	0.004	0.00043
Cadmium	NA	0.0005	NA	NA	0.0078	ND	0.005	ND
Chromium	NA	0.005	NA	NA	0.078	ND	NA	0.0123
Copper	NA	0.04	NA	NA	0.63	ND	1.3	0.0027
Manganese	NA	0.023	NA	NA	0.36	ND	NA	2.56
Nickel	NA	0.02	NA	NA	0.31	ND	0.1	0.0152
Thallium	NA	8E-05	NA	NA	0.0013	ND	0.0005	ND
Vanadium	NA	0.007	NA	NA	0.11	ND	NA	0.0114
Zinc	NA	0.3	NA	NA	4.7	ND	NA	0.0273
<b>Volatile Organic Compounds</b>								
Acetone	NA	0.1	NA	NA	1.6	ND	NA	NA
Benzene	0.029	NA	0.029	0.00171	ND	0.0023	0.005	NA
Bromodichloromethane	0.062	0.02	NA	NA	0.31	0.0011	0.1	NA
Chlorobenzene	NA	0.02	NA	0.00571	0.31	ND	NA	NA
Chloroform	0.0061	0.01	0.0805	0.01	0.16	0.011	0.1	NA
1,2-Dichlorobenzene	NA	0.09	NA	0.04	1.4	ND	0.6	NA
1,4-Dichlorobenzene	0.024	NA	NA	0.229	ND	0.0028	0.075	NA
1,1-Dichloroethene	0.6	0.009	0.175	0.009	0.14	0.00011	0.007	NA
1,2-Dichloroethene	NA	0.009	NA	0.009	0.14	ND	0.07	NA
Tetrachloroethene	0.052	0.01	0.00203	0.01	0.16	0.0013	0.005	NA
Trichloroethene	0.011	0.006	0.006	0.006	0.094	0.0061	0.005	NA
Vinyl chloride	1.9	NA	0.3	NA	ND	0.000035	0.002	NA
<b>Semivolatile Organics</b>								
Pentachlorophenol	0.03	NA	NA	NA	ND	0.0022	0.001	NA
<b>Polychlorinated Dioxins/Furans</b>								
Dioxin total TEQs	156,000	NA	NA	NA	ND	4.3E-10	3E-08	NA
<b>Pesticides</b>								
alpha-BHC	6.3	NA	NA	NA	ND	0.000011	NA	NA
beta-BHC	1.8	NA	NA	NA	ND	0.000037	NA	NA
alpha-Chlordane	1.3	6E-05	NA	NA	0.00094	0.000052	0.002	NA
gamma-Chlordane	1.3	6E-05	NA	NA	0.00094	0.000052	0.002	NA
Heptachlor	4.5	0.0005	NA	NA	0.0078	0.000015	0.0004	NA

**EXPOSURE ASSUMPTIONS:**

Body weight-child (kg) - 15  
Averaging time-cancer (days) - 25,550  
Averaging time-noncancer, child (days) - 2,190  
Exposure frequency (days/year) - 350  
Exposure duration-child (years) - 6  
Ingestion rate-child (L/day) - 1  
Ingestion rate-age adjusted (L<sup>3</sup>/kg<sup>3</sup>\*day) - 1.09  
Inhalation rate-child (m<sup>3</sup>/day) - 12  
Inhalation rate-age adjusted (m<sup>3</sup>\*y/kg<sup>3</sup>\*day) - 11.66  
Target risk (-) - 1E-06  
Target hazard quotient (-) - 1

that become airborne through domestic or process use of groundwater. The following equations were used to calculate risk and hazard-based groundwater RGOs.

For inorganics, SVOCs, pesticides, PCBs, and dioxin congeners:

**Equation 5**

$$RGO_R = \frac{TR \cdot AT_c \cdot 1000 \text{ ml/L}}{EF_r \cdot IR_{adj} \cdot SF_o}$$

**Equation 6**

$$RGO_{HI} = \frac{THQ \cdot AT_{nc} \cdot 1000 \text{ ml/L}}{EF_r \cdot ED_{child} \cdot IR_{child} / RfD_o}$$

For VOCs:

**Equation 7**

$$RGO_R = \frac{TR \cdot AT_c \cdot 1000 \text{ ml/L}}{EF_r \cdot ((IR_{adj} \cdot SF_o) + (IR_{adj} \cdot SF_i))}$$

**Equation 8**

$$RGO_{HI} = \frac{THQ \cdot AT_{nc} \cdot 1000 \text{ ml/L}}{EF_r \cdot ED_{child} \cdot ((IR_{child} / RfD_o) + (IR_{child} / RfD_i))}$$

Where:

$RGO_R$	=	Risk-based RGO for a target risk of 1E-06	7
$RGO_{HI}$	=	Hazard-based RGO for a target HQ of 1	8
THQ	=	Target hazard quotient; 1	9
TR	=	Target risk; 1E-06	10
$AT_c$	=	Averaging time - cancer; 25,550 days (upper-bound lifetime)	11
$AT_{nc}$	=	Averaging time - noncancer; 2,190 days (child)	12
$EF_r$	=	Residential exposure frequency; 350 days/yr	13
$ED_{child}$	=	Exposure duration child; 6 yrs	14
$IR_{adj}$	=	Age-adjusted ingestion rate 1.09 L*yr/kg*day	15
$IR_{child}$	=	Child ingestion rate; 1 L/day	16
$SF_o$	=	Oral slope factor; compound specific	17
$SF_i$	=	Inhalation slope factor	18
$RfD_o$	=	Oral reference dose; compound specific	19
$RfD_i$	=	Inhalation reference dose	20

Risk and/or hazard summary tables and maps are produced as described for soil. Industrial exposure to groundwater is not considered in the FRE since groundwater is neither currently used as a potable water source nor is it expected to provide potable water under future industrial use. Residential risk/hazard due to groundwater exposures serves as a point of reference for any risk-based remedial decisions.

### **Lead**

The lead soil concentration is presented on maps using Zone E background (265 mg/kg), OSWER's residential child-based cleanup level (400 mg/kg), and the industrial cleanup level (1,300 mg/kg) as applicable thresholds. Applicable lead concentrations for groundwater include Zone E background (4.8 µg/L) and the treatment technique AL for lead (15 µg/L).

### **Uncertainty**

In general, FRE combines exposure assessment, toxicity assessment, and risk characterization and applies them to a single sample location. Under traditional risk assessment methods, an exposure area is defined and represented by data from the defined area in the form of a statistically derived EPC. In the case of FRE, it is unlikely that an individual's exposure will occur within the an area represented by a single sample location. As a result, FRE may only identify isolated areas of elevated risk/hazard, which can overestimate risk/hazard with respect to the entire site. Conversely, as contiguous sample location associated with elevated risk resemble more likely exposure areas, the uncertainty of FRE diminishes.

FREs do not consider risk/hazard for constituents that may be present at or below the quantitation limits which could lead to over or underestimating risk/hazard. The significance of sample quantitation limit (SQL) with respect to risk/hazard estimates is examined on a SWMU/AOC-specific basis.

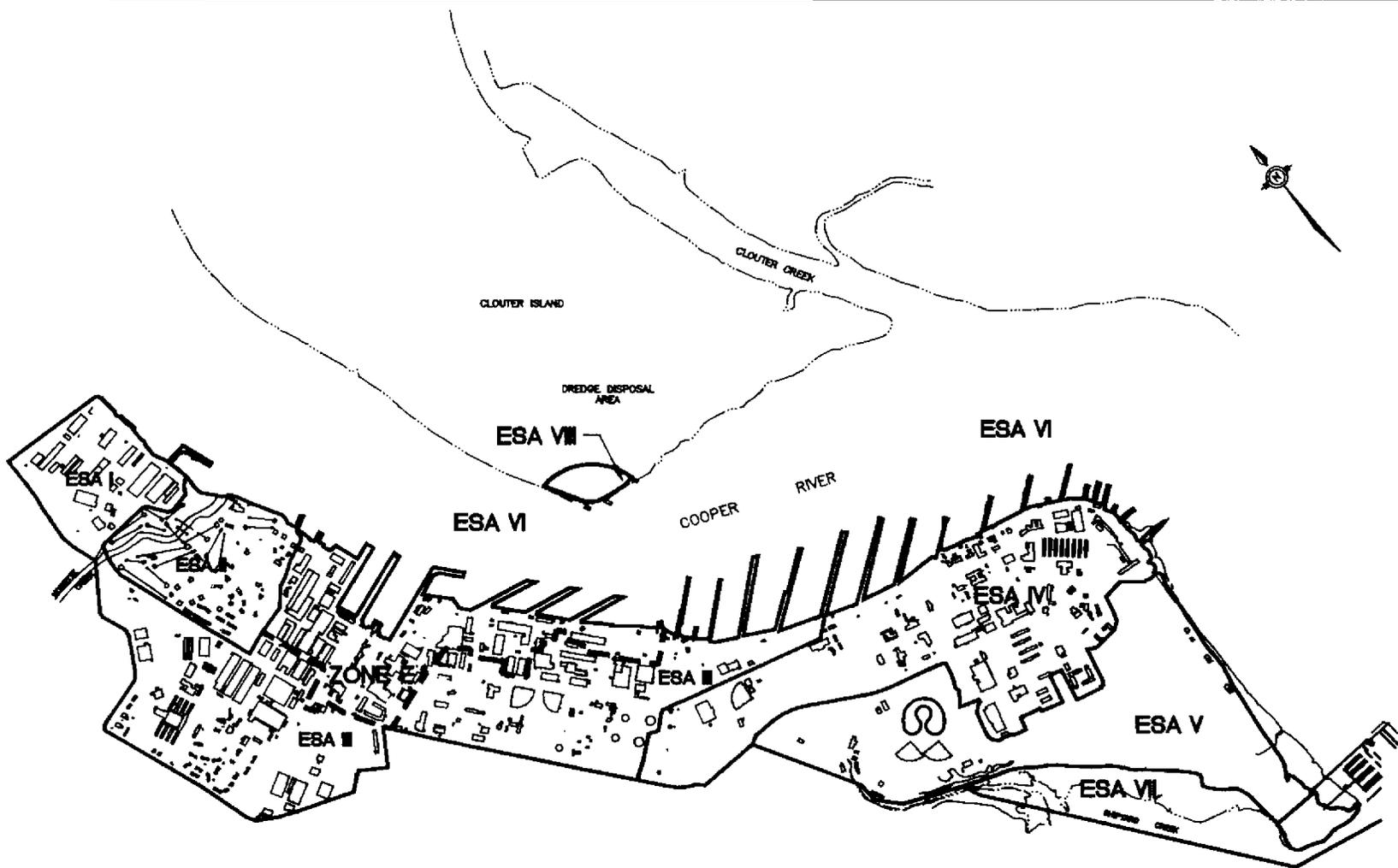
## 8.0 ECOLOGICAL RISK ASSESSMENT

The ecological risk assessment (ERA) is a key component of the BRA. Its purpose is to develop a qualitative and/or quantitative ecological appraisal of the actual or potential effects of Zone E contamination on the surrounding the ecosystem. The assessment considers environmental media and exposure pathways that could result in unacceptable levels of exposure to flora and fauna now or in the foreseeable future. The approach to assessing risk components at Zone E was based on *Ecological Risk Assessment — Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA, September 1994); *Risk Assessment Guidance for Superfund, Volume II — Environmental Evaluation Manual* (USEPA, 1989b), and *Framework for Ecological Risk Assessment* (USEPA, 1992a).

### Zone Rationale

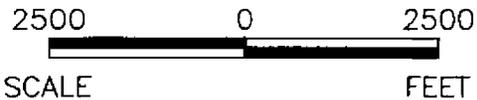
Basewide, eight Ecological Study Areas (ESAs) were designated to assist in appropriately qualifying geographic boundaries with contiguous habitats or similar ecosystem distributions (Figure 8.1). Within these ESAs, Areas of Ecological Concern (AECs) were further specified to focus the investigation relative to potential SWMU/AOC contribution and consequent receptor exposure. This survey method, which is used for the Zone E RFI report, is also described in the Zone J RFI Work Plan (E/A&H, November 20, 1996).

Basewide, zone configurations were based on SWMU or AOC locations and, therefore, do not necessarily parallel ESA boundaries. As shown in Figure 8.1, Zone E is entirely within ESA III which is a completely developed and industrial area, lacking any natural upland habitat or receptors. There is, however, a potential for contaminant migration to the adjacent Cooper River from activities conducted within Zone E, particularly in and around the drydock areas. The Zone E ERA preliminarily evaluates the ecological risks to applicable receptors from the Zone E outfalls using the analytical results of the 19 Zone E samples collected in the Cooper River. Figure 8.2 presents the outfall locations along the Zone E coast which were investigated during



LEGEND

- — — — — ESA BOUNDARY
- - - - - ZONE BOUNDARY



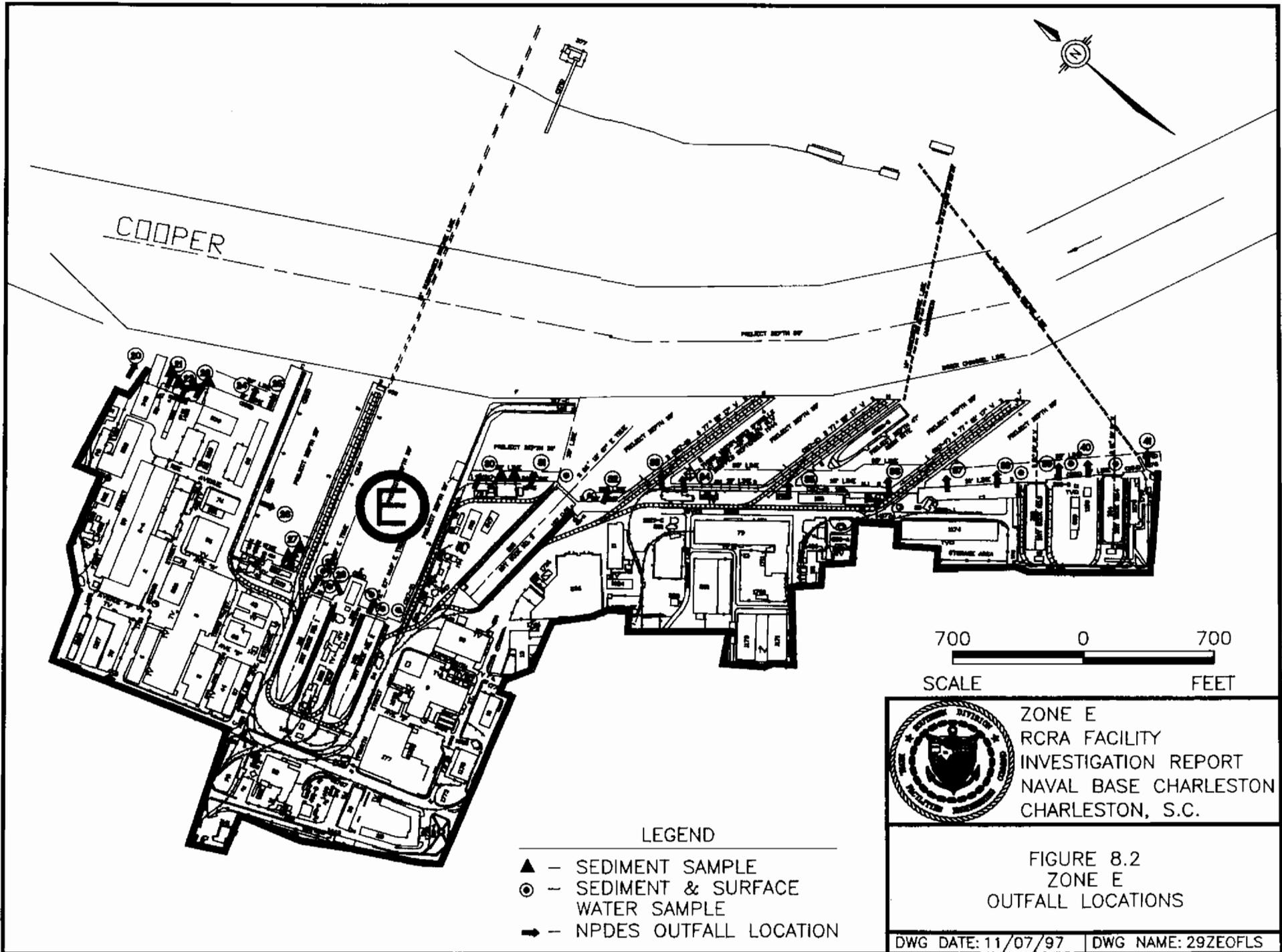
SOURCE: SOUTHW, n.d. ESE, 1991.



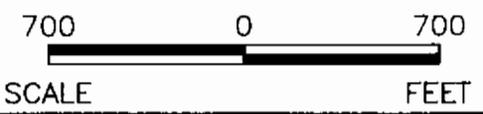
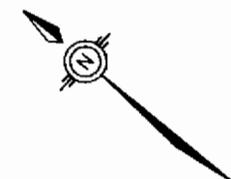
ZONE E  
 RCRA FACILITY  
 INVESTIGATION REPORT  
 NAVAL BASE CHARLESTON  
 CHARLESTON, S.C.

FIGURE 8.1  
 ECOLOGICAL STUDY AREA  
 LOCATION MAP

DWG DATE: 11/07/97 | DWG NAME: 29ZESALM



COOPER



LEGEND

- ▲ - SEDIMENT SAMPLE
- ⊙ - SEDIMENT & SURFACE WATER SAMPLE
- ➔ - NPDES OUTFALL LOCATION



ZONE E  
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FIGURE 8.2  
ZONE E  
OUTFALL LOCATIONS

the Zone E RFI. Overall impacts from NAVBASE, including Zone E, to the Cooper River will be further assessed during the Zone J investigation of this water body.

The Zone E AOCs/SWMUs potentially impacting receptors within the Cooper River and which were investigated through Zone E sediment and/or surface water sampling are AOCs 555 and 556, the drydocks and drydock discharges; SWMU 54, the abrasive blast area; and SWMU 81, a nearshore hazardous waste storage area.

## **8.1 Environmental Setting**

### **Problem Formulation**

During the basewide ecological survey, no areas of ecological concern (AECs) were identified within Zone E; therefore, the focus of this ERA is the preliminary assessment of nearshore environments in the Cooper River which may have been impacted by Zone E activities or outfalls. Although Zone E has 23 identified outfalls along its shoreline, each a potential contaminant pathways to the Cooper River, there are also numerous other outfalls along the NAVBASE shoreline. The Zone J RFI is specifically designed to assess the NAVBASE water bodies, including the Cooper River. The Zone E ERA will therefore estimate the potential excess risk from the sediment and surface water collected from the Zone E outfalls associated with AOCs 555 and 556 and SWMUs 54 and 81. This assessment will provide valuable source characterization information for the subsequent and more comprehensive Zone J RFI.

### **Threatened and Endangered Species**

No species of concern are expected to occur within Zone E. Table 8.1 lists those species of concern which have either been historically or recently identified at locations on or near NAVBASE. Risks to these species from contamination observed will be addressed as appropriate. Appendix J presents a list of species observed at NAVBASE.

**Table 8.1**  
**Federal and State Listed Threatened, Endangered, and Candidate Species**  
**That Occur or Potentially Occur at NAVBASE**

Common Name	Species Scientific Name	Residence Status	Status	
			USF&WS	SCWMRD
<b>Reptiles and Amphibians</b>				
American Alligator	<i>Alligator mississippiensis</i>	PR	T/SA	T/SA
Flatwoods Salamander	<i>Ambystoma cingulatum</i>	UR	C2	SC
Eastern Tiger Salamander	<i>Ambystoma tigrinum tigrinum</i>	PR	–	SC
Broad-striped Dwarf Siren	<i>Pseudobranchius striatus striatus</i>	PR	–	SC
Crawfish Frog	<i>Rana areolata</i>	PR	–	SC
Loggerhead Turtle	<i>Caretta caretta</i>	PM	T	T
Kemp's Ridley Sea Turtle	<i>Lepidochelys kempi</i>	PM	E	E
Island Glass Lizard	<i>Ophisaurus compressus</i>	UR	SR	SR
<b>Birds</b>				
Brown Pelican	<i>Pelecanus occidentalis</i>	LM	–	SC
Wood Stork	<i>Mycteria americana</i>	LM	E	E
Osprey	<i>Pandion haliaetus</i>	CR	–	SC
American Swallow-tailed Kite	<i>Elanoides forficatus forficatus</i>	PM	SR	E
Bachman's Sparrow	<i>Aimophila aestivalis</i>	UR	SR	SR
Red-cockaded Woodpecker	<i>Picoides borealis</i>	UR	E	E
Bachman's Warbler	<i>Vermivora bachmanii</i>	UR	E	E
Bald Eagle	<i>Haliaeetus leucocephalus</i>	LM	E	E
Arctic Peregrine Falcon	<i>Falco peregrinus tundrius</i>	PM	T	T
Piping Plover	<i>Charadrius melodus</i>	PM	T	T
Least Tern	<i>Sterna antillarum</i>	CR	–	T
Least Tern Breeding Colony		CR	–	SC
Wading Bird Breeding Colony		CR <sup>a</sup>	–	SC
<b>Mammals</b>				
Black Bear	<i>Ursus americanus</i>	UM	–	SC
West Indian Manatee	<i>Trichechus manatus</i>	PM	E	E

**Table 8.1**  
**Federal and State Listed Threatened, Endangered, and Candidate Species**  
**That Occur or Potentially Occur at NAVBASE**

Common Name	Species Scientific Name	Residence Status	Status	
			USF&WS	SCWMRD
<b>Fish</b>				
Shortnose Sturgeon	<i>Acipenser brevirostrum</i>	LM	E	E
<b>Plants</b>				
Canby's Dropwort	<i>Oxypolis canbyi</i>	UR	E	E
Pondberry	<i>Lindera melissifolia</i>	UR	E	E
Incised Groovebur	<i>Agrimonia incisa</i>	UR	C2	NC
Sea-Beach Pigweed	<i>Amaranthus pumilus</i>	UR	SR	NC
Cypress Knee Sedge	<i>Carex decomposita</i>	UR	SR	-
Climbing Fern	<i>Lygodium palmatum</i>	UR	-	SL
Piedmont Flatsedge	<i>Cyperus tetragonus</i>	PR	-	SL
Baldwin Nutrush	<i>Scleria baldwinii</i>	UR	-	SL
Nodding Pogonia	<i>Triphora trianthophora</i>	UR	-	SL
Savannah Milkweed	<i>Asclepias pedicellata</i>	UR	-	RC
Venus's Fly-trap	<i>Dionaea muscipula</i>	UR	-	RC
Sweet Pinesap	<i>Monotropsis odorata</i>	UR	-	RC
Climbing Fetter-Bush	<i>Pieris phillyreifolia</i>	UR	-	SL
Sea Purslane	<i>Trianthema portulacastrum</i>	CR	-	SC

**Notes:**

- |    |   |  |        |   |   |
|----|---|--|--------|---|---|
| a  | = | Wading bird colony has been a confirmed resident at the base, but was not present during field studies in April 1994 | E      | = | Endangered                                  |
| CR | = | Confirmed resident   | T      | = | Threatened                                  |
| PR | = | Possible resident  | SL     | = | State listed                                |
| UR | = | Unlikely resident  | RC     | = | Of concern, regional                        |
| LM | = | Likely migrant or occasional visitor   | NC     | = | Of concern, national                        |
| PM | = | Possibly migrant or occasional visitor   | C2     | = | Candidate for federal listing, Category 2   |
| UM | = | Unlikely migrant or occasional visitor   | T/SA   | = | Threatened due to similarity of appearance  |
| SC | = | Of concern, state  | USF&WS | = | U.S. Fish and Wildlife Service              |
| SR | = | Status review  | SCWMRD | = | SC Wildlife and Marine Resources Department |
|    |   |  | -      | = | not listed                                  |

Source: Final Environmental Impact Statement for Disposal and Reuse of the Charleston Naval Base (E&E, June 1995).

## **8.2 Conceptual Model**

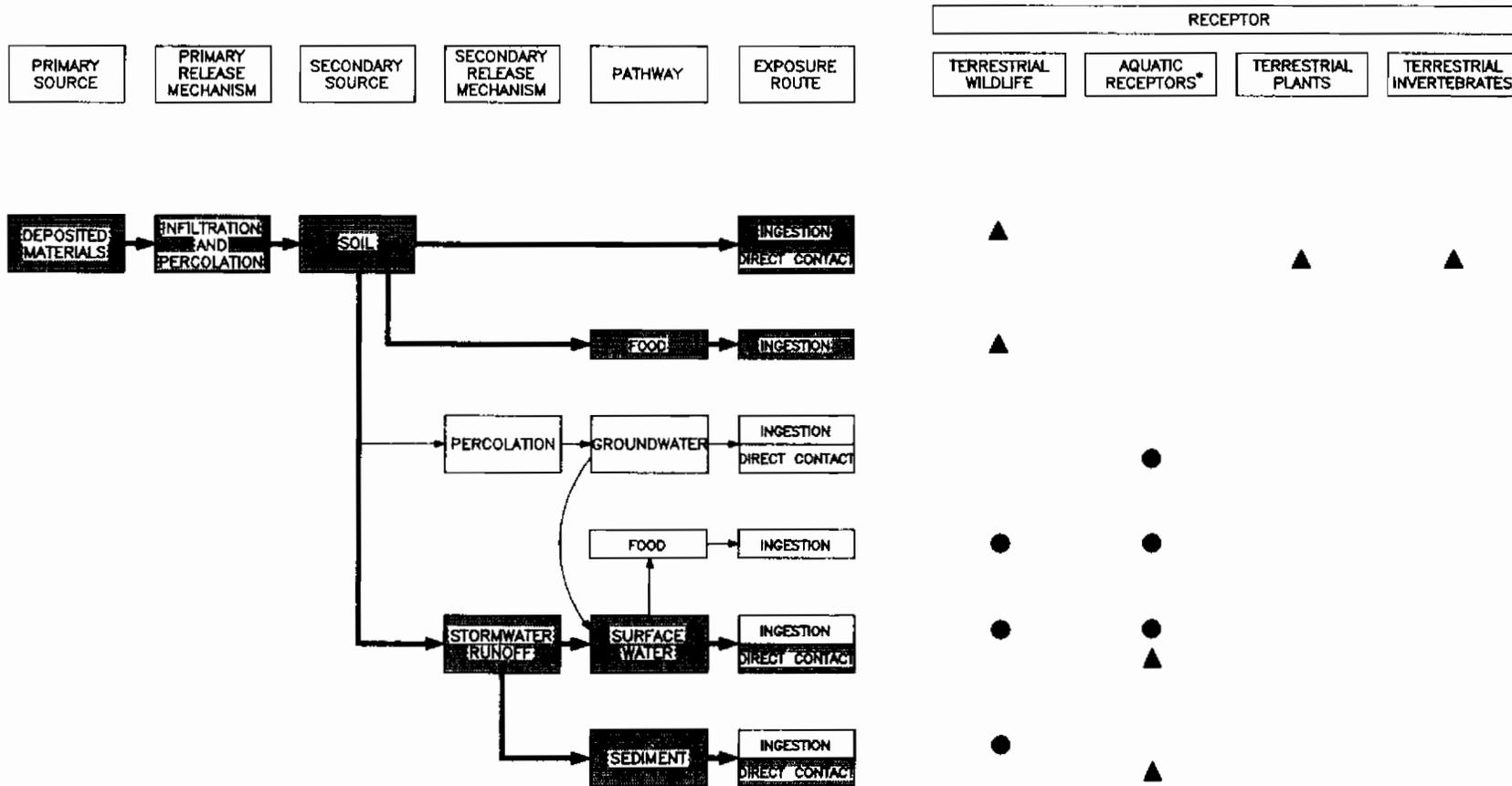
Figure 8.3 presents a conceptual model of the potential contaminant pathways from suspected sources in Zone E to ecological receptors in the Cooper River. For this assessment, only exposure routes directly related to sediment and surface water pathways are evaluated to determine the need for subsequent assessment during the Zone J RFI.

## **8.3 Selection of Ecological Chemicals of Potential Concern**

Section 10 of this report discusses activities at SWMUs and AOCs associated with Zone E, including those sites with releases or wastestreams that may impact receptors within the surrounding aquatic ecosystem. COCs resulting from these activities have been identified and quantified according to USEPA methods and protocols for analyses of surface water and sediment.

To determine ecological chemicals of potential concern (ECPCs) in the portion of the Cooper River near Zone E, the analytical results from surface water and upper layer of sediment (0 to 6 inches) were considered. Based on the transient or mobile nature of some biological components, the constant tidal flow of surface water, and the natural movement of upper sediment, the parameter concentrations detected at one location will be used to assess nearshore ecological conditions along the entire Zone E coast. Both maximum and mean concentrations of parameters detected at the sample locations are used in this assessment.

In sediment, analytes were selected as ECPCs if the maximum detected concentration exceeded either the USEPA Region IV Sediment Screening Value (SSV) (November 1995) or a conservative effects level found in literature, if the calculated hazard quotient (using the maximum or mean concentration) exceeded 1.0, or if appropriate benchmarks were unavailable.



AQUATIC RECEPTORS - INVERTEBRATES, PLANTS, ALGAE, AMPHIBIANS, AND FISH

NOTE: SHADED BOXES, BOLD ARROWS, AND TRIANGLES INDICATE SELECTED PATHWAY



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FIGURE 8.3  
CONTAMINANT PATHWAY MODEL FOR  
ECOLOGICAL RECEPTORS

DWG DATE: 11/07/97 | DWG NAME: 29ZECPMF

In surface water, analytes were selected as ECPCs if the maximum concentration detected exceeded the South Carolina or USEPA water quality criteria, exceeded the USEPA Region IV Surface Water Screening Value (November 1995), or if appropriate benchmarks were unavailable.

Calcium, magnesium, potassium, and sodium were not assessed as they are naturally occurring nutrients. Tables 8.2 and 8.3 present ECPCs identified for Zone E nearshore environments.

**Table 8.2**  
**Zone E Sediment Samples in Cooper River**

Parameter	Number Detected	Range	Mean	Effect Level	No. EL Exceeded	Max HQ	Mean HQ	ECPC
<b>N= 19</b>								
<b>Inorganics (mg/kg)</b>								
Aluminum	19	2,140-16,500	9,687.37	N/A	N/A	NC	NC	Yes
Antimony	8	0.75-23.20	4.25	12	1	1.93	0.35	Yes
Arsenic	19	3.70-21.80	13.56	7.24	15	3.01	1.87	Yes
Barium	19	14.10-56.80	28.19	N/A	N/A	NC	NC	Yes
Beryllium	19	0.26-2.50	0.95	N/A	N/A	NC	NC	Yes
Cadmium	8	0.27-3.60	0.83	1	1	3.60	0.83	Yes
Chromium	19	20.90-177	43.47	52.3	2	3.38	0.83	Yes
Cobalt	19	2.90-18.30	7.61	N/A	N/A	NC	NC	Yes
Copper	19	24.60-1,930	193.62	18.7	19	103.21	10.35	Yes
Iron	19	7,170-28,500	20,324.74	40,000 <sup>a</sup>	0	0.71	0.001	No
Lead	19	13.40-482	91.78	30.2	11	15.96	3.04	Yes
Manganese	19	47.10-865	364.11	1110 <sup>a</sup>	0	0.78	0.33	No
Mercury	11	0.05-0.67	0.24	0.13	5	5.15	1.85	Yes
Nickel	19	7.30-42.40	17.48	15.9	6	2.67	1.10	Yes
Selenium	7	0.60-10.50	2.52	N/A	N/A	NC	NC	Yes
Silver	4	0.67-0.75	0.70	2	0	0.38	0.35	No
Sodium	19	925-23,700	12,087.11	N/A	N/A	NC	NC	Yes
Tin	7	12.30-55.70	26.97	N/A	N/A	NC	NC	Yes
Vanadium	19	5.40-58.30	33.86	N/A	N/A	NC	NC	Yes
Zinc	19	55.40-1,390	290.25	124	8	11.21	2.34	Yes

**Table 8.2**  
**Zone E Sediment Samples in Cooper River**

Parameter	Number Detected	Range	Mean	Effect Level	No. EL Exceeded	Max HQ	Mean HQ	ECPC
<b>N=19 Pesticides/PCBs (µg/kg)</b>								
4,4'-DDE	1	7.60-7.60	7.60	3.3	1	2.30	2.30	Yes
Aroclor-1260	2	170-1,200	685	33	2	36.36	20.76	Yes
Endrin ketone	3	7.80-14	10.93	N/A	N/A	NC	NC	Yes
Methoxychlor	1	45-45	45	18.8 <sup>b</sup>	1	2.39	2.39	Yes
2-Methylnaphthalene	1	220-220	220	330	0	0.67	0.67	No
<b>N=19 SVOCs (µg/kg)</b>								
Acenaphthene	5	260-1,100	642	330	4	3.33	1.95	Yes
Acenaphthylene	1	350-350	350	330	1	1.06	1.06	Yes
Anthracene	8	410-2,500	1,251.25	330	8	7.58	3.79	Yes
Benzo(a)anthracene	12	210-6,400	1,970.83	330	10	19.39	5.97	Yes
Benzo(a)pyrene	12	210-5,500	1,661.67	330	8	16.67	5.04	Yes
Benzo(b)fluoranthene	8	170-4,300	1,297.50	N/A	N/A	NC	NC	Yes
Benzo(g,h,i)perylene	10	120-3,300	973	N/A	N/A	NC	NC	Yes
Benzo(k)fluoranthene	13	210-11,000	2,253.08	N/A	N/A	NC	NC	Yes
Carbazole	1	220-220	220	N/A	N/A	NC	NC	Yes
Chrysene	13	160-10,000	2,541.54	330	11	30.30	7.70	Yes
Di-n-octylphthalate	1	290-290	290	N/A	N/A	NC	NC	Yes
Dibenz(a,h)anthracene	7	90-1,500	611.43	330	5	4.55	1.85	Yes
Dibenzofuran	3	150-590	376.67	418 <sup>b</sup>	1	1.41	0.90	Yes
Fluoranthene	14	250-18,000	4,628.57	330	12	54.55	14.03	Yes
Fluorene	4	320-760	582.50	330	3	2.30	1.77	Yes
Indeno(1,2,3-cd)pyrene	10	110-3,000	928	N/A	N/A	NC	NC	Yes
Naphthalene	2	250-590	420	330	1	1.79	1.27	Yes
Phenanthrene	8	260-6,900	2,852.50	330	7	20.91	8.64	Yes
Pyrene	16	130-10,000	3,017.50	330	15	30.30	9.14	Yes
2-Butanone(MEK)	11	4-42	24	271 <sup>b</sup>	0	0.15	0.09	No



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Table 8.3  
 Zone E Surface Water Samples in Cooper River

Parameter	Detects	Range	Mean	Effect Level	No. Exceeding EL	Max HQ	Mean HQ	ECPC
<b>N=25</b>		<b>SVOCs (<math>\mu\text{g/L}</math>)</b>						
Pentachlorophenol	1	1 - 1	1	13	0	0.08	0.08	No
Pyrene	1	1 - 1	1	N/A	N/A	NC	NC	Yes
<b>HAZARD INDEX - SVOCs =</b>						<b>150.2</b>	<b>41.31</b>	
<b>N=25</b>		<b>VOCs (<math>\mu\text{g/L}</math>)</b>						
Acetone	7	7 - 17	11	507,640 <sup>b</sup>	0	3.34e-05	2.16e-05	No
Chloroform	1	2 - 2	2	289	0	0.01	0.01	No
Methylene chloride	2	5 - 9	7	1,930	0	0.00	0.00	No
Xylene (Total)	4	2 - 4	2.50	62,308 <sup>b</sup>	0	3.20e-05	4.01e-05	No
<b>HAZARD INDEX - VOCs =</b>						<b>1.01e-02</b>	<b>1.01e-02</b>	
<b>N=25</b>		<b>Dioxins (pg/L)</b>						
1234678-HpCDF	2	4.27 - 7.52	5.90	N/A	N/A	NC	NC	Yes
OCDD	2	46.4 - 57.1	51.75	N/A	N/A	NC	NC	Yes
Total Hepta-Dioxins	2	7.59 - 20.8	14.20	N/A	N/A	NC	NC	Yes
<b>HAZARD INDEX - DIOXINS =</b>						<b>NC</b>	<b>NC</b>	
<b>N=25</b>		<b>Organotins (<math>\mu\text{g/L}</math>)</b>						
Tributyltin	4	27 - 28	27.50	0.026 <sup>c</sup>	4	1,077	1,058	Yes
<b>HAZARD INDEX - ORGANOTINS =</b>						<b>1,077</b>	<b>1,058</b>	

**Notes:**

Effect Level (EL) is USEPA/SCDHEC Ambient Water Quality Criteria -- Chronic saltwater unless otherwise noted

a = Secondary Chronic Value (Tier 2), USEPA 1993

b = Lowest Chronic Value for All Organisms, USEPA

c = Region IV Chronic Value, USEPA

HQ = Hazard Quotient -- calculated using maximum concentration divided by EL

NA = Not available

NC = Not calculable due to insufficient data

ECPC = Ecological Chemical of Potential Concern

$\mu\text{g/L}$  = micrograms per liter

$\text{pg/L}$  = picograms per liter

## 8.4 Contaminant Fate and Transport

Since the ERA for Zone E is limited to the preliminary assessment of offshore sediment and surface water adjacent to Zone E only, it is too early to perform an in-depth evaluation of specific contaminant fate and transport mechanisms as they relate to ecological risk. Instead, it is considered more prudent and less redundant to examine the comprehensive ecological effects of basewide activities upon the Cooper River by assimilating Zone E data with both the analytical and physical data obtained from the Zone J RFI, which includes impacts from Zone E. The following section describes some of the known characteristics of various stressor chemicals.

### Stressor Characteristics

#### *Inorganics*

In general, heavy metals adversely affect survival, growth, reproduction, development, and metabolism of aquatic invertebrate species, but effects are substantially modified by physical, chemical, and biological variables.

Arsenic naturally occurs and, with respect to cycling in the environment, is constantly changing. Many inorganic arsenicals are known teratogens and are more toxic than organic arsenicals (Eisler, 1988). Adverse effects to aquatic organisms have been reported at concentrations of 19 to 48 parts per billion (ppb) in water. Arsenic in soil does not appear to magnify along the aquatic food chain.

Cadmium is a relatively rare heavy metal. It is a known teratogen and carcinogen and probably a mutagen, and has been implicated as the cause of severe deleterious effects on fish and wildlife (Eisler, 1985). Birds and mammals are comparatively resistant to the biocidal properties of cadmium. Freshwater organisms appear to be the group most susceptible to cadmium toxicity and this is modified significantly by water hardness. Adsorption and desorption processes are likely to be major factors in controlling cadmium concentrations in natural waters. Adsorption and

desorption rates of cadmium are rapid on mud solids and particles of clay, silica, humic material, and other naturally occurring solids. 1  
2

Hexavalent chromium (Cr VI) produces more adverse effects to biota than does the trivalent phase. 3  
In clayey sediments, trivalent chromium dominates and benthic invertebrate bioaccumulation is 4  
limited (Neff et al., 1978). 5

Copper is an essential micronutrient and, therefore, it is readily accumulated by aquatic organisms. 6  
It is a broad spectrum biocide, which may be associated with both acute and chronic toxicity. 7

In sediments, lead is primarily associated with iron and manganese hydroxides and may also 8  
associate with clay and organic matter. Under oxidizing conditions, lead tends to remain tightly 9  
bound to sediments, but is released into the water column under reducing conditions. Lead may 10  
accumulate in aquatic biota. 11

Mercury is a known mutagen, teratogen, and carcinogen. It adversely affects reproduction, 12  
growth, development, motor coordination, and metabolism. Mercury has a potential for 13  
bioaccumulation and biomagnification, and is slow to deplete. Organomercury compounds 14  
produce more adverse effects than inorganic mercury compounds. Inorganic mercury can be 15  
modified to organic mercury compounds through biological transformation processes. 16

In natural waters zinc speciates into the toxic aquo ion, other dissolved chemical species, and 17  
various inorganic and organic complexes, and is readily transported. Most zinc introduced into 18  
aquatic environments is eventually partitioned into the sediments. Reduced conditions enhance 19  
zinc's bioavailability. 20

No information was available on the toxicological effects associated with other inorganic ECPCs for soil and sediment.

### *Organics*

Polynuclear aromatic hydrocarbons (PAHs) vary by molecular weight. With increasing molecular weight, aqueous solubility decreases and the logarithm of octanol-water partition coefficient ( $\log K_{ow}$ ) increases, suggesting increased solubility in fats, a decrease in resistance to oxidation and reduction, and a decrease in vapor pressure (Eisler, 1987a). Accordingly, PAHs of different molecular weight vary substantially in their behavior and distribution in the environment and in their biological effects. In water, PAHs either evaporate, disperse into the water column, become incorporated into sediment, or undergo degradative processes such as photooxidation, chemical oxidation, and biological transformation by bacteria and animals (Neff, 1979).

Most environmental concern has focused on PAHs that range in molecular weight from 128.16 (naphthalene) to 300.36 (coronene). Generally, lower molecular weight PAH compounds, containing two or three aromatic rings, exhibit acute toxicity but are not carcinogenic. Higher molecular weight PAH compounds, those with four to seven rings, are less toxic, but are demonstrably carcinogenic, mutagenic, or teratogenic to aquatic species. PAHs show little tendency to biomagnify in food chains because most are rapidly metabolized (Eisler, 1987a). Very little information is available on food chain adverse effects as a result of soil PAH contamination.

Organochlorine pesticides have been used extensively in the United States since the 1940s. They appear to be ubiquitous in the environment, being found in surface water, sediment, and biological tissue. They are readily absorbed by warm-blooded species and degradatory products are frequently more toxic than the parent form. Food chain biomagnification is usually low, except in some marine mammals. Most environmental effects studies have been directed at mammals and birds.

PCBs are distributed worldwide with measurable concentrations recorded in fishery and wildlife resources from numerous locations (Eisler, 1986). They are known to bioaccumulate and to biomagnify within the food chain and to elicit biological effects such as death, birth defects, tumors, and a wasting syndrome.

Dioxins are present as trace compounds in some commercial herbicides and chlorophenols (Eisler, 1986). The most toxic and most extensively studied dioxin is 2,3,7,8-TCDD. Laboratory studies with birds, mammals, aquatic organisms, and other species have demonstrated that exposure to 2,3,7,8-TCDD can result in acute and delayed mortality as well as mutagenic and reproductive effects.

### **8.5 Exposure Pathways and Assessment**

The primary exposure pathway evaluated for aquatic wildlife species in Zone E's nearshore environments will be through contact/interface with contaminated water and sediment. An assessment endpoint evaluating the aquatic community health has been selected with a measurement endpoint that predicts chronic-effects to aquatic community species.

### **8.6 Ecological Effects Assessment**

Potential adverse ecological effects to aquatic species from identified ECPCs are predicted based on the most conservative benchmark available (i.e., chronic water quality criteria, sediment screening value, or effects information from literature). Effects will be predicted using a preliminary screening approach. Both maximum and mean water and sediment concentrations for ECPCs will be divided by the available benchmark to produce an HQ to offer an assessment of specific locations as well as the site as a whole. Calculated HQs for ECPCs from each media will be summed to determine an HI. HQs with a result higher than 1 are considered to demonstrate a potential excess risk. Values higher than 10 are considered to be of moderately high potential excess risk and above 100, extreme risk.

## 8.7 Risk Characterization

Studies related to toxicological effects present concentration information in several forms (i.e.,  $\mu\text{g/g}$ ,  $\mu\text{g/kg}$ ,  $\text{mg/kg}$ ). For comparison and ease of reading, data presented in the following section is presented as either parts per million (ppm) or ppb concentrations. Contaminants in surface water and sediment were measured to assess the potential for excess risk to aquatic species in the Cooper River.

**Surface Water** — The only five analytes with published surface water quality effects levels exceed those levels. According to the maximum concentration detected, BEHP appeared to be the most critical contaminant (HQ = 146.67), with aluminum, barium, lead, thallium, and iron each having HQs above 1. Except for aluminum (HQ=13.33), all other contaminants had an HQ below 10.

Using mean concentrations to calculate the HQ, only BEHP's HQ of 37.78 exceeded the moderate risk classification of 10. Lead, barium, aluminum, and thallium each had an HQ greater than 1 (HQ=7.65, 3.08, 2.70, and 1.55, respectively). The HQs for the remaining parameters were all below 1. Overall, based on the concentrations observed, only a moderate risk to surface water quality exists.

**Sediment** — A low potential excess risk to aquatic receptors from sediment near Zone E exists based on exceedances of USEPA Region IV SSVs or applicable effect levels (see Table 8.2). HQ values greater than 1 but less than 3 for copper, arsenic, chromium, nickel, lead, zinc, and pyrene were determined. As SSVs are derived from statistical interpretation of effects databases obtained from literature, actual risks to receptors within the portion of the Cooper River near Zone E may be lower than that implied by use of the SSVs in the screening assessment. Overall risk to aquatic receptors from sediment concentrations appears low. This information will be used and referenced during the subsequent Zone J RFI.

**8.8 Uncertainty**

General uncertainties are associated with the ERA for Zone E.

- Degradation of chemicals has not been considered in the ECPC selection process.
- Specific effects to biota within the area are unknown.
- Acute and chronic effects data on some ECPCs were unavailable.
- Synergistic or antagonistic effects cannot be quantified.
- For some ECPCs, only assumptions relative to similar compounds or classes of elements can be made.
- Dermal or inhalation exposure pathways were not evaluated.
- Maximum exposure scenarios and concentrations may tend to overestimate risk potentials.
- Actual occurrence of selected wildlife species within the contaminated area is uncertain.
- SSVs are obtained from laboratory studies and may not reflect field-based exposure scenarios.

**8.9 Risk Summary**

Risk for ecological receptors was evaluated for ECPCs in surface water and sediment at Zone E.

Risk associated with exposure to ECPCs by native aquatic organisms were evaluated by calculating

HQs from benchmark values that are either promulgated or proposed by federal and state regulatory agencies. 1  
2

*Aquatic Wildlife* — Moderate risks are predicted to aquatic wildlife from ECPCs in surface water near Zone E. Potential low-level risk to aquatic wildlife exists from sediment ECPCs in the Cooper River. For both inorganic and organic ECPCs, there were HQ values above 1. 3  
4  
5

## 9.0 CORRECTIVE MEASURES

According to Permit Condition IV.E. Corrective Action Plan, SCDHEC will review the final RFI report and notify NAVBASE of the need for further investigations, corrective actions, corrective action studies, or plans to meet the requirements of R.61-79.264.101, Corrective Action for SWMUs. This section has been prepared based on SCDHEC's comment that "the RFI report should discuss whether the extent of contamination has been defined, and proposed recommended actions for the SWMUs and AOCs, such as collection of additional samples, proceed into a Corrective Measures Study, or No Further Investigation, whichever is appropriate." The NAVBASE project team established ALs for assessing whether to conduct a CMS at  $10^6$  residential risk and/or 100 mg/kg TPH. The following discussions address the overall approach for looking at Corrective Measures (CMs), list potential remedies, and outline the steps to be conducted during a CMS. The site-specific conclusions regarding which sites will require CMs are discussed in Section 10, Site-Specific Evaluations.

### 9.1 Introduction

Any CMS at NAVBASE will be conducted according to standard methods presented in the USEPA guidance document, *RCRA Corrective Action Plan* (USEPA, 1994). The standard methodology will be presented in a zone-specific CMS Work Plan and will facilitate collecting necessary data, evaluating potential alternatives, and developing a final remedial alternative by establishing a set procedure for evaluation and assessment, as described in the Comprehensive CMS Work Plan.

To establish this procedure, the zone-specific CMS Work Plan will outline the CMS report and discuss basic elements. The overall structure of the plan will be explained to illustrate the decision-making process. Briefly, the report outline is:

<b>Report Outline</b>	1
• Introduction/Purpose	2
• Description of Current Conditions	3
• Corrective Action Objectives	4
• Identification, Screening, and Development of Corrective Measure Alternatives	5
• Evaluation of a Final Corrective Measure Alternative	6
• Recommendation by a Permittee/Respondent for a Final Corrective Measure Alternative	7
• Public Involvement Plan	8

Each required element will be discussed in detail in the CMS Work Plan. The discussion will achieve the following: 9  
10

- Identify minimum requirements for CMS reports in each area. 11
- Define the base *pool* of technologies to be evaluated for each medium. 12
- Define the evaluation process. 13
- Identify selection criteria for the final corrective measure alternative. 14

Issues to be discussed under each element are identified below: 15

- An activity-specific description of the overall purpose of the CMS for NAVBASE. 16

*SWMUs and AOCs at NAVBASE will be discussed in the CMS Work Plan on a zonewide basis. Activities, contaminants, and issues specific to each zone will be discussed. The CMS Work Plan will identify: specific sites to be addressed in the CMS, any focused approach (such as naming a primary technology in lieu of the full screening), and the subsequent cleanup goals.* 17  
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- A description of the corrective action objectives for NAVBASE, including how target media cleanup standards, points of compliance, or risk assessments will be established and performed for each site, zone, and activity.

*Cleanup standards will be developed for each site, zone, or activity using the designated exposure scenario (residential, commercial, or industrial) for that area. BRAs, conducted in conjunction with the RFI for each zone, will be used to identify areas with unacceptable risk/hazard as per the designated exposure scenario. During the CMS, areas with unacceptable risk will be evaluated according to media, primary contaminants contributing to risk, and the potential for groundwater contamination.*

- Identification, screening, and development of corrective measures alternatives.

*Tables similar to those presented in the NAVBASE RFI Work Plans will be used in the CMS Work Plan to present the pool of technologies initially evaluated in the CMS. These tables represent a range of technologies with different applications; each technology must be screened and evaluated before it is discarded from further consideration. The tables, therefore, preclude any bias toward a particular technology through full-scale screening techniques.*

*Technologies will be screened using site- and waste-specific characteristics. The CMS Work Plan will identify factors to be considered, including type of media, depth of contamination, areal extent of contamination, number and type of contaminants, remedial goals, future land use scenarios, and adjacent remedial activities. In addition, the CMS Work Plan will present the requirements for implementing Corrective Action Management Units (CAMUs).*

*Once technologies have been screened, they will be assembled into corrective action alternatives. These alternatives will be evaluated according to criteria discussed below.*

- A description of the general approach to investigating and evaluating potential corrective action measures.

*Corrective measures alternatives will be evaluated using four primary and five secondary criteria, listed below:*

***Primary***

1. *Protect human health and the environment.*
2. *Attain media cleanup standards set by the implementing agency.*
3. *Control the source of releases so as to reduce or eliminate, to the extent practical, further releases that may pose a threat to human health and the environment.*
4. *Comply with any applicable waste management standards.*

***Secondary***

1. *Long-term reliability and effectiveness*
2. *Reduction in the toxicity, mobility, or volume of waste*
3. *Short-term effectiveness*
4. *Implementability*
5. *Cost*

*Alternatives will be discussed and compared according to these criteria, which are used to gauge their relative effectiveness and implementability.*

- A detailed description of how pilot, laboratory, and/or bench-scale studies will be selected, performed, evaluated, reported, and transferred to full scale.

*Treatability studies will be implemented when more involved treatment units are being considered. For example, air stripping technologies usually do not require treatability studies to determine optimal process for treating groundwater. However, ultraviolet (UV)/oxidation, an innovative technology, may require extensive treatability testing to determine oxidant dosages and retention times.*

*The base structure and objectives of a treatability study will be discussed. Objectives may include: dosages, percent reduction in contaminant(s), treatment cost per unit volume, and implementation constraints. Study results will be used to assess the alternatives presented in the CMS and determine the optimal remedial approach for each site, zone, or activity.*

- A description of how statement of basis/response to comments or permit modifications are to be processed.

*Statement of basis/response to comments will be handled through NAVBASE and Southern Division, Naval Facilities Engineering Command (SOUTHDIV). The Comprehensive Long-term Environmental Action Navy (CLEAN) contractor, E/A&H, will assist the Navy in preparing statement of basis/response to comments. Permit modifications will be managed through NAVBASE as the permit holder until the base is closed. Upon closure, SOUTHDIV and NAVBASE's caretaker will manage permit modifications. According to*

*the RCRA permit issued May 4, 1990, Appendix C, Facility Submission Summary, a permit modification is required to prepare and conduct a Corrective Action Study/Plan.*

- A description of the overall project management approach, including levels of authority (i.e., organizational charts), lines of communication, project schedules, budgets, and personnel.

*The overall project management is the responsibility of SOUTHDIV for NAVBASE. The lines of authority, communication, and project schedules have been developed and agreed upon and are provided in the Comprehensive Project Management Plan dated August 30, 1994, and amendments. In general, NAVBASE is responsible for ensuring conditions of the permit are satisfied with the ultimate responsibility held by the Commander of Charleston Naval Shipyard (CNSY). The budget for conducting a CMS is defined by SOUTHDIV and funds are provided by the U.S. Congress. Personnel to conduct the CMS will be assigned by E/A&H as needed for project-specific items. E/A&H will manage the CMS effort through its Charleston, South Carolina, office.*

- Qualifications of personnel to direct or perform the work will be described.

*E/A&H will use trained qualified and/or registered geologists and engineers of South Carolina where required.*

## **9.2 Remedy Selection Approach**

As agreed in the *Final Comprehensive Project Management Plan*, remedies will be selected in accordance with statutory and RCRA CMS criteria. Particular attention will be given to the following items when evaluating alternatives:

- Background concentrations, particularly of inorganic compounds 1
- Land use/risk assessment 2
- Basewide treatment facilities 3
- Presumptive remedies 4
- Remedies for petroleum, oils, lubricants, and other contaminants of this type 5

CAMUs and temporary units (TUs) will be used where necessary to facilitate storage and treatment during remediation activities. 6  
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### **9.3 Proposed Remedy 8**

Section 9.3 of the Zone A RFI report discusses the proposed remedy process for NAVBASE Charleston. 9  
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### **9.4 Development of Target Media Cleanup Goals 11**

Section 9.4 of the Zone A RFI report discusses the development of target media cleanup goals for soil, groundwater, sediment, surface water, and air. 12  
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### **9.5 Identification, Screening, and Development of Corrective Measures Technologies 14**

The initial step in assembling corrective measures alternatives is to identify, screen, and develop corrective measure technologies which apply to the site. Technologies are typically screened using waste-, media-, and site-specific characteristics. This section addresses the range of technologies which may be assessed for each site, the screening process, and screening criteria. 15  
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#### **9.5.1 Identification of Corrective Measure Technologies 19**

Each site will be assessed using the cleanup standard methodology described in Section 9.2. An initial list of impacted media and COCs have been identified in the RFI. The site-specific BRAs 20  
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in Section 10 identify soil and groundwater as the contaminated media of concern. For each site, the major contaminants present have been grouped into one or more of the following categories:

- Chlorinated volatiles
- Nonchlorinated volatiles
- Chlorinated semivolatiles
- Nonchlorinated semivolatiles
- Pesticides/herbicides
- PCBs
- Dioxins
- Inorganic compounds (includes metals)
- Petroleum hydrocarbons

Table 9.1 lists nontreatment options for soil, groundwater/leachate, sediment, surface water, and air. These options include removal, containment, and disposal. Table 9.2 lists types of compounds and the recommended types of treatment for each medium. These tables supply general waste management options for various situations. Remedial technologies are described in Section 9.5.2 of this document.

Some sites may contain a combination of contaminants (i.e., inorganics, pesticides, and petroleum hydrocarbons). As a result, multiple technology types may be required to remove these contaminants. However, some sites may contain only one type of contaminant.

The following example presents a common situation where more than one type of contaminant exists onsite. The site contains volatile and semivolatile compounds that have been identified as slightly exceeding risk-based remedial goals. A containment alternative in this situation may include fencing to restrict unauthorized access, aerating the contaminated area, adding fertilizer and enriched soil, seeding to maintain a vegetative cover to control runoff, and monitoring. This containment approach seeks to minimize health risks through land management and natural attenuation.

**Table 9.1**  
**Removal/Containment/Disposal Options**

Action	Soil	Groundwater/ Leachate	Sediment	Surface Water	Air
Removal	Excavation	Groundwater extraction Leachate collection	Dredging	Diversion Pumping	N/A
Containment	Institutional controls Capping Storm water controls Long-term monitoring Intrinsic (natural) bioremediation/attenuation	Slurry wall Gradient controls Long-term monitoring Intrinsic (natural) bioremediation/attenuation	Berms/diversion Storm water controls	Diversion	N/A
Disposal	Landfill	POTW NPDES discharge Land application	Landfill	POTW NPDES discharge	Discharge via air permit

**Notes:**

- POTW = Publicly owned treatment works
- NPDES = National Pollutant Discharge Elimination System
- N/A = Not Applicable

Table 9.2  
 Treatment Technology Options

Contaminant Type	Soil	Groundwater/ Leachate	Sediment	Air
Chlorinated volatiles	Soil washing Incineration Thermal desorption Bioremediation	Chemical oxidation Bioremediation Adsorption Air stripping UV/ozone oxidation	Same as soil	Oxidation
Nonchlorinated volatiles	Soil washing Incineration Thermal desorption Soil vapor extraction Bioremediation Steam extraction	Oxidation Bioremediation Adsorption Air stripping	Same as soil	Adsorption Oxidation
Chlorinated semivolatiles	Soil washing Bioremediation Incineration Thermal desorption Solidification/stabilization	Oxidation Bioremediation Air stripping	Same as soil	Adsorption Oxidation
Nonchlorinated semivolatiles	Soil washing Incineration Thermal desorption Bioremediation Solidification/stabilization	Oxidation Bioremediation Sorption	Same as soil	Oxidation Adsorption

**Table 9.2  
 Treatment Technology Options**

Contaminant Type	Soil	Groundwater/ Leachate	Sediment	Air
Pesticides/ Herbicides	Solidification/stabilization Soil washing Bioremediation Incineration Thermal desorption	Oxidation Bioremediation Sorption	Same as soil	Oxidation
PCBs	Solidification/stabilization Soil washing Dehalogenation Incineration Thermal desorption	Oxidation Dehalogenation Incineration Solidification	Solvent extraction Dehalogenation Solidification/stabilization	Oxidation
Dioxins	Incineration Solidification/stabilization	Oxidation		Oxidation
Inorganics	Solidification/stabilization Soil washing	Chemical precipitation Adsorption Sedimentation Filtration	Same as soil	Filtration Scrubbers Adsorption

As discussed in previous sections, because each site may be evaluated under both residential and site worker scenarios, COCs may vary between scenarios. Two lists of applicable technologies may be developed for each site, one for each scenario.

### 9.5.2 Description of Prescreened Technologies

The following paragraphs describe technologies that appear to be the most feasible for the initial CMS. These technologies are divided into four categories: in-situ soil, ex-situ soil, in-situ groundwater, and ex-situ groundwater.

#### **In-Situ Soil**

##### ***Bioremediation***

This technology uses microorganisms to biologically oxidize contaminants into harmless chemicals such as carbon dioxide and water. The organisms can be naturally occurring or they can be added to the soil. In many circumstances, nutrients can be supplemented to enhance this process. Nitrate and phosphate are often the limited nutrients at a site. However, insufficient electron acceptors are the greatest variable limiting bioremediation. The most common electron acceptor is oxygen for aerobic biodegradation. For these sites, bioremediation via natural attenuation is likely to be a good candidate for some of the compounds. Typically nonchlorinated VOCs and SVOCs are good candidates for this technology.

##### ***Solidification/Stabilization***

This technology consists of mixing reagents with soil to prevent contaminants from leaching to the groundwater below. This technology immobilizes contaminants, preventing migration. However, this technology does not remove the contaminant.

## **Ex-Situ Treatment of Soils**

All ex-situ soil treatments require excavation to another location or at least bringing the material to the surface. Typically heavy equipment is used to move the soil. If contaminated soil is limited in volume and considered nonhazardous, it may be feasible to dispose of it in a landfill. If sites have a limited area of contaminated soil then, it may be feasible to remove the soil with heavy equipment and treat it ex-situ; or, if nonhazardous, it could be disposed in a landfill.

### ***Soil Washing***

Soil washing physically separates soil particles by size, then treats the smaller grains with solutions which desorb the contaminants. The resulting contaminated solution is then treated by another technology. In general, small soil particles such as clay and silt have a higher TOC content which tends to absorb hydrophobic compounds such as chlorinated contaminants. Essentially the technology compacts contaminated soil, then washes it with a solvent to remove the contaminants.

### ***Thermal Desorption***

Thermal desorption technologies are performed at high or low temperatures depending on the contaminant. Both of these technologies are used in combination with incineration or some other type of offgas treatment. Soil is excavated and put in the treatment systems for both high- and low-temperature desorption to separate the contaminants from the soil, not to destroy the chemicals. The volatilized contaminants enter an airstream and travel to some type of gas treatment for the contaminant destruction. Low-temperature (200°F to 600°F) thermal desorption (LTTD) applies only for VOCs while high-temperature (600°F to 1000 °F) thermal desorption (HTTD) applies to SVOCs, PAHs, PCBs, and pesticides.

### ***Thermal Destruction/Incineration***

This technology is used in conjunction with ex-situ soil technologies. Typically the contaminant is removed from the soil matrix and transferred to an airstream. The airstream is treated with the

thermal destruction on a catalyst or burned in an incinerator or a combination of the two. High 1  
temperatures (1800°F to 2000°F) are required to destroy organics such as PCBs, dioxins, furans, 2  
pesticides, and others. 3

***Solidification/Stabilization*** 4

This technology is similar to the in-situ methods; however, the soil is first excavated before being 5  
mixed with the chemical reagents or concrete. 6

**In-Situ Groundwater Treatment** 7

***Bioremediation*** 8

Bioremediating contaminants in groundwater involves adding nutrients (phosphate, nitrate, etc.) 9  
and an electron acceptor (i.e., oxygen, nitrate, etc.) to the groundwater via injection wells. The 10  
most typical electron acceptor addition comes from either oxygen via air sparging, and/or nitrate 11  
with the addition of other nutrients. 12

***Intrinsic Remediation*** 13

This technology, also called natural attenuation, simply allows naturally occurring bioremediation, 14  
oxidation, hydrolysis, dispersion, and advection to occur unassisted. No nutrients or electron 15  
acceptors are added to the site. The site may be monitored to observe the contaminant reduction. 16  
Many case studies have demonstrated this technology on TPH. 17

**Ex-Situ Treatment of Groundwater** 18

Any ex-situ treatment of groundwater requires a system of extraction wells and pumps to deliver 19  
the groundwater to the treatment location. 20

### ***Chemical Precipitation***

The solubility of many metals is a function of pH. As a result, chemical agents can be added to change the pH of the water, which results in the metals becoming insoluble. In other cases, a chemical can be added to chelate the metal and precipitate it out of the solution. Either way, the contaminants then can be removed by filtering.

### ***Air Stripping***

Groundwater can be extracted from the subsurface and pumped to a nearby publicly owned treatment works (POTW). While the contaminated groundwater is in the aeration basin of the water treatment plant, the volatile compounds (compounds with a high Henry's law constant) will mass-transfer from the water to the air. Steam can also be used to heat the groundwater, causing organics to volatilize. These air vapors can be treated with an appropriate technology or can be permitted as an air emission source.

### ***Chemical Oxidation/UV-Ozone***

Ozone is one of the strongest chemical oxidizers. Almost any organic compound can be oxidized. Ozone can be generated with UV light sources. Water can pass through a flowstream surrounded by UV lights. Oxygen in the water is converted to ozone and the organics are oxidized into harmless by-products. Compounds that typically are recalcitrant to biological oxidation, such as chlorinated organics, can easily be oxidized with ozone. Good light transmission is essential; therefore, very turbid water is not a good candidate for UV ozonation.

### ***Activated Sludge***

Activated sludge treatment of wastes occurs in a wastewater treatment plant. The activated sludge process uses microorganisms to convert organic wastes to inorganic wastes and/or bacterial cell mass, carbon dioxide, and water.

### **9.5.3 Screening Criteria**

When more than one technology applies to a specific site, it is necessary to evaluate the limitations to show why certain CMS technologies may prove infeasible to implement waste- and site-specific conditions. Therefore, for each technology, the following criteria will be discussed:

- Site characteristics
- Waste characteristics
- Technology limitations

#### **Site Characteristics**

Site characteristics define the site and any constraints that may impact selecting and implementing remedial technologies. Characteristics to be considered include primarily the current and future use of the AOC or SWMU. Other characteristics include the contaminated media, areal distribution of contamination, and depth to/of contamination. Current migration pathways and the potential for intrinsic remediation will also be considered. Each site may have one or two technology lists which will be evaluated for residential and BRAC-specified future uses.

#### **Waste Characteristics**

Waste characteristics define the nature of contamination. The primary waste characteristic to be considered is the general type of contamination — volatiles, semivolatiles, pesticides/herbicides, PCBs, dioxins, inorganic compounds, and TPH analysis. Also critical is the presence of halogenated compounds, such as chlorinated benzenes or trichloroethylene.

Where multiple types of contamination are present (such as PCBs and dioxins, or pesticides and volatiles), certain technologies may be eliminated from consideration due to the inability to effectively treat the wastes. For example, soil vapor extraction (SVE) typically is not used on pesticide sites, although it is very effective for most volatile compounds. If both contaminants

must be treated concurrently, SVE would be eliminated from further evaluation. Where appropriate, contaminant concentrations will be considered to screen remedial technologies.

### **Technology Limitations**

Technology limitations are used to assess the implementation feasibility of a particular technology. These limitations may include technical restrictions on application, including the presence of a shallow water table, depth to bedrock, etc. Additional limitations include minimum or maximum process volumes, such as technologies which are cost-effective only when contaminated soil volume exceeds 1,000 cubic yards. Other limitation to be assessed include effectiveness in meeting treatment goals and remedial time frame. Technologies meeting this screening criterion may differ from residential to BRAC-specified use scenarios due to the differences in cleanup goals for each scenario.

### **9.6 Identification of Corrective Measure Alternatives**

Section 9.6 of the Zone A RFI report discusses identification of corrective measure alternatives.

### **9.7 Evaluation of Corrective Measure Alternatives**

Section 9.7 of the Zone A RFI report details evaluation of corrective measure alternatives.

### **9.8 Ranking the Corrective Measures Alternatives**

Section 9.8 of the Zone A RFI report details ranking of the corrective measures alternatives.

**SECTION 10**

**LOCATED IN VOLUMES III THROUGH VI**

**11.0 CONCLUSIONS AND PRELIMINARY RECOMMENDATIONS**

The Zone E RFI was conducted to determine which sites, if any, designated as AOCs and/or SWMUs during the RFA pose unacceptable risk to human health or the environment (ecological concerns), and will require additional evaluation under the CMS. The conclusions reached regarding each site are based on a technical evaluation of the data following procedures outlined in the NAVBASE Charleston *Comprehensive RFI Work Plan*, regulatory guidance, and as required by the Part B permit. The NAVBASE Charleston project team has established a conservative protocol for using risk- and hazard-based thresholds to make preliminary recommendations for each site. The recommendations will be: no further action, additional evaluation under the CMS, and additional sampling needed to complete the RFI (in which case an addendum to the report will be required). The protocol for determining which course of action may be appropriate is as follows:

- NFA — Human health risks do not exceed the  $1E^{-6}$  ILCR and the hazard index is  $< 1$  under a residential scenario. Potential risk to ecological receptors is low based on the criteria described in Section 11.51.
- CMS — One or more of the thresholds listed above for NFA is exceeded.
- Additional Sampling Required — Data gaps exist for one or more media investigated. The data gaps are significant enough to preclude an NFA or CMS recommendation.

Due to the prevailing conditions in Zone E, a modified approach was used to characterize risk at most of the SWMUs/AOCs. As a result, no single estimate of risk or hazard was made for specific media at a SWMU/AOC based on conventional determination of exposure point concentration across the site. Instead, the distribution of fixed-point risk/hazard estimates was presented along with the computed mean for each set of media pathways. For purposes of

recommendation, the mean of fixed-point estimates will be used as the decision tool. In many instances, groundwater quality was assessed (for a specific SWMU/AOC) using a very limited monitoring network. As such, preliminary recommendations for these sites may necessarily be made based upon maximum detected (or "worst case") results.

The recommendations are to be considered preliminary until the risk managers with the USEPA, SCDHEC, and the Navy have reviewed the data and a final decision is reached. The reason being that the USEPA and SCDHEC generally find a residential risk range of 1E-04 to 1E-06 acceptable for human health because of the conservative nature of the baseline risk assessment. This means some sites currently recommended for CMS may not require further action once all the weight of evidence such as frequency of detection/spatial distribution, realistic exposure potential, nature of contaminants driving risk, data trends for quarterly groundwater monitoring events, etc. are considered. No further action recommendations are not acceptable for sites where a potential risk exists under a residential scenario even though an industrial reuse of the property is expected since institutional controls for the site will be required. Final recommendations and the rationale for the risk management decisions will be documented in an addendum to this report.

It should be noted that the screening process for site-specific risk assessments is very conservative and many relatively insignificant chemicals make it through the process to become COCs, although, not all COCs drive risk at individual sites. COCs driving risk are those which are detected consistently above risk-based concentrations (RBCs) and reference concentrations (RCs) in soil, and above maximum contaminant levels (MCLs) in groundwater. First round groundwater results were used for risk assessment purposes, however, data from subsequent rounds of groundwater sampling were also evaluated to confirm chemical presence and concentrations, and to assess trends.

Identifying potential sources and trends of groundwater contamination included research of subsurface distribution lines (i.e. sewer lines) and reviewing analytical data collected during the Zone L RFI, which investigated subsurface distribution lines throughout NAVBASE Charleston, including Zone E. Maps of subsurface lines have been included in Appendix L as a reference for the distribution of storm drains, sewage collection, and sanitary and industrial sewer lines in Zone E.

The majority of second round soil sampling was conducted on the basis of arsenic and BEQs detected in the initial round of sampling. Results of second round sampling confirmed that these constituents were wide-spread across Zone E as well as NAVBASE Charleston in general. Since arsenic and BEQs are rather ubiquitous throughout NAVBASE, they are not considered an unacceptable risk/hazard in an industrial scenario unless concentrations are beyond those commonly detected in soil, however, concentrations commonly detected in Zone E are considered unacceptable in a future residential scenario and have increased the number of sites recommended for CMS.

Thallium was also commonly detected in both shallow and deep groundwater, however these concentrations were often, if not always, similar to those detected in grid-based wells. Reference concentrations were calculated for thallium in deep and shallow groundwater but were considered unacceptable because they were above its MCL. Thallium concentrations detected at numerous sites were considered an unacceptable hazard in a future residential scenario, increasing the number of sites recommended for CMS.

Table 11.1 lists all AOCs and SWMUs investigated in Zone E and the preliminary recommendations for no further action, additional evaluation under the CMS, or additional sampling.

**Table 11.1**  
**Zone E Site Conclusions**

Site Designation	Conclusions/Recommendations
✓ SWMUs 5, 18, AOC 605	Recommended for CMS — Surface Soil; Shallow Groundwater
✓ SWMUs 21, 54	Recommended for CMS — Surface and Subsurface Soil; Shallow Groundwater; Refer to Zone J RFI for Sediment Conclusions
✓ SWMUs 22, 25, AOC 554	Recommended for CMS — Surface and Subsurface Soil; Shallow Groundwater; Sediment
✓ SWMUs 23, 63, AOCs 540, 541, 542, 543	Recommended for CMS — Surface Soil; Shallow Groundwater
✓ SWMU 53, AOC 526	Recommended for CMS — Surface and Subsurface Soil; Shallow Groundwater
✓ SWMU 65, AOCs 544, 546	Recommended for CMS — Surface and Subsurface Soil; Shallow and Deep Groundwater; Sediment
SWMU 67	No Further Action
✓ SWMU 70, AOCs 548, 549	Recommended for CMS — Surface Soil; Shallow and Deep Groundwater
SWMU 81	No Further Action; Refer to Zone J RFI for Sediment Conclusions
✓ SWMUs 83, 84, AOC 574	Recommended for CMS — Surface and Subsurface Soil; Shallow and Deep Groundwater
✓ SWMUs 87, 172, AOC 564	Recommended for CMS — Surface Soil; Shallow and Deep Groundwater
SWMU 97	No Further Action
SWMU 100	No Further Action
✓ SWMU 102	Recommended for CMS — Surface and Subsurface Soil; Shallow Groundwater
✓ SWMU 106, AOC 603	Recommended for CMS — Surface Soil; Shallow and Deep Groundwater
✓ SWMU 145	Recommended for CMS — Deep Groundwater
SWMU 170, 171	No Further Action
SWMU 173	Recommended for CMS — Sediment

**Table 11.1**  
**Zone E Site Conclusions**

Site Designation	Conclusions/Recommendations
AOC 525	No Further Action
AOC 528	No Further Action
AOC 530	Recommended for CMS — Surface Soil; Shallow and Deep Groundwater
AOC 531	Recommended for CMS — Surface Soil
AOCs 538, 539	Recommended for CMS — Surface Soil; Shallow and Deep Groundwater; Sediment
AOC 550	Recommended for CMS — Subsurface Soil; Shallow Groundwater
AOCs 551, 552	Recommended for CMS — Surface and Subsurface Soil; Shallow Groundwater
AOC 555	No Further Action — Refer to Zone J RFI for Sediment Conclusions
AOC 556	No Further Action — Refer to Zone J RFI for Sediment and Surface Water Conclusions
AOC 558	No Further Action
AOCs 559, 560, 561	Recommended for CMS — Surface and Subsurface Soil; Shallow and Deep Groundwater
AOC 562	No Further Action
AOC 563	Recommended for CMS — Surface Soil; Shallow Groundwater
AOC 566	Recommended for CMS — Surface and Subsurface Soil; Shallow and Deep Groundwater
AOC 567	No Further Action
AOCs 569, 570, 578	Recommended for CMS — Surface and Subsurface Soil; Shallow and Deep Groundwater
AOC 571	No Further Action
AOC 572	Recommended for CMS — Surface and Subsurface Soil; Shallow Groundwater; Sediment
AOC 573	Recommended for CMS — Surface Soil; Shallow Groundwater; Sediment

**Table 11.1**  
**Zone E Site Conclusions**

Site Designation	Conclusions/Recommendations
AOC 576	Recommended for CMS — Surface Soil; Shallow and Deep Groundwater
AOC 579	Recommended for CMS — Surface Soil
AOC 580	Recommended for CMS — Surface and Subsurface Soil; Shallow and Deep Groundwater
AOC 583 ✓	Recommended for CMS — Surface Soil; Shallow and Deep Groundwater
AOC 586	Recommended for CMS — Surface Soil
AOC 590 ✓	Recommended for CMS — Surface Soil; Shallow and Deep Groundwater; Sediment
AOC 592	No Further Action
AOC 596	Recommended for CMS — Surface and Subsurface Soil; Shallow and Deep Groundwater
AOC 597	Recommended for CMS — Surface Soil
AOCs 598, 599 ✓	Recommended for CMS — Surface and Subsurface Soil; Shallow Groundwater; Sediment
AOC 602	No Further Action
AOC 604	No Further Action
Supplemental Sample Locations	Recommended for Additional Investigation — Shallow and Deep Groundwater

The following sections summarize the recommendations for each site, level of risk/hazard posed by each of the sites recommended for corrective measures, the media affected, and the chemicals driving that risk.

**11.1 SWMUs 5 and 18 and AOC 605**

**SWMU 5** — Former Battery Electrolyte Treatment Area, Pad 1278 (Solvents, Lead/Acid Batteries). This site was used to neutralize submarine battery acid and consisted of a platform and two USTs.

**SWMU 18** — PCB Spill Area, Public Works Resource Recovery Facility Storage Area (Pyranol Insulating Fluid). This site consists of a 20 by 20-foot area in which a transformer ruptured in 1987, and discharging approximately 75 gallons of Pyranol insulating fluid.

**AOC 605** — Waste Paint Storage Area, Pad 1278 (Acids, Paints, Solvents, Petroleum Hydrocarbons, Lead). This site consists of a 40 by 250-foot concrete pad used to store materials such as paints, used oils, solvents, and chemicals.

Table 11.2 identifies the affected medium, the risk/hazard, and the chemicals driving the risk. An interim measures action has been conducted for the removal of soil at this site. Risk and hazard estimates were calculated based on results generated prior to the interim measures activities.

**Table 11.2**  
**SWMUs 5 and 18 and AOC 605**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in the Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR (6.23E-05) and/or HI (1)	Antimony, beryllium, BEQs, copper, zinc
	Yes	Lead
Shallow Groundwater	Yes — ILCR and/or HI	Antimony, arsenic
	NA	Lead (exceeded TTAL)

**Note:**

NA = Not applicable to risk/hazard

**11.2 SWMUs 21 and 54**

**SWMU 21** — Old Paint Storage Area, Pad 1275 (Paint Waste). This site consists of a 20 by 80-foot concrete pad formerly used for the storage of containerized paint waste.

**SWMU 54** — Former Abrasive Blasting Area, Area around Pad 1275 (Paint Waste, Solvents, Abrasive Blast Media). This area was used for abrasive blasting and painting of ship components.

Table 11.3 identifies the media affected, the risk/hazard, and the chemicals driving the risk. An interim measures action has been conducted for the removal of soil at this site. Risk and hazard estimates were calculated based on results generated prior to the interim measures activities.

**Table 11.3  
 SWMUs 21 and 54  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in the Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR and/or HI	Antimony, beryllium, BEQs
	Yes	Lead
Subsurface Soil	NA	Arsenic, cadmium, BEQs (exceeded SSLs)
		Lead (exceeded TTAL)
Shallow Groundwater	Yes — HI	Antimony, thallium

*Note:*

NA = Not applicable to risk/hazard

**11.3 SWMUs 22 and 25 and AOC 554**

**SWMU 22** — Old Plating Shop Wastewater Treatment System, Building 5 (Chromic Acid, Cadmium, Copper, Chromium, Lead, Nickel, Silver). This site consists of a 5-foot x 5-foot

x 8-foot concrete collection sump used to collect acidic wastewater, cyanide and alkaline wastewater, and a clarifier, four mixing tanks, chemical feed equipment and associated piping.

**SWMU 25** — Old Plating Operation, Building 44 (Silver, Cadmium, Chromium, Nickel, Mercury, Lead, Cyanide, Barium). This site consisted of an electroplating operation which contained approximately 40 metal tanks that contained solutions used in plating processes until operations ceased in 1983.

**AOC 554** — Paint Shop, Former Building 1003 (Waste Paint, Paint Thinner, Solvents, Heavy Metals). This site was the location of a former paint shop that operated from approximately 1909 to 1940.

Table 11.4 identifies the media affected, the risk/hazard, and the chemicals driving the risk. An interim measures action has been conducted at SWMU 25, including the demolition and removal of the Building 44 Annex. Risk and hazard estimates were based on results generated prior to the interim measures activities. A completion report for the process closure and demolition of the Building 44 Annex was prepared by the Environmental Detachment Charleston and is included in Appendix M.

**Table 11.4  
SWMUs 22 and 25 and AOC 554  
Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in the Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR and/or HI	BEQs, cadmium, chromium
	Yes	Lead
Subsurface Soil	NA	Arsenic, cadmium, dieldrin, tetrachloroethene (exceeded SSLs)

**Table 11.4**  
**SWMUs 22 and 25 and AOC 554**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in the Future Residential Scenario	Chemicals Driving Risk
Shallow Groundwater	Yes — ILCR and/or HI	Antimony, cadmium, chromium, nickel, thallium, tetrachloroethene, trichloroethene, alpha and gamma chlordane
Sediment	NA	Chromium, lead

*Note:*

NA = Not applicable to risk/hazard

**11.4 SWMUs 23 and 63 and AOCs 540, 541, 542, and 543**

**SWMU 23** — New Plating Shop Wastewater Treatment System, Building 226 (Sulfuric Acid, Sodium Metabisulfite, Sodium Hydroxide, Potassium Hydroxide, Chromium, Cadmium). This site consists of rinse water pumps, holding tanks, transfer pumps, a clarifier, a neutralization tank, and a plate and frame filter press which handles chrome effluent, acid/alkali effluent and cadmium effluent.

**SWMU 63** — Battery Charging Station, Former Building 73 (Acids, Metals). This site is the location of a former battery charging area (1941-1970) which is now covered by Building 226, a plating facility.

**AOC 540** — Plating Plant, Building 226 (Acids, Metals, Hydraulic Fluid, Petroleum Hydrocarbons). This site consists of a pump and valve test area, a plating area, and a hydraulic repair area including a wet scrubber, 120 plating dip tanks, a sludge pit, an oil/water separator, a 300-gallon fuel oil tank, and a waste treatment facility.

**AOC 541** — Oil Storage Shop, Former Building 38 (Petroleum Hydrocarbons). This site was an oil storage area (1909-1939) currently located in the asphalt parking lot between Buildings 6 and 226.

**AOC 542** — Paint Shop and Oxy-Acetylene Plant, Former Building 22 (Acids, Metals, Paints, Solvents, Acetylene Gas, Abrasive Grit). This site was used for the manufacture of oxy-acetylene gas (1922-1942) and then for chemical and abrasive paint stripping (1943-1976) and is currently located in the asphalt parking lot between Buildings 6 and 226.

**AOC 543** — Storage Facility, Former Building 1026 (Petroleum Hydrocarbons). This site was used as a storehouse (until 1970) and is currently covered by Building 226.

Table 11.5 identifies the affected medium, the risk/hazard, and the chemicals driving the risk.

**Table 11.5**  
**SWMUs 23 and 63 and AOCs 540, 541, 542, and 543**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in the Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR and/or HI	Antimony, Aroclor-1254, BEQs
Shallow Groundwater	Yes — HI	Thallium

**11.5 SWMU 53 and AOC 526**

**SWMU 53** — Former Satellite Accumulation Area, Building 212 (Acids, Metals, Paints, Solvents, Petroleum Hydrocarbons). This site contained an SAA unit used to store hazardous waste in 55-gallon drums on an asphalt surface.

**AOC 526** — Paint Area, Building 212 (Metals, Solvents, Paints — containing organotin and tributyltin). This site was formerly used for spray painting ship components (1974-1993) using two types of metal-based paints. 1  
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Table 11.6 identifies the media affected, the risk/hazard, and the chemicals driving the risk. 4

**Table 11.6  
 SWMU 53 and AOC 526  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in the Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	BEQs
Subsurface Soil	NA	BEQs (exceeded SSLs)
Shallow Groundwater	Yes — HI	Thallium

*Note:*  
 NA = Not applicable to risk/hazard

**11.6 SWMU 65 and AOCs 544 and 546** 5

**SWMU 65** — Lead Storage, Building 221 (Lead). This site was used for storing lead blankets and shielding materials and as a staging area for scrap lead awaiting disposal. 6  
7

**AOC 544** — Former Pickling Plant, Building 221 (Acids, Metals, Solvents, Petroleum Hydrocarbons). This site consisted of an open-air facility using a series of chemical baths and water rinses in the pickling process. Pickling bath solutions discharged into the Cooper River via the storm drainage system, which was discontinued in 1984. 8  
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**AOC 546** — Galvanizing/Pickling Shop, Former Building 1025 (Acids, Solvents). This site consisted of a galvanizing/pickling shop that operated at the current location of Building 3 (until 12  
13

1942) and in the area southwest of Building 74 (until 1967) which are currently covered by pavement and structures.

Table 11.7 identifies the media affected, the risk/hazard, and the chemicals driving the risk.

**Table 11.7**  
**SWMU 65 and AOCs 544 and 546**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes – ILCR	Aldrin, dieldrin, BEQs
Subsurface Soil	NA	Arsenic, dieldrin, BEQs (exceeded SSLs)
Shallow Groundwater	Yes – ILCR and/or HI	Aluminum, antimony, arsenic, beryllium, cadmium, chromium, mercury, thallium, trichloroethene, vinyl chloride
	Yes	Lead (exceeded TTAL)
Deep Groundwater	Yes – ILCR and/or HI	Trichloroethene, vinyl chloride
Sediment	NA	Arsenic, lead, BEQs

*Note:*

NA = Not applicable to risk/hazard

**11.7 SWMU 67**

**SWMU 67 – Mercury Gauge Room, Building 3 (Mercury).** This site consists of a mercury gauge room (2nd floor), a former mercury gauge room (1st floor), and a mercury storage area (1st floor) used to conduct calibration and leak tests on mercury gauges.

No COCs were identified in soil or groundwater; therefore, no further action is recommended.

**11.8 SWMU 70 and AOCs 548 and 549**

**SWMU 70** — Dip Tank Area, Building 5 (Acids, Metals, Solvents). This site is the former location of a dip tank used to treat wood with fire retardant until 1981.

**AOC 548** — Hydraulic Elevator, Building 5 (Hydraulic Fluid, Petroleum Hydrocarbons). This site consists of an electric hydraulic elevator in a shaft that is paved on the bottom with approximately 8 inches of concrete and a container that captures hydraulic fluid leaks and returns it to the main reservoir.

**AOC 549** — Former Scrap Yard, Buildings 3 and 5 (Metals, Petroleum Hydrocarbons). This site consists of a former scrap yard north of Building 5 (1920s and 1930s) which is currently paved with concrete and asphalt.

Table 11.8 identifies the media affected, the risk/hazard, and the chemicals driving the risk.

**Table 11.8**  
**SWMU 70 and AOCs 548 and 549**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR and/or HI	BEQs, copper
	Yes	Lead
Shallow Groundwater	Yes — ILCR and/or HI	Antimony, cadmium, chromium, thallium, trichloroethene, vinyl chloride
Deep Groundwater	Yes — ILCR and/or HI	Antimony, chromium, thallium, tetrachloroethene, trichloroethene

**11.9 SWMU 81**

**SWMU 81** — Former <90 Day Accumulation Area, Building 1245 (Lead, Metals, Paints, Solvents). This site was used to store hazardous waste (until 1994), had a wooden floor with no spill containment and is currently an open area covered by concrete and asphalt.

Sediment and concrete were the only media sampled at this site with no COCs identified; therefore, no further action is recommended.

**11.10 SWMUs 83 and 84 and AOC 574**

**SWMU 83** — Former Foundry, Building 9 (Lead, Paints, Solvents, Friable Asbestos, Dielectric Fluid, Petroleum Hydrocarbons). This site was used to cast metal parts, primarily copper alloy parts, and contained equipment which appeared to be contaminated with PCBs and lead.

**SWMU 84** — Former Lead Storage Area, Building 9 (Lead). This site consists of an area outside of Building 9 used to store lead blankets and shielding.

**AOC 574** — Fuel Tank, Building 9 (Petroleum Hydrocarbons). This site consists of a 3,700-gallon fuel oil AST, no longer in use, in an unpaved area with no secondary containment.

Table 11.9 identifies the medium affected, the risk/hazard, and the chemical driving the risk.

**Table 11.9**  
**SWMUs 83 and 84 and AOC 574**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR (3.55E-04) and/or HI (1.31)	Antimony, BEQs, copper
	Yes	Lead
Subsurface Soil	NA	Arsenic, dieldrin, BEQs (exceeded SSLs)
Shallow Groundwater	Yes — HI	Thallium
Deep Groundwater	Yes — ILCR and/or HI	Arsenic, thallium

*Note:*

NA = Not applicable to risk/hazard

**11.11 SWMUs 87 and 172 and AOC 564**

**SWMU 87** — <90 Day Accumulation Area, Building 80 (Paint, Mercury, Anti-Freeze, Petroleum Hydrocarbons). This site was used to store hazardous waste (until 1994) in 55-gallon drums and plastic bags and has an asphalt foundation.

**SWMU 172** — Steam Cleaning Operations, Building 80 (Petroleum Hydrocarbons). This site consisted of an area for steam cleaning various types of equipment, including engines and generators, with a concrete-paved area which drains into a storm drain.

**AOC 564** — Oil/water Separator, Building 80 (Petroleum Hydrocarbons). This site consists of a 300-gallon oil/water separator used for wastewater from machine and parts cleaning in Building 80.

Table 11.10 summarizes the media affected, the risk/hazard, and the chemicals driving that risk.

**Table 11.10  
 SWMUs 87 and 172 and AOC 564  
 Conclusion Summary**

<b>Affected Medium</b>	<b>Unacceptable Risk/Hazard in Future Residential Scenario</b>	<b>Chemicals Driving Risk</b>
Surface Soil	Yes — ILCR	BEQs, dieldrin
Shallow Groundwater	Yes -- ILCR and/or HI	Arsenic, chlorobenzene, 1,4- dichlorobenzene, 1,2- dichloroethene, trichloroethene, vinyl chloride
Deep Groundwater	Yes — HI and/or HI	Arsenic, manganese, thallium

**11.12 SWMU 97**

**SWMU 97** — < 90 Day Accumulation Area, Building 236 (Freon, Metals, Solvents, Petroleum Hydrocarbons). This site consisted of a 20 by 20-foot steel shed on asphalt pavement, used to store hazardous waste in 55-gallon drums.

No COCs were identified at SWMU 97; therefore, no further action is recommended.

**11.13 SWMU 100**

**SWMU 100** — Satellite Accumulation Area, Building 218 (Metals, Paints, Epoxies, Solvents, Used Blast Grit, Petroleum Hydrocarbons). This site was used to store hazardous waste in 55-gallon drums on an asphalt-paved area.

No COCs were identified at SWMU 100; therefore, no further action is recommended.

**11.14 SWMU 102**

**SWMU 102** – Mercury Spill, Building 79 (Metals, Mercury, Petroleum Hydrocarbons). This site is in the central portion of the building where mercury was reported to have spilled and seeped under the concrete floor in 1969.

Table 11.11 summarizes the media affected, the risk/hazard, and the chemicals driving that risk.

**Table 11.11  
 SWMU 102  
 Conclusion Summary**

Medium Affected	Unacceptable Risk/Hazard in Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes – ILCR and/or HI	Arsenic, BEQs, mercury
Subsurface Soil	NA	Arsenic, BEQs, dieldrin (exceeded SSLs)
	NA	Lead (exceeded TTAL)
Shallow Groundwater	Yes – HI	Thallium

*Note:*

NA = Not applicable to risk/hazard

**11.15 SWMU 106 and AOC 603**

**SWMU 106** – Blast Area, Drydock 3 (Metals, Paints, Solvents, Blasting Material). This site consists of an area where blasting operations were conducted using steel grit and sodium bicarbonate.

**AOC 603** – Burning Dump, Drydock 3 (Petroleum Hydrocarbons, Products of Incomplete Combustion). This site consists of an area near the present location of Drydock 3 where a burning dump was operated from the late 1920s through the 1930s.

Table 11.12 summarizes the media affected, the risk/hazard, and the chemicals driving that risk. 1

**Table 11.12  
 SWMU 106 and AOC 603  
 Conclusion Summary**

<b>Medium Affected</b>	<b>Unacceptable Risk/Hazard in Future Residential Scenario</b>	<b>Chemicals Driving Risk</b>
Surface Soil	Yes – ILCR	BEQs
Shallow Groundwater	Yes – ILCR and/or HI	Arsenic, thallium
Deep Groundwater	Yes – HI	Thallium

**11.16 SWMU 145** 2

**SWMU 145** – Mercury Spill, Building 13A (Mercury). This site consists of a reported mercury spill beneath Building 13A. 3  
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Table 11.13 summarizes the media affected, the risk/hazard, and the chemicals driving that risk. 5

**Table 11.13  
 SWMU 145  
 Conclusion Summary**

<b>Medium Affected</b>	<b>Unacceptable Risk/Hazard in Future Residential Scenario</b>	<b>Chemicals Driving Risk</b>
Deep Groundwater	Yes – ILCR	Arsenic

**11.17 SWMUs 170 and 171** 6

**SWMU 170** – PCB Removal Operations, Drydock 1 Area (PCBs). This site consists of an area where missile launching tubes removed from submarines were dismantled for the removal of PCB-containing components (1980s-1990s). 7  
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**SWMU 171** — PCB Removal Operations, Drydock 2 Area (PCBs). This site consists of an area where missile launching tubes removed from submarines were dismantled for the removal of PCB-containing components (1980s-1990s).

Aroclor-1260 was detected in two surface soil locations at concentrations above its residential RGO, however, the area of contamination is very limited. The mean risk was calculated below  $1E-06$ ; therefore, no further action is recommended.

#### **11.18 SWMU 173**

**SWMU 173** — Lead Storage Areas, Building 1297 (Metals, Hazardous Materials). This site consists of 10 separate storage areas inside the building used for storing lead ingots and hazardous materials.

No COCs were identified in soil; therefore, no further action is recommended. Sediment samples collected from catch basins had concentrations of arsenic and lead exceeding their respective RBCs; therefore, a CMS for sediment is recommended at SWMU 173.

#### **11.19 AOC 525**

**AOC 525** — Paint Booth, Building 223 (Paints, Solvents). This site consists of a paint booth inside the building, used to paint miscellaneous parts.

No COCs were identified at AOC 525; therefore, no further action is recommended.

#### **11.20 AOC 528**

**AOC 528** — Steam Cleaning Shop, Building 59 (Caustic, Petroleum Hydrocarbons, Kerosene). This site consists of a steam cleaning shop used to clean boiler parts, using kerosene, trisodiumphosphate, caustic, and detergents to remove Cosmoline grease from the parts.

BEQs were detected in one AOC 528 surface soil sample at concentrations above their residential RGOs, however, the mean risk was calculated below 1E-06; therefore, no further action is recommended. No COCs were identified in groundwater.

**11.21 AOC 530**

**AOC 530** — Paint and Oil Storage, Building 35 (Alcohols, Paints, Solvents, Petroleum Hydrocarbons, Heavy Metals). This site was used for storage of paint, oil, and waste generated from the printing operations for Naval Publications (ferric chloride acid etching bath, lithographic developing solution, and photographic developing solution).

Table 11.14 summarizes the media affected, the risk/hazard, and the chemicals driving that risk.

**Table 11.14  
 AOC 530  
 Conclusion Summary**

<b>Medium Affected</b>	<b>Unacceptable Risk/Hazard in Future Residential Scenario</b>	<b>Chemicals Driving Risk</b>
Surface Soil	Yes — ILCR	Arsenic, BEQs
	Yes	Lead
Shallow Groundwater	Yes — HI	Thallium
Deep Groundwater	Yes — HI	Thallium

**11.22 AOC 531**

**AOC 531** — Substation and Storage, Building 459 (Batteries, Dielectric Fluid, Petroleum Hydrocarbons). This site was used for storage and an enclosure for a substation, with two sections and a 20,000-gallon fuel oil UST.

Table 11.15 summarizes the media affected, the risk/hazard, and the chemicals driving that risk. 1

**Table 11.15**  
**AOC 531**  
**Conclusion Summary**

Medium Affected	Unacceptable Risk/Hazard in Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	BEQs

**11.23 AOCs 538 and 539** 2

**AOC 538** — Forge Shop, Building 6 (Waste Oils and Paints, Heavy Metals, Ceramic Refractory Materials, Galvanizing Flux, Coal and Charcoal Coke). This site consisted of various metal-working processes with numerous quench oil tanks and oil-fired furnaces. 3  
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**AOC 539** — Propeller Shop, Building 6 (Zyglo Penetrant [99% 1,1,1-trichloroethane], Metals). This site used the Zyglo process until it was replaced by a red dye process in 1979. 6  
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Table 11.16 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 8

**Table 11.16**  
**AOCs 538 and 539**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	BEQs
Shallow Groundwater	Yes — ILCR and HI	Arsenic, thallium
Deep Groundwater	Yes — HI	Thallium
Sediment	NA	Arsenic, copper, BEQs, dieldrin

**11.24 AOC 550**

**AOC 550** — Boiler House, Former Building 1111 (Petroleum Hydrocarbons, Heavy Metals). This site consisted of a transportable boiler house used in two separate locations.

Table 11.17 summarizes the media affected, the risk/hazard, and the chemicals driving that risk.

**Table 11.17  
 AOC 550  
 Conclusion Summary**

Medium Affected	Unacceptable Risk/Hazard in Future Residential Scenario	Chemicals Driving Risk
Subsurface Soil	NA	BEQs (exceeded SSL)
Shallow Groundwater	Yes — ILCR and HI	Arsenic, thallium

*Note:*

NA = Not applicable to risk/hazard

**11.25 AOCs 551 and 552**

**AOC 551** — Boiler House, Building 1119 (Petroleum Hydrocarbons, Heavy Metals). This AOC has undergone renovations since being used as a boiler house before 1942.

**AOC 552** — Former Galvanizing Shop, Former Building 1030 (Inorganic Acids, Heavy Metals, Zinc). This site was used as a galvanizing shop and tooling shop and is currently paved with asphalt, traversed by a pair of nuclear-grade railroad tracks.

Table 11.18 identifies the medium affected, the risk/hazard, and the chemical driving the risk.

**Table 11.18  
 AOCs 551 and 552  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	BEQs
	Yes	Lead
Subsurface Soil	NA	BEQs
Shallow Groundwater	Yes — HI	Thallium

*Note:*

NA = Not applicable to risk/hazard

**11.26 AOC 555**

**AOC 555** — Latrine and Substation, Former Building 29 (Organic Waste, Heavy Metals, PCBs). This facility was used as a latrine and substation from 1922 to 1967 with its contents diverted directly into the Cooper River.

Sediment was sampled from the Cooper River; therefore, a formal risk assessment was not conducted for this site. Refer to the Zone J RFI for conclusions and recommendations.

**11.27 AOC 556**

**AOC 556** — Drydock Discharges, Drydocks 1, 2, 3, 4, and 5 (PCBs, Lead, Acids, Freon, Metals, Paints, Mercury, Caustics, Solvents, Antifreeze, Raw Sewage, Hydraulic Fluid, Cleaning Compounds, Petroleum Hydrocarbons, Abrasive Blasting Grit). These sites consist of drains along each drydock which discharge into the Cooper River upon completion of ship overhauling, refueling, defueling, welding, painting, mechanical work, and industrial work.

Sediment and surface water were sampled from the Cooper River; therefore, a formal risk assessment was not conducted for this site. Refer to the Zone J RFI for conclusions and recommendations.

**11.28 AOC 558**

**AOC 558** — Substation, Building 77 (Heavy Metals, Ethylene Glycol, Monoethanolamine Mercury, Perchloroethylene, TCE, Petroleum Hydrocarbons, PCBs). This site consists of transformers, switches, and other electrical equipment housed within a substation which have the last PCB-containing equipment removed in 1991.

No COCs were identified at AOC 558; therefore, no further action is recommended.

**11.29 AOCs 559, 560, and 561**

**AOC 559** — Central Power Station, Building 32 (Solvents, Heavy Metals, Lube Oil, Morpholene, PCBs, Acids/Caustics, Oils/Oily Wastes, Trisodiumphosphate). This site is a three-story brick and concrete structure which has historically burned coal, fuel oil, and diesel fuel.

**AOC 560** — Disinfector, Former Building 34 (Iron-Reducing Agent, Chlorine, VOCs). This site is believed to have been used to treat water prior to use in the power plant, or treated steam with a rust inhibitor after it was generated.

**AOC 561** — Substation, Building 451B (Dielectric Fluid). This site is a substation used as one of the principal feeds for electrical power to the shipyard and the CIA.

Table 11.19 identifies the medium affected, the risk/hazard, and the chemical driving the risk.

**Table 11.19**  
**AOCs 559, 560, and 561**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR (2.43E-04) and/or HI (2.11)	Arsenic, beryllium, BEQs, Aroclor-1254, Aroclor-1260, n-nitrosomethylethylamine
Subsurface Soil	NA	Arsenic, BEQs (exceeded SSLs)
Shallow Groundwater	Yes — ILCR	Benzene, chlorobenzene, 1,2- dichlorobenzene, 1,4- dichlorobenzene
Deep Groundwater	Yes — ILCR and/or HI	Trichloroethene, thallium

*Note:*

NA = Not applicable to risk/hazard

**11.30 AOC 562**

**AOC 562** — Substation, Building 84 (Dielectric Fluid). This site consists of a single-story structure with several metal-enclosed transformers adjacent to the building.

No COCs were identified at AOC 562; therefore, no further action is recommended.

**11.31 AOC 563**

**AOC 563** — Locomotive House, Former Building 37 (Lubricants, Heavy Metals, Dielectric Fluid, Petroleum Hydrocarbons, Chlorinated Solvents and Degreasers, Coal/Coal Byproducts). This site was believed to have maintained locomotive engines involving the use of petroleum-based lubricants and was located in the current location of Building 177.

Table 11.20 identifies the medium affected, the risk/hazard, and the chemical driving the risk.

**Table 11.20  
 AOC 563  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes -- ILCR	BEQs
Shallow Groundwater	Yes -- ILCR	Arsenic, trichloroethene

**11.32 AOC 566**

**AOC 566** — Paint Shop Storage, Building 194 (Metals, Paint, Solvents, Blasting Media). This site has been used to store unused blast grit and paints, with paint mixed outside the building at one time.

Table 11.21 identifies the medium affected, the risk/hazard, and the chemical driving the risk.

**Table 11.21  
 AOC 566  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes -- ILCR	BEQs
Subsurface Soil	NA	BEQs (exceeded SSLs)
Shallow Groundwater	Yes -- HI	Beryllium, thallium
Deep Groundwater	Yes -- ILCR and/or HI	Arsenic, thallium

*Note:*  
 NA = Not applicable to risk/hazard

**11.33 AOC 567**

**AOC 567** — Substation, Building 75 (PCBs, Lead, Acids). This site consists of a single-story structure with several metal-enclosed transformers adjacent to the building.

No COCs were identified at AOC 567; therefore, no further action is recommended. 1

**11.34 AOCs 569, 570, and 578** 2

**AOC 569** — Former Gas Station and Oil Storehouse, Former Building 1279 (Petroleum Hydrocarbons, Heavy Metals). This site consisted of three USTs which were removed in 1992, with soil excavation and sampling conducted during the removal. 3  
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**AOC 570** — Former Coal Storage Area, Area from Building 30 to Sixth Avenue and Carolina Avenue to Hobson Avenue (Coal, Coal By-products). This site was a coal storage area from 1919 until 1941. 6  
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**AOC 578** — Transportation Shop and Garage, Building 25 (Acids, Paints, Solvents, Anti-freeze, Petroleum Hydrocarbons). This site was originally used as an automobile garage and is currently a transportation and appliance maintenance shop. 9  
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Table 11.22 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 12

**Table 11.22  
 AOCs 569, 570, and 578  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	Arsenic, BEQs
Subsurface Soil	NA	Benzene, ethyl benzene, xylene (exceeded SSLs)
Shallow Groundwater	Yes — ILCR and/or HI	Aluminum, chromium, tetrachloroethene, trichloroethene
	NA	Lead (exceeded TTAL)
Deep Groundwater	Yes — ILCR and HI	Trichloroethene, thallium

**Note:**

NA = Not applicable to risk/hazard

**11.35 AOC 571**

**AOC 571** — Paint Booth, Building 177 (Paints, Solvents, Metals). This site is on the third floor of the building used for painting miscellaneous parts.

No COCs were identified at AOC 571; therefore, no further action is recommended.

**11.36 AOC 572**

**AOC 572** — Motor Area, Building 177 (Solvents, Petroleum Hydrocarbons, Heavy Metals). This site is a former motor cleaning area south of Building 177 used at one time for steam cleaning electrical motors and equipment.

Table 11.23 identifies the medium affected, the risk/hazard, and the chemical driving the risk.

**Table 11.23  
 AOC 572  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR (1E-05)	BEQs
Subsurface Soil	NA	Lead (exceeded TTAL)
Shallow Groundwater	Yes — HI	Thallium
Sediment	NA	Arsenic, BEQs

**Note:**

NA = Not applicable to risk/hazard

**11.37 AOC 573** 1

**AOC 573** — Anodizing Process, Building 177 (Acids, Hexavalent Chromium, Metals, Petroleum Hydrocarbons). This site included an anodizing process with a 2,000-gallon irradiate (chromic acid solution) dipping tank and a spray area with a 110-gallon sump. 2  
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Table 11.24 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 5

**Table 11.24  
 AOC 573  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	BEQs
Shallow Groundwater	Yes — HI	Thallium
Sediment	NA	Arsenic, chromium, lead, BEQs

*Note:*

NA = Not applicable to risk/hazard

**11.38 AOC 576** 6

**AOC 576** — Oil and Paint Storehouse/Print Office, Former Building 1012 (Inks, Paints, Metals, Solvents, Petroleum Hydrocarbons). This site was used for storing oil and paint from 1909 until 1930 at the location currently occupied by Building 80. 7  
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Table 11.25 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 1

**Table 11.25  
 AOC 576  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	BEQs
Shallow Groundwater	Yes — ILCR and HI	Beryllium, bromodichloromethane, thallium
Deep Groundwater	Yes — ILCR	Arsenic

**11.39 AOC 579** 2

**AOC 579** — Former Paint Shop, Building 1035 (Paints, Solvents). This site was used for storing paint from 1955 until 1977. 3  
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Table 11.26 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 5

**Table 11.26  
 AOC 579  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	Arsenic, BEQs

**11.40 AOC 580** 6

**AOC 580** — Former Pattern and Electric Shop, Building 10 (Solvents, Degreasers). This site was used as a pattern and electric shop until 1955. 7  
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Table 11.27 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 1

**Table 11.27**  
**AOC 580**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR and/or HI	Antimony, arsenic, copper, manganese, vanadium, BEQs
	Yes	Lead
Subsurface Soil	NA	Arsenic (exceeded SSL)
Shallow Groundwater	Yes — HI	Thallium
Deep Groundwater	Yes — ILCR	Arsenic

*Note:*

NA = Not applicable to risk/hazard

**11.41 AOC 583** 2

AOC 583 — Northeast Corner of Building 236 (Freon, Paints, Solvents, Petroleum Hydrocarbons). This site consists of a freon recycling system with three USTs, five petroleum USTs, and an area in which 200 gallons of paint stripper were discharged to a storm drain. 3  
4  
5

Table 11.28 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 6

**Table 11.28**  
**AOC 583**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	BEQs
Shallow Groundwater	Yes — HI	Thallium
Deep Groundwater	Yes — HI	Thallium

**11.42 AOC 586**

**AOC 586** – Temporary Powerhouse, Former Building 1014 (Acids, Solvents, Dielectric Fluids, Petroleum Hydrocarbons, Lead/Acid Batteries, Coal By-products). This site was a temporary powerhouse used for industrial salvage until being demolished in 1957 and is now bisected by a railroad spur.

Table 11.29 identifies the medium affected, the risk/hazard, and the chemical driving the risk.

**Table 11.29  
 AOC 586  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes – ILCR	Aroclor-1260, BEQs

**11.43 AOC 590**

**AOC 590** – Alley between Buildings 1760 and 79 (Acetone, Petroleum Hydrocarbons). This site is an area in which releases of acetone and cutting oil were reported, and is currently paved with asphalt.

Table 11.30 identifies the medium affected, the risk/hazard, and the chemical driving the risk.

**Table 11.30  
 AOC 590  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes – ILCR	BEQs
Shallow Groundwater	Yes – HI	Thallium
Deep Groundwater	Yes – HI	Beryllium, thallium
Sediment	NA	BEQs

*Note:*

NA = Not applicable to risk/hazard

**11.44 AOC 592** 1

AOC 592 — Asbestos-Shredding Shelter, Former Building 1225 (Asbestos). This site was used for shredding asbestos until it was removed in 1955 and is now paved and bisected by a railroad spur. 2  
3  
4

No COCs were identified at AOC 592; therefore, no further action is recommended. 5

**11.45 AOC 596** 6

AOC 596 — Former Torpedo Storage, Building 101 (Solvents, Degreasers, Explosives, Propellants, Petroleum Hydrocarbons). This site was used for storing torpedoes until 1943 and for various purposes including a machine shop, a storehouse, and for storing radioactive-contaminated materials. 7  
8  
9  
10

Table 11.31 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 11

**Table 11.31  
 AOC 596  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	Arsenic, BEQs
Subsurface Soil	NA	Arsenic, BEQs, Isophorone, N-Nitro-di-n-propylamine (exceeded SSLs)
Shallow Groundwater	Yes — ILCR and/or HI	Arsenic, thallium
	NA	Lead (exceeded TTAL)
Deep Groundwater	Yes — HI	Arsenic, thallium

*Note:*

NA = Not Applicable to risk/hazard

**11.46 AOC 597** 1

**AOC 597** – Substation, Building 91 (Dielectric Fluid, Lead/Acid Batteries). This site consists of a single-story structure with several metal-enclosed transformers adjacent to the building and two transformers mounted within the building. 2  
3  
4

Table 11.32 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 5

**Table 11.32  
 AOC 597  
 Conclusion Summary**

<b>Affected Medium</b>	<b>Unacceptable Risk/Hazard in a Future Residential Scenario</b>	<b>Chemicals Driving Risk</b>
Surface Soil	Yes – ILCR and/or HI	Antimony, arsenic, Aroclor-1248, Aroclor-1254, Aroclor-1260

**11.47 AOCs 598 and 599** 6

**AOC 598** – Sonar Dome Area, End of Pier J (Paints, Solvents, Adhesives, Blasting Grit). This site was used to clean and repaint sonar domes and to remove adhesives. 7  
8

**AOC 599** – Pump House, Pier J (Petroleum Hydrocarbons). This site was formerly used as a transfer station for diesel fuel. 9  
10

Table 11.33 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 11

**Table 11.33**  
**AOCs 598 and 599**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Surface Soil	Yes — ILCR	BEQs
	Yes	Lead
Subsurface Soil	NA	BEQs (exceeded SSLs)
Shallow Groundwater	Yes — HI	Thallium
Sediment	NA	Arsenic, copper

*Note:*

NA = Not applicable to risk/hazard

**11.48 AOC 602**

**AOC 602** — Substation and Storage, Building 95 (Dielectric Fluid). This site housed PCB-containing transformers until 1989.

Aroclor-1254 and Aroclor-1260 contribute to risk estimates for AOC 602 surface soil, exceeding 1E-06 at only one of four sample locations. The risk estimate for 602SB004, the only sample in which detectable concentrations of PCBs were reported, was 2E-06. Assuming a de minimus risk value of 1E-07 in samples where no PCBs were reported, the arithmetic mean risk for AOC 602 is 5E-07; therefore, no further action is recommended.

**11.49 AOC 604**

**AOC 604** — Substation and Storage, Building 96 (Dielectric Fluid). This site once housed PCB-containing transformers and now has two permanent and one temporary transformer next to the building.

No COCs were identified at AOC 604; therefore, no further action is recommended. 1

**11.50 Supplemental Sample Locations** 2

To characterize background conditions and fill data gaps, supplemental grid-based monitoring wells were installed throughout Zone E. 3  
 4

Table 11.34 identifies the medium affected, the risk/hazard, and the chemical driving the risk. 5

**Table 11.34  
 Supplemental Sample Locations  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in a Future Residential Scenario	Chemicals Driving Risk
Shallow Groundwater	Yes – ILCR and/or HI	Arsenic, thallium
	NA	Lead (exceeded TTAL at NBCEGDE024)
Deep Groundwater	Yes – ILCR	Tetrachloroethene, trichloroethene (NBCEGDE17D, NBCEGDE26D)

*Note:*

NA = Not applicable to risk/hazard

**11.51 Ecological Risk Summary** 6

Risk for ecological receptors was evaluated for ECPCs in surface water and sediment at Zone E. 7  
 Risk associated with exposure to ECPCs by native aquatic organisms were evaluated by calculating 8  
 HQs from benchmark values that are either promulgated or proposed by federal and state 9  
 regulatory agencies. 10

*Aquatic Wildlife* – Moderate risks are predicted to aquatic wildlife from ECPCs in surface water 11  
 near Zone E. Potential low-level risk to aquatic wildlife exists from sediment ECPCs in the 12  
 Cooper River. For both inorganic and organic ECPCs, there were HQ values above 1. These risk 13  
 will be addressed further in the Zone J RFI. 14

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### 13.0 SIGNATORY REQUIREMENT

Condition I.E. of the Hazardous and Solid Waste Amendments (HSWA) portion of RCRA Part B Permit (EPA SCO 170 022 560) states: *All applications, reports, or information submitted to the Regional Administrator shall be signed and certified in accordance with 40 CFR §270.11.* The certification reads as follows:

*I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.*



\_\_\_\_\_  
P. M. ROSE  
Officer In Charge  
Caretaker Site Office, Charleston

11/12/97

Date